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

Cover: Photograph of *Eubrontes* at the base of the Kayenta Formation near Tuba City, Arizona, USA, by Spencer G. Lucas (see also article on pp. 75-84)

Executive Notes

From the Chair

This issue of Albertiana demonstrates the activity of the Subcommission as it works towards GSSP definition. In particular, the effort put into the study of the Anisian-Ladinian boundary is remarkable - we have in this issue our assembled wisdom for all to see and I congratulate the members of the task force for producing the proposals. Our next meeting in the Dolomites in September will be the final forum for discussions on the A-L boundary - the meeting will be followed by a formal vote and hopefully a final resolution of the GSSP. Progress on other boundaries is also evident. The Olenekian-Anisian boundary candidate at Desli Caira now has a wealth of data available and is not far from a formal proposal. Much progress has been made this winter with work on a candidate for the Induan-Olenekian boundary in Chaohu, China: this contains a good conodont and ammonoid succession as well as other attributes published recently in Albertiana. The Ladinian-Carnian boundary deliberations will benefit from new data from Nevada and promise to move forward to agreement as we approach the IGC in Florence 2004. Similarly, the Carnian-Norian has recently received a lot of attention in the literature and was the subject of a conodont workshop held in Vancouver during May: it will also be the main focus of a workshop at the IGC. Finally, the Norian-Rhaetian boundary task force have also been active and alternative levels for the GSSP are under active discussion. So, I would like to take this opportunity to thank all those researchers who have, and continue to support task force activities. We are on track to have a solid temporal framework.

I would like to draw your attention to several future meetings that are now planned as formal meetings of the STS and of IGCP Project 467, both of which share the goal of achieving a stable time scale and global correlations. Many of you are participants in both groups and I would encourage you to include acknowledgement in your published works to "contribution to IGCP 467": it will benefit us all as funding could support meetings through 2006. I hope to see many of you in the Dolomites (Sept. 2003), in Florence (August 2004), New Zealand (2005) and Spitsbergen (2006) - see elsewhere in this issue for details. We also plan a wrap-up meeting on the Global Triassic in New Mexico in 2007 - mark your calendars!

From the Secretary

ICS Subcommission on Triassic Stratigraphy

Minutes of joint Business Meeting of the STS and IGCP Project 467, Vancouver, Canada, 27 May 2003

Chairman: M. Orchard

Secretary: G. Warrington

PRESENT:

V. Atudorei, M. Balini, E. Carter, A. Caruthers, R. Hanger, C. Henderson, E. Hopkin, E. C. Katvala, H. Kozur, L. Krystyn, S. Lucas, A. Marzoli, C. McRoberts, J. Pálfy, C. Rapaille, D. G. Taylor, T. Tozer, G. Walkden, J.-P. Zonneveld.

Agenda:

1) Review present state of Triassic GSSP studies.

2) Future meetings

3) Composition of new STS Executive

Chairman opened the meeting at 17.35 and welcomed participants to this part of Special Session 18 (SS18) of the annual GAC-MAC-SEG Joint Annual Meeting. SS18 (Extinction events, faunal turnovers and natural boundaries within and around the Late Triassic) was sponsored by the Subcommission of Triassic Stratigraphy (STS) and IGCP projects 458 (Triassic-Jurassic boundary events) and 467 (Triassic time and trans-Panthalassan correlations). He explained that he had proposed IGCP Project 467 as a means to stimulate and focus activity on the Triassic stages, the GSSPs for which were the responsibility of the STS. Part of the STS agenda was, therefore, shared by the IGCP project group and their business was being combined on this occasion. IGCP 467 was initiated in 2002 and the SS18 event was its second formal involvement (the first in Hungary last year).

ITEM 1.

Chairman opened this item by reminding those present that, of the GSSPs for which the STS is responsible, only that for the base of the Induan Stage, defining, inter alia, the base of the Trias and its boundary with the Permian, has been proposed and subsequently ratified. The ICS has issued a requirement that 'task forces' must complete work on all remaining Phanerozoic GSSPs by 2008.

Chairman proceeded to review the present situation regarding the six remaining Triassic GSSPs and invited discussion and feedback.

A. Base Olenekian GSSP (Task Force Leader (TFL): Y. Zakharov). Articles had appeared in Albertiana regarding possible candidate GSSPs in Siberia and China; there are also important sections in Spiti. Kozur asked why the Salt Range was not being considered; Chairman and Krystyn pointed out that it had not been proposed by anyone. Henderson asked about the Anhui section, China; Chairman reviewed the work carried out there, and reported in Albertiana; a candidate Olenekian GSSP has not been formally proposed but the Anhui section is a contender, with completion possible in 2005 or 2006.

B. Base Anisian (TFL: E. Gradinaru). Chairman referred to the Romanian section (Desli Caira) that was the subject of exhaustive discussion during the STS meeting in Hungary in 2002. A magnetostratigraphy is newly available but we await documentation of the ammonites. At the STS meeting in Hungary an informal vote was taken regarding the use of the conodont *Chiosella timorensis* to mark the base of the Anisian in the Desli Caira section. Work by the Chairman and Nicora, following that of Mirauta, had related conodont occurrences to the magnetostratigraphy and to a positive carbon isotope excursion. Atudorei remarked that Gradinaru was concerned about the identification of *timorensis*. Chairman advised the meeting that he plans to communicate with other conodont workers to obtain unanimity on the diagnosis of *timorensis*. There are no other candidate GSSPs for this boundary which he felt might be settled in 2004.

C. Base Ladinian (TFL: A. Baud). Possible levels for this boundary are near the bases of the *reitzi*, or *curionii* ammonite zones, the last level being near the first occurrence of the conodont *Budurovignathus*. In general, Hungarian colleagues advocate use of the base of the reitzi Zone and Italians colleagues that of the base of the curionii Zone. Krystyn remarked that another Italian group has recently proposed a compromise level at the base of avisianum Zone. Candidate GSSPs are in Italy and Hungary, with a reference section in the Humboldt Range, North America. Chairman noted that this TF is the only one that has a well defined list of its voting members, and that this will be necessary for all TF as decision time approaches.

D. Base Carnian (TFL: M. Gaetani). The boundary will probably be recognized near the first occurrence of the ammonites *Daxatina* or *Trachyceras* and the conodont *Metapolygnathus polygnathiformis*. The candidate GSSP is in Italy, and reference sections in Spiti and Nevada. Work on this GSSP is well advanced and completion is expected in 2004, by the IGC in Florence.

E. Base Norian (TFL: M. Orchard). The boundary will probably be recognized near the bases of the *macrolobatus* or *kerri* ammonoid zones and of the *Metapolygnathus communisti* or *M. primitius* conodont zones. Work is required on conodont taxonomy. Primary candidate GSSPs are in Sicily and Canada (no magnetostratigraphy, but better biostratigraphy than in Sicily).

F. Base Rhaetian (TFL: L. Krystyn). Suggested horizon near the lowest occurrences of the ammonite *Cochloceras*, the conodonts *Misikella posthernsteini* and *Epigondollela mosheri*, and the radiolarian *Proparvicingula moniliformis*. Candidate GSSPs in Austria, Canada and Turkey, but a good section has still to be found. Krystyn is attempting correlation between marine fossils and palynomorphs.

G. The upper boundary of the Triassic, defined by the base of the Hettangian Stage (Jurassic) is outside the remit of the STS and is the responsibility of the TJBTF of the ISJS. Warrington, as TJBTFL, reviewed the present situation regarding a GSSP for the base Hettangian. The boundary is clearly of interest to the STS, and notices of the contact for the TJBTF has appeared in Albertiana, though reports of that TF appear in the newsletter of the ISJS. Warrington presented a report on the candidate GSSPs to at the International Jurassic Symposium in Sicily in 2002 and this will appear in the next ISJS newsletter. Warrington advised STS workers who wished to receive relevant information from the ISJS to contact him directly.

In general discussion of this agenda item Henderson asked whether the TFs vote on GSSP proposals. Warrington confirmed that this is so; each TF must provide a list of Voting Members before proceeding to a formal vote on a GSSP. A vote must be conducted by post and/or e-mail, with a limit of 60 days for responses to be received by the TF executive; schedules for TF activity in relation to the ICS 2008 deadline must allow time for this procedure to take place at TF level, followed by STS and ICS level. If more than one candidate is proposed the TF must first vote to eliminate all but one which must itself be subjected to an additional vote to confirm it as the preferred candidate. Chairman reiterated his comment that only one STS TF (Ladinian) had, so far, a properly constituted list of voting members; the other TFs must provide these before they can carry out any formal voting.

ITEM 2.

Chairman announced the following programme of future meetings:

Seceda, Italy: 11-15 September 2003. See notices in Albertiana 27.

Spiti: June/July 2004. See notice this issue.

Florence, Italy: 20–28 August 2004. (STS and related sessions to be held during the International Geological Congress). A Symposium on Triassic of Tethys, and a workshop on Upper Triassic boundaries.

New Zealand: November/December 2005. See notice this issue.

Spitzbergen: summer 2006. See notice this issue.

New Mexico: 2007. See notice in this issue?

Chairman felt that a meeting should be held in China, to focus on the Lower Triassic and the possible candidate Olenekian GSSP; no date for this was under consideration.

ITEM 3.

A review of the composition of the STS executive is required under ICS statutes. The following changes are proposed and will be subject to a formal vote:

Present executive:	*Proposed new executive:*
Chairman:	
M. Orchard	M. Orchard (continuing)
Vice Chairmen:	
Y. D. Zakharov	M. Balini (new)
Yin Hongfu	Yin Hongfu (continuing)
Secretary:	
G. Warrington	C. McRoberts (new)

Chairman thanked those present for their participation, and declared the meeting closed at 18.35

G. Warrington
Secretary: STS

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 have arisen since the last changes were notified (Albertiana 27, December 2002).

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The Secretary retires from the British Geological Survey at the end of July and will not be there after 25 July 2003. His e-mail address and phone number at BGS will not be effective after that date. Items may be posted to BGS but ***must*** be addressed to Dr S. G. Molyneux and clearly marked 'for the attention of G. Warrington'. After 25 July FAX messages may be sent to the main BGS FAX number (+44 (0)115 9363200) but these ***must*** also be addressed to Dr S. G. Molyneux and clearly marked 'for the attention of G. Warrington'. Any future changes to contact information, including any new e-mail address, will be communicated as soon as possible.

Meeting Report

Extinction Events, Faunal Turnovers and Natural Boundaries Within and Around the Late Triassic

Geological Association of Canada, Mineralogical Association of Canada and Society of Economic Geologists Joint Annual Meeting, Vancouver Canada, 25-28 May, 2003

Christopher A. McRoberts[1] *and Michael J. Orchard*[2]

[1]*Department of Geology, State University of New York at Cortland, Cortland, New York 13045 USA, and* [2]*Geological Survey of Canada, 101-605 Robson Street, Vancouver, V6B 5J3, Canada*

A special 3-day plenary session on Extinction Events, Faunal Turnovers and Natural Boundaries Within and Around the Late Triassic was recently held as part of the joint Geological Association of Canada, Mineralogical Association of Canada and Society of Economic Geologists Annual meeting in Vancouver Canada. This meeting was sponsored by the Subcommission of Triassic Stratigraphy (STS) and International Geological Correlation Program (IGCP) Projects 458 (Triassic/Jurassic Boundary Events) and 467 (Triassic Time and Correlations). The session, organized and chaired by McRoberts and Orchard, contained 15 oral and 5 poster presentations on a wide variety of subjects relating to Triassic biochronology, diversity and extinction analyses within the Late Triassic and the Triassic/Jurassic boundary, and geological, geophysical, and geochemical events of the Late Triassic and Early Jurassic.

Abstracts in electronic form (Adobe PDF format) of all the presentations can be downloaded from the IGCP 458 website at http://paleo.cortland.edu/igcp458/index.html.

ORAL PRESENTATIONS

Atudorei, V., Orchard, M., Zonneveld, J.-P., McRoberts, C., & Boyd, A.: The carbon isotope record and the Triassic-Jurassic transition in northeast British Columbia, Canada

Carter, E.S.: Radiolarian faunal turnover at the T/J boundary: Western Canada and Japan

Krystyn, L.: Upper Triassic substage boundaries and their ammonoid record: divided between gradation, faunal turnover and extinction

Kozur, H.W.: Micropaleontological definition of the Norian-Rhaetian boundary

Lucas, S.G., Tanner, L.H., & Chapman, M.G.: No mass extinction at the Triassic-Jurassic boundary

Marzoli, A., Cirilli, S., Knight, K., Martini, R., Allenbach, K., Neuwerth, R., Verati, C., Bertrand, H., Youbi, N., & Bellieni G.: Temporal relationship between the oldest CAMP lava flows in Morocco and the Triassic-Jurassic boundary

McElwain, J.C., Hesselbo, S.P., Popa, M.E., & Surlyk, F.: New floral, sedimentological and isotopic data from the Triassic–Jurassic boundary strata in Jameson Land, East Greenland

Pálfy, J.: Did volcanism of the Central Atlantic Magmatic Province trigger the end-Triassic mass extinction?

McRoberts, C.A.: Late Triassic-Early Jurassic bivalve biochronology and bioevents from northeast British Columbia

Orchard, M.J.: Changes in conodont faunas through the Upper Triassic and implications for boundary

Stanley, G.D. Jr.: Major events in the evolution of Triassic reef ecosystems

Taylor, D., Taylor, L., Morganstern, A., Boelling, K., Guex, J., & Bartolini, A.: Biochronology, community analysis, and geochemistry of the latest Triassic Gabbs Formation, Gabbs Valley Range, Nevada

Walkden, G.M., Parker, J., Kelley, S.P., & Cohen, A.S.: Is there a “Manicouagan Event Horizon” in the late Trias?

Ward, P.L.: Stable isotope and paleontological results from the Norian /Rhaetian and Triassic/Jurassic boundaries, Kennecott Point, Queen Charlotte Islands, British Columbia

Zonneveld, J-P., Orchard, M.J., Tozer, E.T., Atudorei, V.N., McRoberts, C.A., Henderson, C.M., & Gingras, M.K.: The Upper Triassic at Williston Lake, Northeastern British Columbia, Canada: Constraints on physical boundaries at a classic biochronology locale

POSTER PRESENTATIONS

Balini, M. & Krystyn, L.: The Ladinian/Carnian boundary succession at South Canyon (Nevada) and its correlation with the GSSP candidate section Prati di Stuores (Dolomites, Italy), and with Spiti (Himalaya, India

Hopkin, E.K. & McRoberts, C.A.: Biochronology and correlation of Middle to Upper Triassic halobiid bivalves in Nevada, USA

Johns, M.J. & Barnes, C.R.: Correlation of ichthyolith assemblages and events in the Upper Triassic Baldonnel and Pardonet formations, Trutch and Halfway River map-areas (94G, 94B), northeastern British Columbia

Katvala, E.C. & Stanley, G.D. Jr.: Stratigraphy and paleoecology of an Upper Triassic intra-arc basin, Alexander Terrane, Keku Strait, Southeast Alaska

Mackay, M.L., Stanley, G.D., & Smith, P.L.: *Heterastridium*: A globally distributed fossil from Upper Triassic terranes of the North American Cordillera

Associated with the thematic special session was a conodont workshop and two business meetings. Michael Orchard organized a workshop that brought together conodont specialists H. Kozur and L. Krystyn, with participation by graduate student E. Katvala and material from Pizzo Mondello, Sicily sent by A. Nicora. The latter was compared with contemporaneous Carnian-Norian boundary material from Black Bear Ridge. In bringing together material and expertise on both Tethyan and North American successions, good progress was made in resolving some complex issues of Upper Triassic conodont taxonomy. This should lead to a more stable nomenclature and taxonomic base for future discussions about Upper Triassic GSSPS.

The first business meeting chaired by Mike Orchard combined STS and IGCP 467 activities. A report of this business meeting is available elsewhere in this issue of *Albertiana.* A second business meeting for IGCP 458 was organized by József Pálfy and Christopher McRoberts who summarized the activities of the project. Of special note was information on the forthcoming 3rd IGCP 458 field workshop at Stara Lesna (High Tatra Mts.), Slovakia. (12-15 October 2003) and the special session on Triassic-Jurassic boundary events as part of the International Geological congress meeting in Florence Italy, August 2004. More information regarding these and other IGCP 458 activites can be found at its website http://paleo.cortland.edu/igcp458/index.html.

Future Meetings

1st Field workshop of IGCP Proj. 467 (Triassic Time) – Spiti-Himalayas, Himajal Pradesh, India

approx. June 25 to July 10, 2004 (1st Circular)

The 2004 Spiti workshop of IGCP 467 will be organized jointly by members of Vienna (L. Krystyn), Milano (M. Balini) and Delhi Universities (D.B. Banerjee), as well as by O.M. Barghava (Chandigarh) with the official support of state of Himajal Pradesh government. It will take place in the tourist resort of Manali, H.P., at the foothills of the high Himalayan range and, will start with a 2-days working session on topics related to IGCP 467. Any contributions to Triassic stratigraphy are welcomed but main emphasis will be given to Triassic stage boundaries definitions, especially for those of the Lower, Middle and base of Upper Triassic. Key lecture notes will introduce specific aspects of Himalayan Triassic (general stratigraphy, palaeobiogeography, sequence stratigraphy and Lower and Middle Triassic biochronology). A business meeting of proj. 467 as well as of the STS will also be held.

The Manali session is followed by a 8-days bus/jeep tour to Spiti where the famous and classical Triassic sections of Muth, Kuling and surroundings will be visited. Principal outcrops will include the fossil-rich *Otoceras* beds of Kuling, as well as the "Himalayan Muschelkalk" (Anisian to Ladinian, with special attention to the Aegean and Bithynian) with several ammonoid-rich sections in the Pin Valley. There will be occasion to sample ammonoid-conodont- (and in part brachiopod-) bearing Induan-Olenekian, Olenekian-Anisian, Anisian-Ladinian and Ladinian-Carnian boundary intervals. Further excursion objects will include Upper Triassic reef and cyclic platform carbonates as well as mixed carbonate/siliclastic series of the Pin respectively Ratang Valley and a general overview on the sedimentology and sequence stratigraphy of the complete Permo-Triassic succession of Spiti.

After completition of several local roads, travelling to and within Spiti has become much easier and shorter than before. It now is convenient to stay in hotel in Kaza, the local capital of Spiti, and to make daily trips from there to the respective outcrops in the Pin and Lingti Valleys. A social program will include the visit of some of the most ancient monasteries in the Himalayas (Thabo, Darkhar Gompa). Despite the location of the region in altitudes between 3500 to 4000 metres, usually the climate is quite mild (25º at day) and dry during our travel time making the stay quite convenient.

Costs: On the basis of an absolutely non-profit calculation the price will amount to 600-800 Euro depending on the number of participants (which is restricted to 18). Included are all expense (transportation, lodging, meals) from New Delhi to Spiti and vv.

Further informations and pre-registration: September 2003. A specific web site will be opened, in order to provide full and up-to-date information. The Spiti web site will be linked to the web site of Milano University: http://www.gp.terra.unimi.it.

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Circum-Panthalassa Triassic Faunas and Sequences IGCP 467 & the Subcommission on Triassic Stratigraphy are co-sponsoring a 3-day meeting in Wellington, New Zealand, March 2005 with the focus on Triassic stratigraphy and correlations in the circum-Pacific region.

Convenor: Hamish Campbell (Institute of Geological & Nuclear Sciences).

REGISTRATION: $US300 Euro300 $NZ600 (N.B. AVERAGE CURRENT RATES OF EXCHANGE ARE $NZ 2 = EURO1 =$US1)

EXCURSIONS

Pre-conference: To Northland (North Island). Starting in Auckland. Return flights Auckland-Kerikeri. Boat travel from Whangaroa to Arrow Rocks return. To see the Arrow Rocks Late Permian to Middle Triassic succession (Waipapa Terrane). Well documented Panthalassa Ocean oceanic association of basalts overlain by conodont and radiolarian bearing cherts and coloured argillite sequences. Includes a Permian –Triassic boundary succession. 4 days. $US625 Euro625 $NZ1,250.

Mid-conference: Wellington (North Island) Late Triassic Torlesse Supergroup sequences (Rakaia Terrane). Examine well-exposed greywacke (accretionary wedge) and associated oceanic sequences, such as at Red Rocks, along the Cook Strait coast. 1 day. $US50 Euro50 $NZ100.

Post-conference 1: To Southland (South Island). Return flights Wellington - Dunedin. To see the classic New Zealand ?Early-Late Triassic shallow marine (shelf) successions (Murihiku Terrane) exposed in the Southland Syncline along the Otago coast (Kaka Pont to Nugget Point; ?Olenekian-Rhaetian) and inland in the Hokonui Hills (Ladinian-Rhaetian), Taringatura Hills (Norian) and Wairaki Hills (Anisian) 4 days. $US625 Euro625 $NZ1,250.

Post-conference 2: To Nelson (South Island). Return flights Wellington - Nelson. Boat travel to D'Urville Island. To see poorly fossiliferous Early Triassic Maitai Group sequences (Dun Mountain Maitai Terrane) exposed in river sections near Nelson city, and on D'Urville Island. 4 days. $US625 • (Euro) 625 $NZ1,250.

The Boreal Triassic, Svalbard, Arctic Norway, 2006

The Triassic Subcommission and IGCP 467 are co-sponsoring a meeting at Longyearbyen, Svalbard, in late summer 2006.

Atle Mork, Chairman organizing committee
Atle.mork@iku.sintef.no

The meeting will be arranged in the premises of UNIS (University Studies of Svalbard), the Worlds northernmost university, and we will be accommodated in the modern hotel close by.

Two days will be used on presentations with particular reference to the Arctic Triassic.

A one day excursion (ship based) to the famous FESTNINGEN SECTION will display the whole Triassic succession in easily accessible coastal exposures. The top Permian and P-T boundary are also well exposed.

Optional visits to central Spitsbergen localities (helicopter based) may be arranged for selected groups.

The meeting will take place in late August earliest September dependent on ship availability. Longyearbyen (78ºN) is easily accessible by scheduled daily flights from the mainland of Norway.

The Global Triassic

The New Mexico Museum of Natural History (Albuquerque, NM, USA) will host a meeting titled "The Global Triassic" in May, 2007. This will be the final meeting of IGCP 467 and quite possibly the final meeting of the STS. Symposia, field trips and publication of the symposia proceedings, as well as a volume on the Triassic timescale, are planned. Co-organizers Spencer G. Lucas and Mike Orchard will send out a first circular in 2004.

Call on abstracts

32th International Geological Congress, August 20 - 28, Florence, Italy:

Topical Symposia T-04.02 Late Permian-Early Triassic events

(accepting both invited and volunteered presentations)

SCIENTIFIC FOCUS

Mass extinction and recovery: Changes in vertebrates, plants and marine invertebrates, scope and categories, instantaneous or episodic, elimination of tropical rain forests and reefs, microbial flourish;

Paleo-Global changes: Pangea formation and disintegration, great regression and abrupt transgression, accumulation and removal of evaporates and coal, anomalous carbon cycle (negative $\delta^{13}C$), silica depletion in deep sea, magneto-stratigraphy and susceptibility, geochemical anomalies, volcanism vs. impact bolide, hydrate degassing and fullerenes;

Geochronology and other topics of interest

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General Symposia G-05.09 Tethys reconstruction

(submission open to all participants)

SCIENTIFIC FOCUS

Archipelagic Tethys model(microcontinents, rifted blocks intercalated with troughs, rifts and seaways) versus 'Clean Ocean' model; Paratethys and other enclosed marine basins; Tethyan evolution (Gondwanan dispersal and Eurasian accretion); biogeography and its role in Tethys reconstruction; oceanography and paleoclimatology.

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The XVth International Congress on Carboniferous and Permian Stratigraphy (XV ICC-P): August 10 – 16th 2003

The Netherlands, University Centre - De Uithof

A special symposium on the ***Permian - Triassic Boundary*** will be held during the XVth International Congress on Carboniferous and Permian Stratigraphy (XV ICC-P), which will take place from August 10th until 16th (2003) in Utrecht (The Netherlands). Convener is Henk Visscher, keynote speaker is Paul Wignall.

The preliminary program of this session is:

Wang: Chemostratigraphy of Permo-Triassic Boundary in Middle Zagros Area, Iran

Shen: Permian-Triassic sequences in southern Tibet and end-Permian mass extinction at high southern palaeolatitude

Peng: Aligning marine and non-marine Permian-Triassic boundary sections using high-resolution eventostratigraphy and biostratigraphy

Cao: Synchronous abnormalities of inorganic and organic carbon isotopes across the Permian-Triassic boundary at Meishan, South China

Chuvashov: Bionomy and biogeographical relations of the Early Permian Biota of Eastern European sedimentary basin

Musashi: Stable carbon isotope signature in mid-Panthalassa shallow-water carbonates across the Permo-Triassic Boundary

Isozaki: Guadalupian-Lopingian Boundary in Mid-oceanic Paleo-atoll Limestone in Japan

Foster: Abnormal pollen grains and carbon isotopic fluctuations: evidence of atmospheric and environmental changes around the Permian Triassic Boundary from Russia and northwest China

Bachmann: Cyclic stratigraphy, magnetostratigraphy and microspherules of the continental Permian-Triassic Boundary interval, Germany

Metcalfe: Age and correlation of the Permian-Triassic Boundary & Mass Extinction in China

Sephton: From land to sea - Haemorrhage of soil deposits during the end-Permian crisis

Looy: Vegetation succession through the end-Permian ecologic crisis

Richoz, Baud, Kozur & Marcoux: Deep-water Records from Middle Permian to Lower Triassic of Oman: the demise of Permian biogenic chert and abnormal C isotope curve.

Baud, Richoz, Cirilli, & Marcoux: Low latitude marine Permian-Triassic transition: a microbialite world.

Baud: The Permian-Triassic boundary and the Griesbachian substage

Wignall: Timing of events during the end-Permian mass extinction

For more information look at http://www.nitg.tno.nl/eng/iccp/index.shtml

Wolfram M. Kürschner
Utrecht

Scientific Reports

The A/L boundary Task Force

Foreword

Aymon Baud, chairman of the A/L boundary Task Force

Following the STS Working groups Meeting at Veszprem last Sept 5 to 8 2002, very nicely organized by our Hungarian colleagues, part of the discussion concerning the Anisian-Ladinian Boundary has been resumed:

1-A majority of those present preferred the use of an evolutionary appearance of an ammonoid taxon for GSSP definition. This should be a species rather than a genus. A generic datum would require a complementary conodont event.

2-Two sections are in competition: Bagolino (It.) and Felsoors (Hu.)

3-Local working groups or individuals will provide to the chairman (A. Baud) until Dec 31 2002, a « dossier » (PDF file sent by e-mail) containing the GSSP proposal according to the GSSP guidelines.

4-All the A-L Task Force members will received from the Chairman a copy of each dossier

All the « dossiers » will be published in Albertiana 28 and all the A-L Task Force members will be encouraged to send their comments to be published in this volume.

Last February all the Member of the A/L boundary Task Force have received two « dossier » (PDF file sent by e-mail) provided on time by local working groups and containing the GSSP proposal concerning the two sections those are in competition for the Anisian-Ladinian Boundary GSSP: Bagolino (It.) and Felsöörs (Hu.).

After delay P. Mietto announced his intention to send a proposal for his group choosing the Bagolino section but with an other boundary proposal. Leopold Krystyn has also supported this dossier and I received it June 10, 2003.

Now in the following pages you will find two section, three boundary proposals and comments. Members of the A/L boundary Task Force have now to read attentively the three dossiers and the comments to these proposals.

As the Mietto et al. "dossier" arrived 6 month after the delay decided unanimously by the STS in Veszprem, two distinct votes are necessary now. The first one concerns an agreement on the eligibility of the Mietto et al. "dossier": yes or no. The eligibility of the Mietto et al. "dossier" for the GSSP will need 60% or more of support (13 yes votes or more from the 21 Members of the A/L boundary Task Force), that means he will get a clear majority and then chosen for the GSSP. If not, the Members of the A/L boundary Task Force will make their choice between the two valid "dossiers" sent on time, choice according to the criteria of the potentiality of the proposed GSSP for long distance marine correlations, and for marine to continental correlations.Again, a clear majority of 60% of positive vote for one section and point will be needed for the GSSP choice.

Members of the A/L boundary Task Force are kindly asked to send before next Sept. 5 in closed envelop with their name and signature to me (postal ballot adressed to Aymon Baud, Geological Museum, UNIL-BFSH2, CH-1015 Lausanne, Switzerland)), their vote concerning the eligibility of the Mietto et al "dossier" (yes, I agree with the eligibility ,or no, I disagree with the eligibility).

Before Sept. 11 (Dolomite meeting), each Members of the A/L boundary Task Force will be informed by e-mail of the result of the vote.

If 13 or more of the Members of the A/L boundary Task Force are present during the STS meeting next Sept. 11-14 at St-Christina (It.), a written vote among the Members will be organized (in-seession ballots according to the ICS voting procedure) concerning their choice between the Bagolino section (Brack et al. proposal), the Felsoors section (Voros et al. proposal) and possibly Bagolino (Mietto et al. proposal) if eligible.

Members of the A/L boundary Task Force who were not able to participate to the STS meeting Sept. 11-14 at St-Christina (It.) will be asked to send their choice between the Bagolino section (Brack et al. proposal), the Felsöörs section (Vörös et al. proposal) and possibly Bagolino if eligible (Mietto et al. proposal) to me within a delay of sixty days from Sept. 22.

If among the three proposals no majority appears, the choice will be proposed between the two who get the best score, with the sixty days rule for sending the vote.

If, one of the three, respectively the two proposals gets a clear majority from the Members of the A/L boundary Task Force, the chosen proposal with the corresponding dossier will be forwarded to the President of the STS with recommendations. Then, the President of the STS will hold a vote among the STS voting Members with the 60 days deadline rule and forward with recommendations the results to the Chairman of the International Commission on Stratigraphy (ICS).

If no majority appears, the A/L boundary will again be waiting for couples of years. According to me this solution will be the worst.

The Global Stratigraphic Section and Point (GSSP) of the base of the Ladinian Stage (Middle Triassic)

A proposal for the GSSP at the base of the Curionii Zone in the Bagolino section (Southern Alps, Northern Italy)

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INTRODUCTION

This article is a slightly modified version of a proposal for the GSSP of the base of the Ladinian Stage as circulated earlier this year for discussion among the members of the A-L working group. The proposal and its contents follow the guidelines published on p.61 of Albertiana 26. Of the items listed in these guidelines, points 4B, 4C and 4D are excluded in this article because the discussion of the proposals will be included in a separate section of Albertiana and the "selected publications" are part of the references.

STRATIGRAPHIC RANK OF BOUNDARY: BASE OF THE LADINIAN STAGE IN THE MIDDLE TRIASSIC SERIES.

PROPOSED GSSP - GEOGRAPHIC AND PHYSICAL GEOLOGY

GEOGRAPHIC LOCATION

The GSSP-candidate at Bagolino (Province of Brescia, Northern Italy) is located in the Brescian Prealps portion of the Southern Alps, and more precisely, in Valle del Caffaro between Val Camonica and Valli Giudicarie (Fig. 1). The Anisian/Ladinian boundary succession is exposed in the bed of the river Caffaro south of the village of Bagolino in the immediate surroundings of the Romanterra bridge (45°49'9''N, 10°28'8''E; altitude: 646m). Bagolino can be reached by car or by public transport from Brescia. A bus station is located at short distance from the Romanterra bridge. From this point the main exposures (Sites A - C; see Fig. 2) lie within walking distance along the banks and in the bed of the Caffaro river. Parts of the outcrops in the river bed at Site B may be submerged during high river waters in spring or after heavy showers. The other sites are inaccessible only with extreme winter conditions.

GEOLOGICAL LOCATION

The Middle Triassic succession at Bagolino is part of a thick sediment prism comprising Lower to Upper Triassic strata which are turned upright in front of an uplifted portion of the Brescian Prealps. The latter area is situated to the north of a bounding fault (Val Trompia Line) and consists of pre-Permian metamorphic basement and Lower Permian - Triassic cover rocks. Alpine deformation of the Middle-Upper Triassic rocks south of the Val Trompia Line was the result of south-directed transport of basement and cover rocks which occurred in two tectonic phases, prior and after the emplacement of the Eocene-Oligocene Adamello intrusives respectively.

Pelagic successions of Middle Triassic age are also exposed at various places south and west of Bagolino (Fig. 1), including the classical locality at Dosso Alto and important complementary sections at Pèrtica, Brozzo and Marcheno. To the north of Bagolino, Middle Triassic pelagic sediments occur along the southern margin of the Adamello intrusives. This area hosts important sections in Giudicarie (Prezzo, at the eastern termination of Val di Daone; Monte Corona - Stabol Fresco) and in Val Camonica (e.g., Contrada Gobbia).

At Bagolino, the pelagic succession consists from bottom to top of the Prezzo Limestone, the Buchenstein Beds and the Wengen Beds. The succession is well exposed at different places in the Caffaro river bed at Romanterra (Fig. 2). The same lithologies occur in scattered outcrops on the southern slopes of M. Pizza (Site D). Additional exposures of these strata are also accessible along the Rio Ricomassimo creek around 3 km east-northeast of Romanterra.

The stratigraphic succession at Romanterra as documented in Figure 3 starts in the uppermost Angolo Limestone with a distinct brachiopod lumachella at its top. The pelagic Prezzo Limestone consists of limestone-shale alternations with nodular to wavy bedding in the lower and more regular and thicker bedding in the upper part. In an interval transitional to the Buchenstein Beds, the first significant volcaniclastic layers are interbedded with increasingly siliceous limestones and shales. The Buchenstein Beds consist of siliceous pelagic nodular limestones and up to a few decimetres thick volcaniclastic layers which can be traced laterally over long distances. A marked change in sedimentation is observed at the top of the Buchenstein Beds with the rapid transition to the predominantly

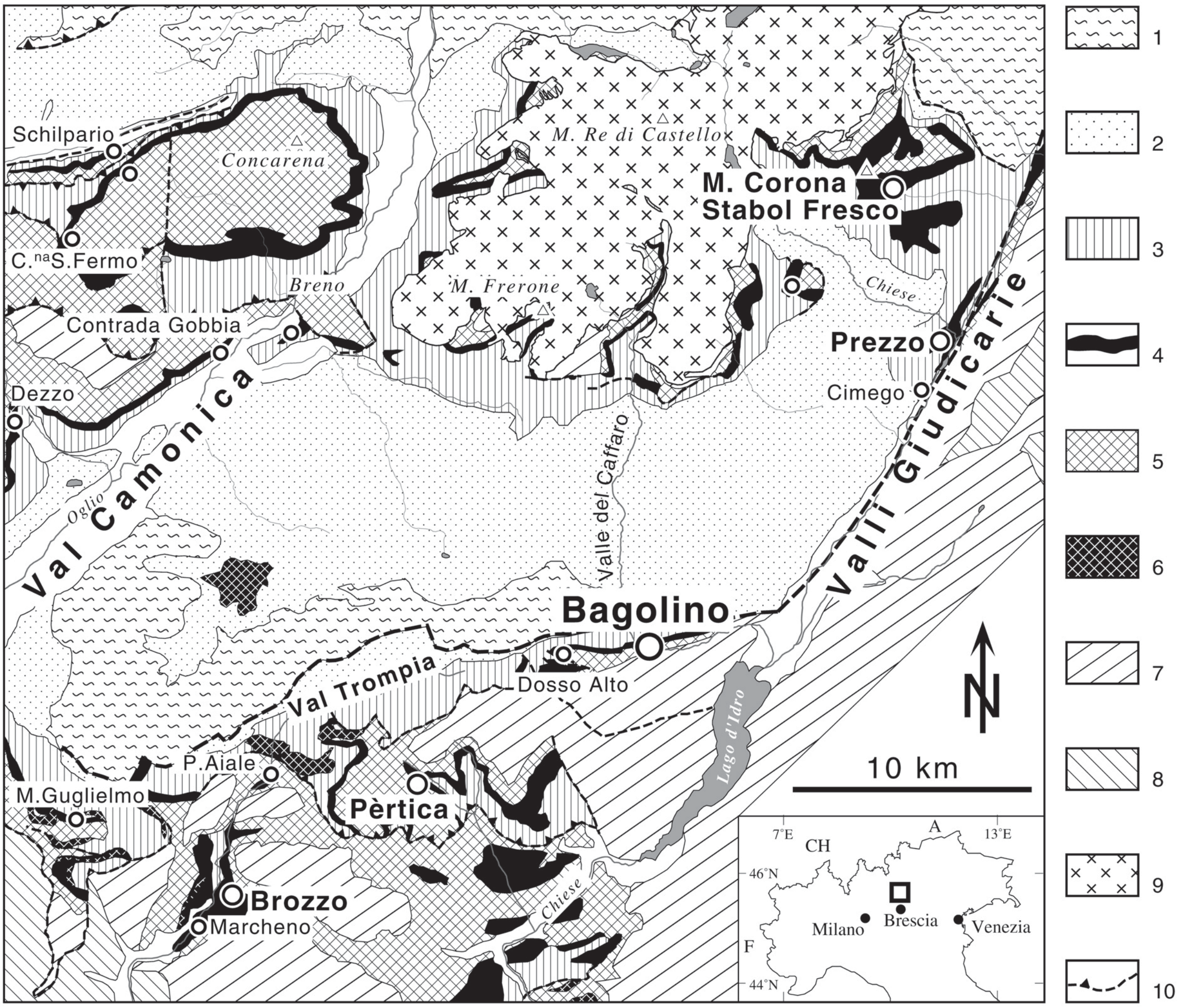

Figure 1: Geological sketch map of the area with classical localities of Middle Triassic stratigraphy in eastern Lombardy and Giudicarie (Trentino). 1: Pre-Permian basement; 2: Permian to Lower Triassic including lowermost Anisian units; 3: Mainly lower/middle Anisian units (Angolo Lst.; Dosso dei Morti / Camorelli Lst.); 4: Upper Anisian - Ladinian pelagic successions (Prezzo Lst., Buchenstein- & Wengen Beds); 5: Ladinian / Carnian platform carbonates and age-equivalent intra platform deposits (Pratotondo Lst., Lozio Shales); 6: Ladinian - Carnian shallow intrusive rocks; 7: Norian - Rhaetian shallow water carbonates and basinal equivalents; 8: Jurassic - Cretaceous units; 9: Tertiary Adamello plutonics; 10: major tectonic lines (faults and thrusts).

siliciclastic Wengen Beds.

The Anisian/Ladinian boundary interval comprises the “transitional beds” and the lower part of the Buchenstein Beds and is best exposed at Sites A - C. In particular, at the eastern end of Site B (Fig. 4; for a detailed map of this outcrop see fig. 4 in Brack & Rieber, 1986), the fully exposed strata from the 57m-level upwards can be traced over several tens of metres along strike. At Site C an undisturbed succession of the 51-65m-interval spans all boundary positions hitherto discussed as potential base of the Ladinian Stage.

LOCATION OF LEVEL AND SPECIFIC POINT

The proposed GSSP-level at Bagolino is defined in the lower part of the Buchenstein Beds, at the top of a distinct 20-25cm-thick interval of limestone nodules in a shaly matrix in contact (upwards) with several thick limestone beds (Fig. 5). The nodular limestone interval is known as the “Chiesense groove” and bears ammonoids such as *Chieseiceras chiesense* and ‘*Stoppaniceras*’ (*ellipticus*-group). On the lower surface of the overlying thick limestone bed *Eoprotrachyceras curionii* appears for the first time. Macrofossils were found at this level at all sites mentioned for Bagolino (Fig. 2). Because of the particularly extended exposure, the eastern end of Site B (Fig. 4) is designated as the main reference outcrop for the proposed GSSP.

STRATIGRAPHIC COMPLETENESS

No signs of stratigraphic gaps have been detected so far in the pelagic part of the Middle Triassic sediment succession at Bagolino. The reduction of clay content at the

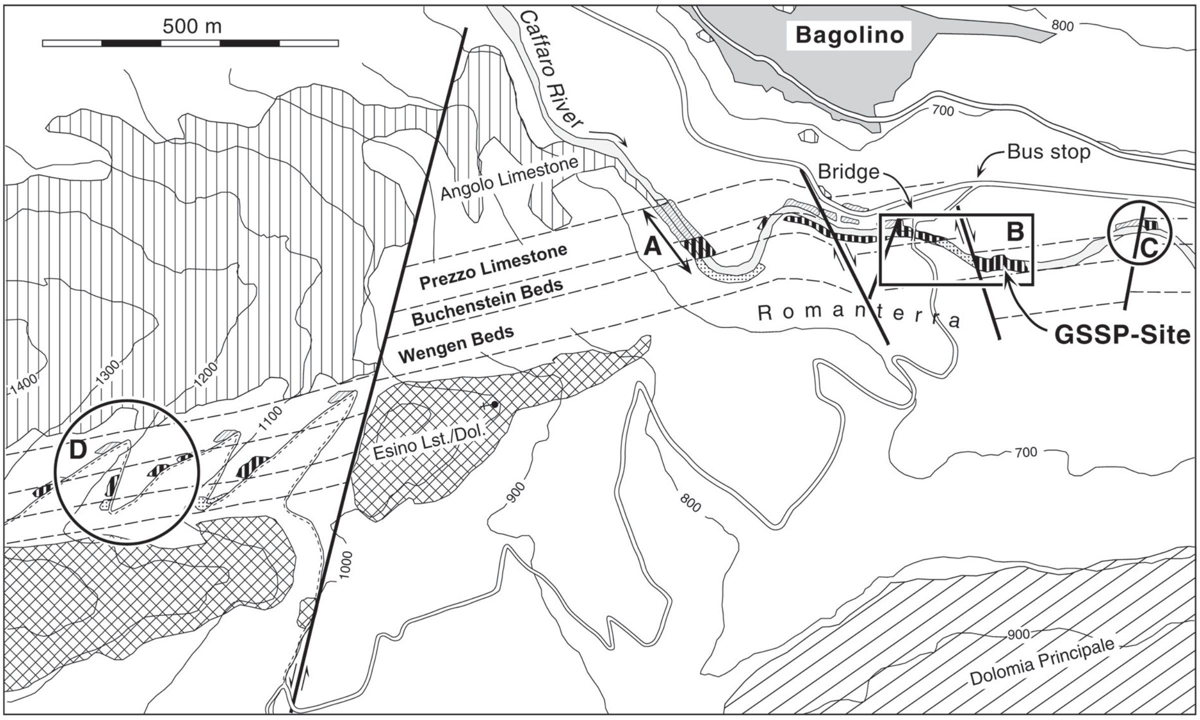

Figure 2: Geological sketch map of the vertical to slightly overturned Middle Triassic succession in the surroundings of Bagolino. The main sites (A - D) with exposures of the Anisian/Ladinian boundary interval are indicated. The stratigraphic ranges of the intervals exposed at each site are shown in Fig. 3. A continuous succession ranging from the uppermost Angolo Limestone to the Wengen Beds is exposed at Site A.

base of the Buchenstein Beds suggests a decrease of the sedimentation rate from moderate to high values in the Prezzo Limestone to low values in the Buchenstein Beds. On the basis of isotopic age constraints, the average sedimentation rates in the (non-decompacted) siliceous pelagic nodular limestone of the Buchenstein Beds are estimated at around 10m/m.y. (Brack & Muttoni, 2000). The volcaniclastic layers obviously represent short lived deposition on the scale of duration of volcanic eruptions. The siliciclastic Wengen Beds again represent rapid sediment accumulation.

In the Anisian/Ladinian boundary interval (Fig. 5) the ammonoid biostratigraphy seems to be exceptionally complete at Bagolino, with somewhat scarce faunas only in the narrow interval between the 58-60m-levels.

ADEQUATE THICKNESS AND STRATIGRAPHIC EXTENT

The entire pelagic succession exposed at Bagolino (Fig. 3) is more than 100m thick and ranges in age from the middle/late Anisian to the late Ladinian. Ammonoid faunas of the Balatonicus Zone and from a stratigraphic level corresponding to the Brachiopod Bed at Bagolino are known from Giudicarie (e.g., Balini et al., 1993; Brack et al., 1999). The Prezzo Limestone at Bagolino bears ammonoids from the Judicarites-horizon upwards. Nearby sections of Prezzo Limestone (e.g., Stabol Fresco, Contrada Gobbia; see Balini et al., 1993; Balini, 1998) bear one of the richest ammonoid faunas reported so far for the Trinodosus Zone in Western Tethys. At Bagolino the ammonoid record shows a particularly high resolution in the Reitzi, Secedensis and Curionii Zones. Ammonoids and *Daonella* are known from the upper Buchenstein and from the Wengen Beds, with representatives of *Frankites* (Regoledanus Zone) being the youngest ammonoids found to date.

In the Southern Alps and beyond, the Bagolino section is arguably one of the most extensive not condensed and macrofossil-bearing Middle Triassic successions known so far. The Anisian/Ladinian boundary interval at Bagolino (i.e. the 51-65m-interval; Fig. 5) is the only place in which all levels hitherto discussed as potential Anisian/Ladinian boundary have been precisely identified on the basis of ammonoids in a single section!

PROVISIONS FOR CONSERVATION AND PROTECTION

The existence of exposures of Buchenstein Beds south of the village of Bagolino was reported by Bittner (1881). Mariani (1906) documented the first ammonoids from these beds. This is sufficient guarantee for a long persistence of the natural exposures in the Caffaro river bed. Moreover, a good portion of the outcrop surface is periodically cleaned by high river waters.

The authorities of Bagolino are prepared to maintain and label an easy access to the river bed of the main outcrop (Site B) and to fix appropriate labels and posters with information also for the public.

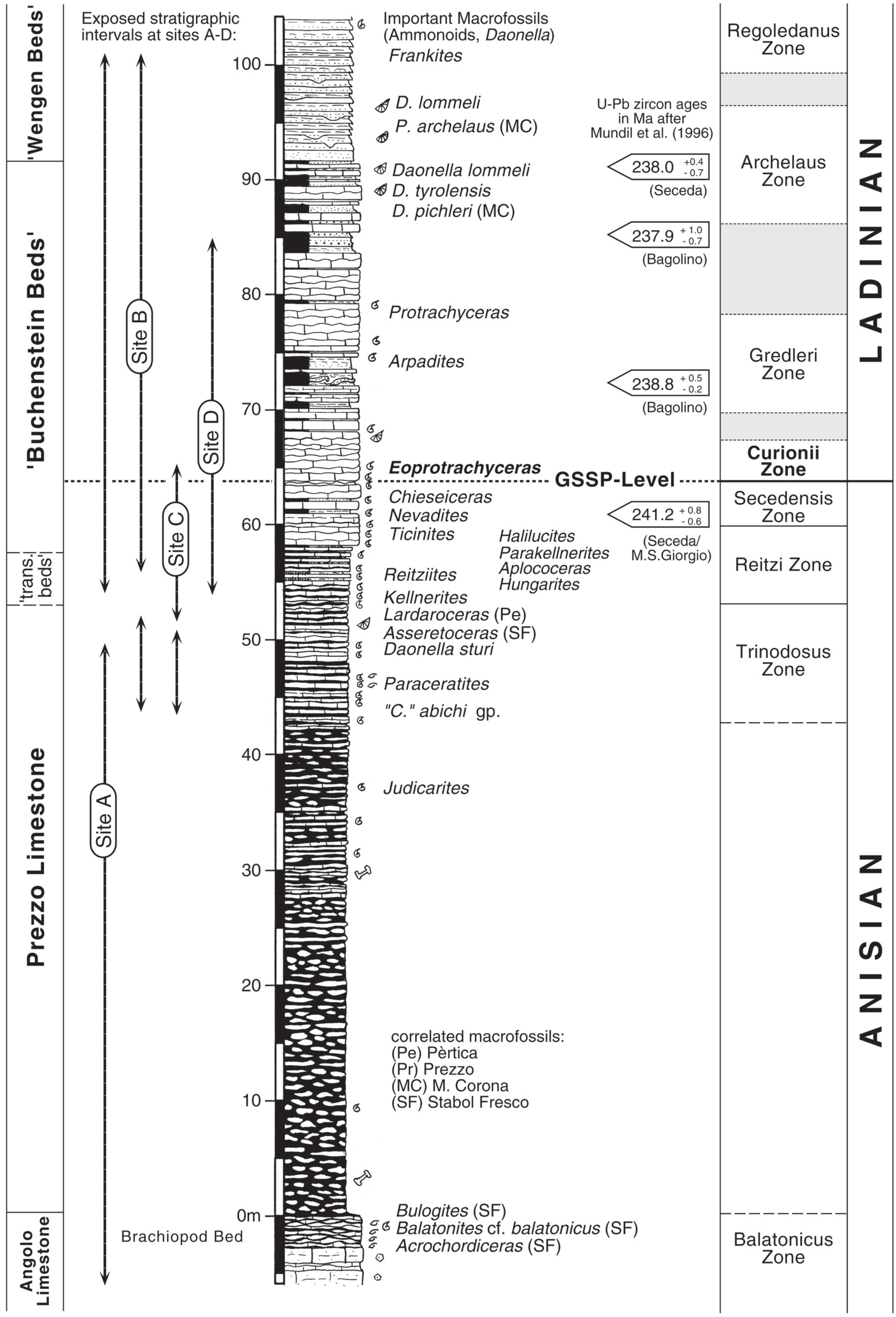

Figure 3: Summary log of the Middle Triassic pelagic succession at Bagolino. The stratigraphic intervals exposed at Sites A - D as well as the main macrofossil horizons and the scheme of ammonoid zones are indicated. Isotopic age data are weighted mean U-Pb-ages on single grain zircon from volcaniclastic layers at Bagolino and Seceda (from Mundil et al., 1996).

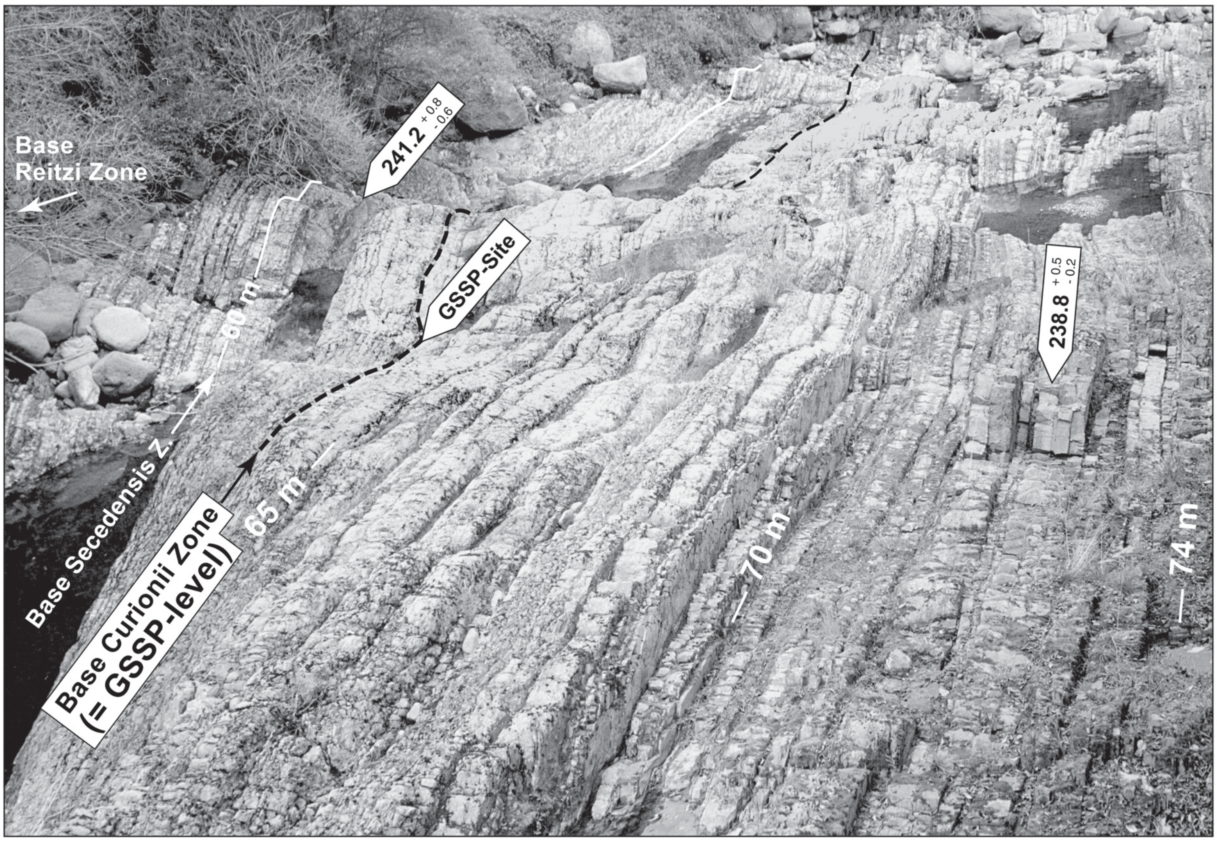

Figure 4: View of the spectacular outcrop of Buchenstein Beds at Site B (eastern end; main GSSP-site) with a continuous exposure of strata between the Reitzi Zone and the Archelaus Zone (base of Wengen Beds).

PRIMARY AND SECONDARY MARKERS

PRINCIPAL CORRELATION EVENT (MARKER) AT GSSP LEVEL

The proposed GSSP-level at Bagolino is defined with the first appearance of the ammonoid species *Eoprotrachyceras curionii* (MOJS.) as outlined in section 2.C. (Fig. 5).

In western Tethys *E. curionii* is so far the oldest known representative of the genus *Eoprotrachyceras* and marks the onset of the family *Trachyceratidae*. The FAD of the genus Anolcites which shares some morphological characters with *Eoprotrachyceras* predates that of *Eoprotrachyceras*. *Anolcites* seems to be a descendant of *Nevadites* which is considered to belong to the *Ceratitidae* (Tozer, 1994; Rieber & Brack 2002).

The proposed GSSP-level allows an excellent correlation of sections not only in the Southern Alps but also the recognition of a corresponding level in Greece (Epidauros). Representatives of the genus *Eoprotrachyceras* have been reported from numerous places including the Triassic successions in North America (Nevada, British Columbia) and is therefore a suitable marker for trans-Panthalassan correlation.

The narrow interval with *Chieseiceras chiesense* immediately below the layer with *E. curionii* is another most suitable marker for correlation of sections in the Southern Alps and Greece.

OTHER STRATIGRAPHY:

BIOSTRATIGRAPHY

Conodonts

Conodont data are available from Bagolino (Nicora & Brack, 1995; Brack & Nicora, 1998) and closely correlated sections (Pèrtica, Brozzo: Nicora & Brack, in prep.; Stabol Fresco: Kovács et al., 1990 and updates). New results from the Dolomites (Muttoni et al. submitted) provide a significant extension of the conodont record reported for Frötschbach (Muttoni et al., 1996, 1997). Figure 6 shows the conodont distribution at Bagolino and compiled data from additional sections accurately correlated with Bagolino on the basis of bio- and lithostratigraphy.

In the Anisian/Ladinian boundary interval the most significant "conodont events" are the following: (1) Close to the base of the Reitzi Zone, *Neogondolella cornuta postcornuta* and the group of *Paragondolella alpina* appear among other taxa; (2) In the upper Reitzi Zone, *Neogondolella pseudolonga*, *Paragondolella fueloepi* and *Paragondolella trammeri* appear for the first time; (3) In the upper part of the Secedensis Zone, *Neogondolella praehungarica* appears together with a precursor form of *Budurovignathus gabriellae* provisionally referred to here

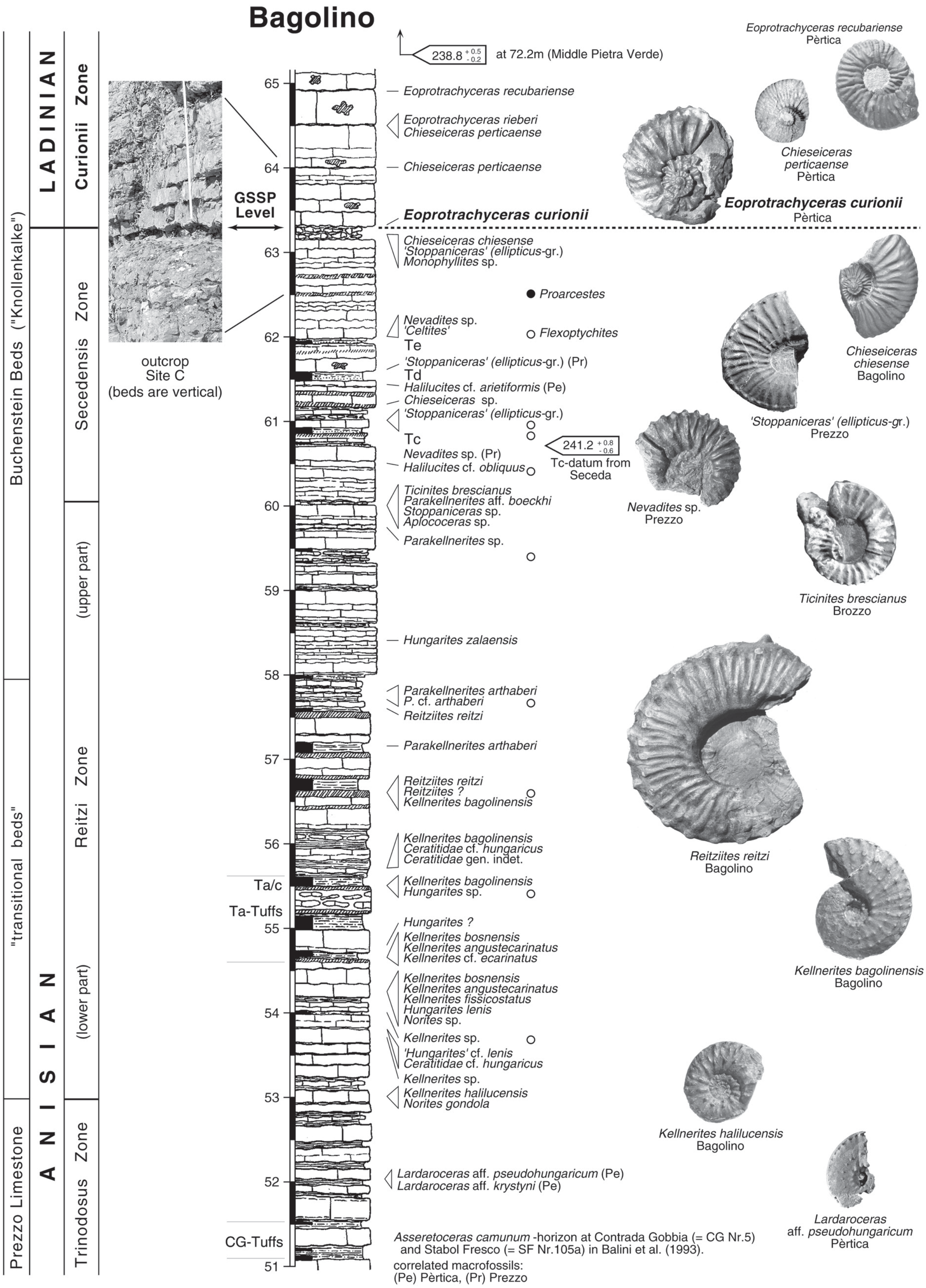

Figure 5: Detailed stratigraphic log of the Anisian/Ladinian boundary interval at Bagolino. The base of the Curionii Zone here proposed as GSSP-level corresponds to the top of a distinctly recessive weathered interval with limestone nodules in a shaly matrix ("Chiesense groove"). Also shown are some specimens of representative ammonoids from Bagolino and other sections correlated on a bed-scale. Following new considerations on the origin of the genus *Nevadites* (Rieber & Brack, 2002), the base of the Secedensis Zone is redefined with the appearance of representatives of *Ticinites*.

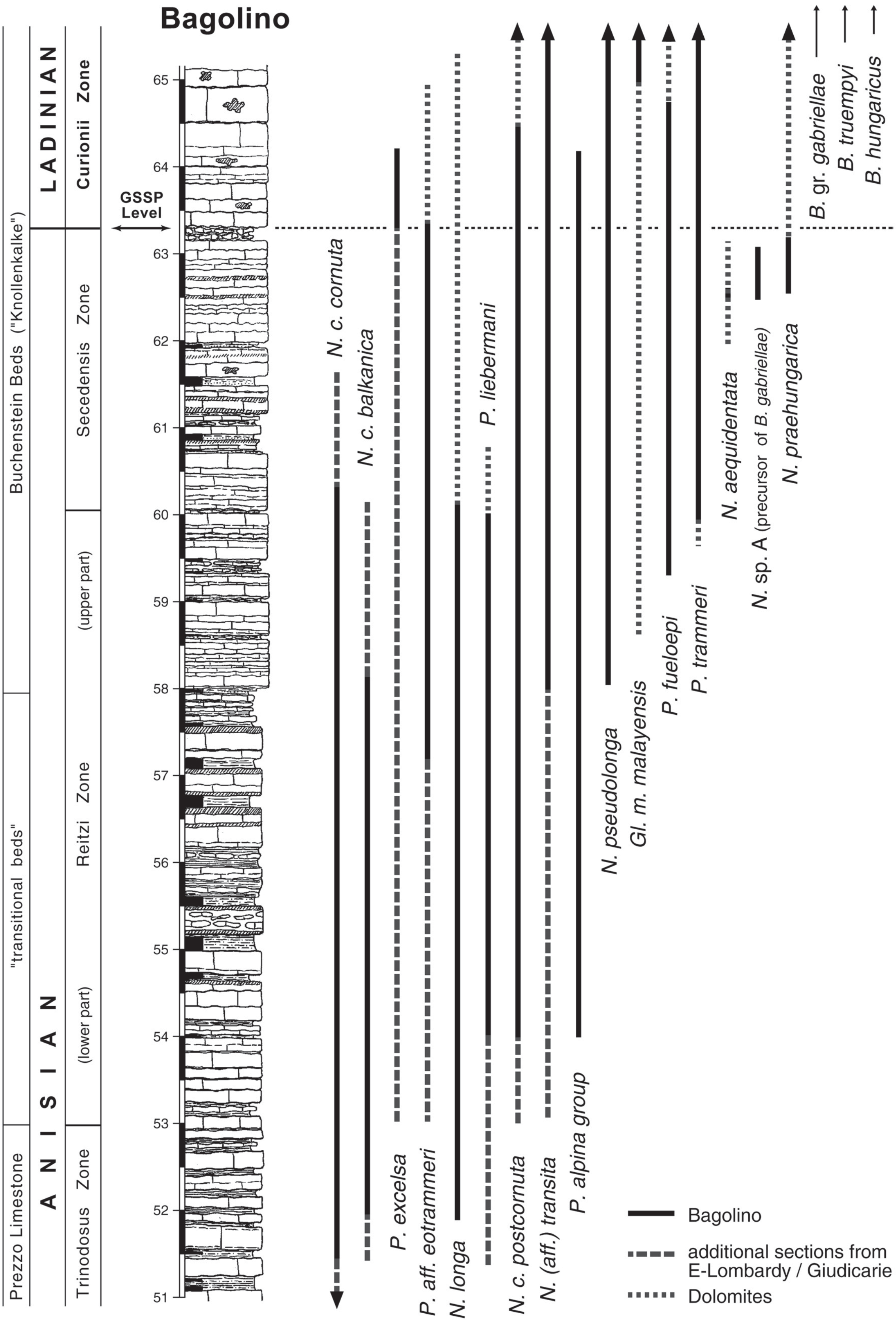

Figure 6: Detailed stratigraphic log of the Anisian/Ladinian boundary interval at Bagolino with the distribution of conodonts. Average sample spacing is around 18cm above and 50cm below the 58m-level respectively (for details see Brack & Nicora, 1998). Also shown are correlated complementary data from additional sections in eastern Lombardy (Brozzo, Pèrtica) and Giudicarie (Stabol Fresco) as well as in the Dolomites.

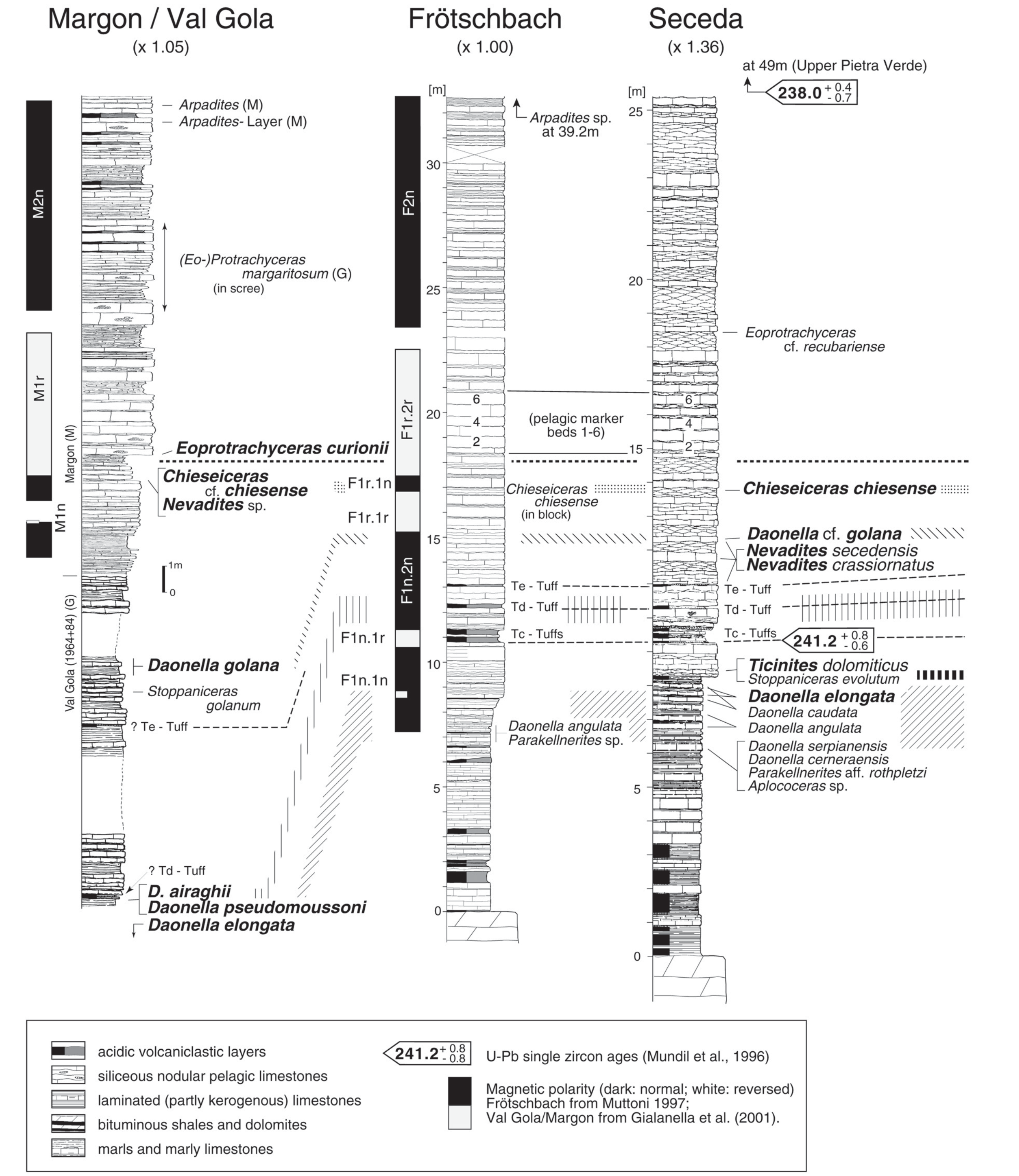

Figure 7a+b: Compilation of important stratigraphic results from correlated key sections of the Anisian/Ladinian boundary interval in the Southern Alps (modified after Brack et al. 2001) with indication of lithological markers (volcaniclastic layers, bedding patterns), magnetic reversals, isotopic age data and the ranges of macrofossils (ammonoids, *Daonella*). The correlation of key fossils and the proposed GSSP-level at the base of the Curionii Zone are highlighted. Also shown is the correlation with the zonal scheme and important fossil horizons of the Balaton highland (Felsoörs section; Vörös, 1998; Budai et al., 2002).

as *Neogondolella sp. A*; (4) *Budurovignathus truempyi* and *B. hungaricus* occur in layers corresponding to the 66m-level of the Bagolino reference column or higher up.

The appearance of *N. praehungarica* and its co-occurrence with *P. fueloepi* in the upper part of the Secedensis Zone, just below the proposed GSSP-level, seems at present to be the only suitable marker for conodont-based correlation with data from Nevada and British Columbia

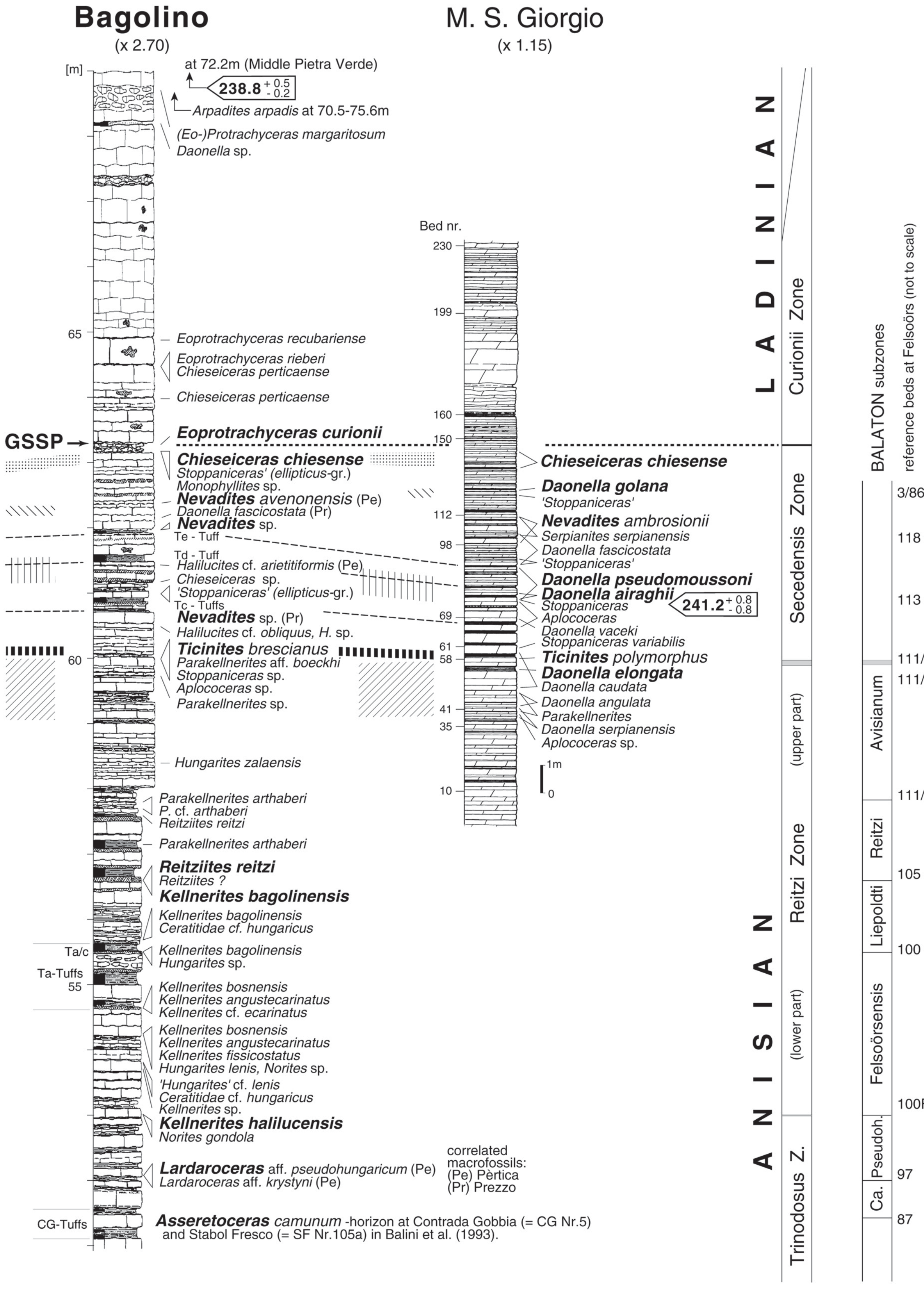

Figure 7b (for caption see previous page)

(Bucher & Orchard, 1995; Orchard & Tozer, 1997).

Daonella

Only a few well preserved specimens of *Daonella* have been extracted from the Anisian/Ladinian boundary interval in sections around Bagolino. Of these, *Daonella fascicostata* was found in the upper Secedensis Zone just above the Te-tuff layer. Figure 7a,b highlights the close match of the distribution of *Daonella* in other South Alpine sections. In particular, the levels with representatives of the group of *Daonella elongata* (*D. serpianensis*-

angulata-caudata-elongata-airaghii) at M.S.Giorgio, Seceda and Val Gola are in excellent agreement. Because of the occurrence of representatives of the *D. elongata*-group in China (*D.* cf. *airaghii*) and in the Meeki Zone of Nevada (*Daonella* cf. *elongata*; Silberling & Nichols, 1982 and new unpublished own finds), these bivalves are of particular interest for far reaching correlation.

No determinable *Daonella* are known so far from the Curionii Zone. Higher up, specimens of *Daonella* are precisely located in layers of the middle (*D.* cf. *longobardica*, *D. moussoni*) and upper Buchenstein Beds (*D. pichleri*, *D. tyrolensis*) at Bagolino, M. Corona and Seceda (Schatz 2001a,b; Maurer & Rettori 2002).

PALYNOMORPHS

A pilot study on potential palynomorph occurrences in samples from Bagolino has just been started but no results are available yet. First results on palynomorphs from Buchenstein Beds of the Seceda core (Dolomites) along with revised data from Val Gola suggest a distinct change in the microflora between assemblages observed in the Lower Plattenkalke (upper Reitzi Zone) and in the Knollenkalke corresponding to the upper Curionii Zone (Hochuli & Roghi, 2002).

MAGNETOSTRATIGRAPHY

Samples taken for magnetostratigraphic analysis at Bagolino show remagnetised Tertiary components (G. Muttoni, pers. commun.). However, the succession of magnetic reversals is well established for almost the entire succession of Buchenstein Beds in correlated sections in the Dolomites (Muttoni et al., 1996, 1997 and submitted; Brack & Muttoni 2000) and at Val Gola (Gialanella et al., 2001; see also discussion by Brack et al., 2001). In this record of magnetic reversals (Fig. 7a), the GSSP-level as proposed at Bagolino lies close to the base of the reversed magnetozone M1r (Margon) and F1r.2r (Frötschbach) respectively and is preceded by a short normal polarity interval of Fr1r.1n.

New data from the Seceda core (Muttoni et al., submitted) confirm the previous results and provide a stratigraphic expansion of this record. Remarkable is the existence of a long zone of reversed polarity in the Lower Plattenkalke below the base of the Secedensis Zone (*Ticinites* horizon). The comparison with the Hungarian record reported in a recent field guide (Budai et al., 2002; fig. 1/5) casts doubts on the reliability of a long normal polarity interval in the corresponding interval at Felsöörs (upper part of Vàszoly Fm.).

CHEMICAL STRATIGRAPHY

No systematic studies on stable isotopes and other chemical markers are available for Bagolino. Unpublished results of a pilot study of stable isotopes (C, O) on 30 outcrop samples evenly distributed over the entire succession of Buchenstein Beds at Seceda show lithology-related variation in the carbon isotopes (R. Abart, pers. commun.). Throughout the entire column no significant excursion is evident in the oxygen isotopes with a mean value of $\delta^{18}O$ (SMOW) of 28.0+/-0.8‰.

SEQUENCE STRATIGRAPHY

The deposition of the pelagic Buchenstein Beds occurred in deep marine conditions. The age calibration of platform-basin settings in the Dolomites (Maurer 1999, 2000; Brack & Muttoni, 2000) suggests that maximum basin depth was reached close to the base of the Curionii Zone (i.e. close to the proposed GSSP-level). Comparison of the pelagic successions of the Southern Alps with the Germanic Middle Triassic suggests that the *Cycloides* γ horizon identified as a maximum flooding surface in the Germanic realm (Aigner & Bachmann, 1992) may indeed correspond to a level at around or just above the base of the Curionii Zone (Brack et al., 1999).

CYCLE STRATIGRAPHY

No cyclostratigraphic data are available for Bagolino.

The spectral analysis of bedding rhythms in distinct intervals of Buchenstein Beds of the Seceda core and section (Maurer et al., in press.) suggests the existence of hierarchical stacking patterns possibly related to variations in orbital parameters. If confirmed and extended, these results will provide a significant refinement of the age resolution in the time interval represented by the Knollenkalk-member of the Buchenstein Beds from the Secedensis Zone upwards and including the proposed GSSP-level.

OTHER EVENT STRATIGRAPHY

TEPHRASTRATIGRAPHY

At Bagolino volcaniclastic layers occur in the uppermost Prezzo Limestone and throughout the entire Buchenstein succession as a few millimetres up to a few decimetres thick acidic ash beds often with a greenish colour ("Pietra verde"). In the Buchenstein Beds the volcaniclastic layers show increased frequencies in three stratigraphic intervals. Individual beds and characteristic stacks of layers can be traced over tens of kilometres and have been identified as far away as in the Dolomites and Southern Switzerland (Fig. 7a,b; see also figs. 7, 10, 11 in Brack & Rieber, 1993 and figs. 2, 3, 11 in Brack & Muttoni, 2000) The lateral persistence of volcaniclastic layers points to an airborne origin of the silt to sand-sized ash particles, probably originating from eruption centres outside the present Southern Alps.

Beyond their occurrences in South Alpine basinal sediments and platform interior carbonates (e.g., at Latemar) comparable volcaniclastic ash layers are well known and show potential for isotopic age dating and stratigraphic correlation in the Reifling Beds of the Eastern Alps as well as in sedimentary successions further afield (e.g., Hungary, Dinarids, Greece).

MARINE - LAND CORRELATION POTENTIAL

If confirmed and properly positioned with respect to the proposed GSSP-level, the distinct change in microflora assemblages between the upper Reitzi Zone and the upper Curionii Zone as indicted above may have potential for correlation with non-marine sections of comparable climate zones.

GEOCHRONOMETRY

High-resolution U-Pb age data obtained on single zircon grains from volcaniclastic layers are available for four distinct stratigraphic horizons in Buchenstein and corresponding layers at Bagolino, Seceda and M.S.Giorgio (Figs. 3, 5, 7; Mundil et al., 1996; Brack et al, 1996). For the proposed GSSP-level an interpolated age of 240.7Ma is estimated from the age values bracketing the base of the Curionii Zone, i.e. the Tc-tuff interval (Secedensis Zone; SEC.22: 241.2+0.8/-0.6Ma and MSG.09: 241.2+0.8/-0.8Ma) and the volcaniclastic layer at the 72.2m-level of Bagolino (BAG.06a: 238.8+0.5/-0.2Ma). The U-Pb age of the lower level (Secedensis Zone) is confirmed by recent Ar-Ar results on sanidines from the layer with an U-Pb data at M.S.Giorgio (Renne et al., in prep.). Moreover, the zircon ages of this level overlap within error with recent multigrain U-Pb-results from stratigraphically somewhat older tuff layers at Felsoörs (Pálfy et al., 2002, 2003; Budai et al., 2002).

DEMONSTRATION OF REGIONAL AND GLOBAL CORRELATION

Regional correlation

The accurate litho-, tephra- and biostratigraphic correlation of Anisian/Ladinian boundary intervals of sections in the Brescian Prealps (including Bagolino) and Giudicarie is illustrated and discussed in Brack & Rieber (1986, 1993) and Brack et al. (1995). Buchenstein intervals in the Dolomites, with magnetostratigraphic data and correlated on a bed-scale are documented in Brack & Muttoni (2000). Selected key sections from these areas and Southern Switzerland, including the most important macrofossils, magnetic reversals and lithostratigraphic markers are shown in Fig. 7a,b (see Brack & Rieber, 1993; Brack et al. 2001 for additional information and references).

Long distance and global correlation

On the basis of ammonoids, excellent correspondence is evident of the ammonoid records below the *Ticinites* horizon at Bagolino and in the Balaton Highland (e.g., Felsoörs; Fig. 7b). The apparent expansion of the stratigraphic record of the Reitzi Zone at Felsoörs (Vörös, 1998; Budai et al., 2002) is due to dilution with abundant volcaniclastic material. The cumulative thickness of fossil-bearing limestone layers is comparable in both sections. The proposed GSSP-level (i.e. the base of Curionii Zone) has not yet been identified at Felsoörs.

The comparison of the Anisian/Ladinian boundary ammonoid records of Bagolino and Epidauros (Krystyn, 1993; unpublished own data) shows good agreement (e.g., representatives of *Kellnerites*, *Nevadites*, *Chieseiceras* including *Ch. chiesense*, *Eoprotrachyceras*, *Arpadites*). At Epidauros the proposed GSSP-level can be properly identified. However, the comparison also suggests strong condensation at different stratigraphic levels in the Epidauros stratigraphy, in particular, in the Curionii Zone.

The correlation of South Alpine pelagic successions (including Bagolino) with the Germanic Middle Triassic is discussed in Brack et al. (1999). The ammonoid based correlation of South Alpine sections with North America is discussed in Brack & Rieber (1994) and Bucher & Orchard (1995).

SELECTION PROCESS

Relation of the GSSP to historical usage

The history of concepts regarding the Anisian/Ladinian boundary is summarized in Brack & Rieber (1994). These views are further discussed by Kozur (1995).

In spite of the complexity and ambiguity of historical issues, Bittners (1892) definition of the term “ladinisch” (ladinian) remains of particular relevance and makes specific reference to stratigraphic successions in the Southern Alps (i.e. “the Buchenstein Beds, Wengen Beds and, if necessary, the Cassian Beds”).

OTHER USEFUL SECTIONS

The most relevant South Alpine sections complementary to Bagolino and with stratigraphic data of significance for the definition of the base of the Ladinian Stage have been mentioned in the previous sections. A compilation of important stratigraphic results from the Southern Alps is shown in Figure 7a,b.

New stratigraphic data are also expected to emerge soon from a multidisciplinary study on the Seceda core (Brack et al., 2000). So far these efforts have resulted in a detailed sedimentological characterisation of Buchenstein lithologies (Maurer & Schlager, 2002).

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Proposal Of The Global Stratigraphic Section And Point (Gssp) For The Base Of The Ladinian Stage (Middle Triassic)

GSSP at the base of the Avisianum Subzone (FAD of *Aplococeras avisianum*) in the Bagolino section (Southern Alps, NE Italy)

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INTRODUCTION

The debate over the best position for the GSSP of the base of the Ladinian remained intense throughout the last decade. The main topics of this debate have been summarized in a recent STS/IGCP meeting in Veszprém, Hungary (September 2002). A major problem on the definition of the GSSP was there emphasized by Vörös (2002), and is related to the physical recognition of the boundary in stratigraphic sections of historical meaning in various regions. Among the proposed possibilities: the highest position (FAD of *Eoprotrachyceras curionii*) is probably accetable for researchers of the Alpine region, but cannot be identified with confidence in Hungary; on the contrary, low positions (i.e., base of Reitzi Zone, or FAD of *Reitziites reitzi*) are clearly identified in hungarian sections but are rarely seen in the Southern Alps. Vörös (2002) points out that at least five possible criteria exist for the Anisian – Ladinian boundary, all more or less satisfactory from the scientific point of view. He thus suggests to move towards a compromise, i.e., a criterion which allows the physical recognition of the boundary in the largest number of stratigraphic sections.

Following these suggestions, in November 2002 we endeavoured an integration of the ammonoid biostratigraphy in the classical section of Bagolino in Lombardy (Brack and Rieber, 1986, 1993), that resulted successful (Mietto et al., in press). We are thus able to raise a compromise proposal for the GSSP of the base of the Ladinian at the FAD of *Aplococeras avisianum* at Bagolino. This boundary can be positively recognized at least in Hungary, in the Southern Alps, and in Nevada.

According to Brack et al. (this volume), we accept Bagolino as a reliable stratigraphic section for the base of the Ladinian. Readers are invited to refer to Brack et al. (this volume) for the description of the section and the geology of the area; only minor adjustments to this part are here proposed.

STRATIGRAPHIC RANK OF BOUNDARY: BASE OF THE LADINIAN STAGE IN THE MIDDLE TRIASSIC SERIES OF THE TRIASSIC SYSTEM.

GEOGRAPHICAL AND GEOLOGICAL DESCRIPTION OF THE PROPOSED GSSP

The readers are invited to refer to Brack et al. (this volume). The authors wish however to comment only minor aspects of the section and particularly of the site C.

LOCATION OF LEVEL AND SPECIFIC POINT

We indicate the stratigraphic section at site C (45°49' 7,98" N 10°28' 24" E, elevation 607 m) as location of the GSSP. The GSSP-level lies in the "transitional beds", in a more consistent intercalation within a 65-cm-thick interval of prevalent dark siltites (bed B2c 10).

STRATIGRAPHIC COMPLETENESS

We find necessary to add a few considerations to what Brack et al. indicate about the stratigraphic completeness of Bagolino, in regard of sedimetation rates and ammonoid abundance.

For the net average sedimentation rate at Bagolino several estimates were directly or indirectly proposed, besides the one cited in Brack et al.'s proposal:

- Brack and Muttoni (2000) suggested a ca. 10 m/Myr, based on radiometric ages. This is given as an average value between a lower limit of 7.5 m/Myr and an upper limit of 23m/Myr, considering the confidence intervals of

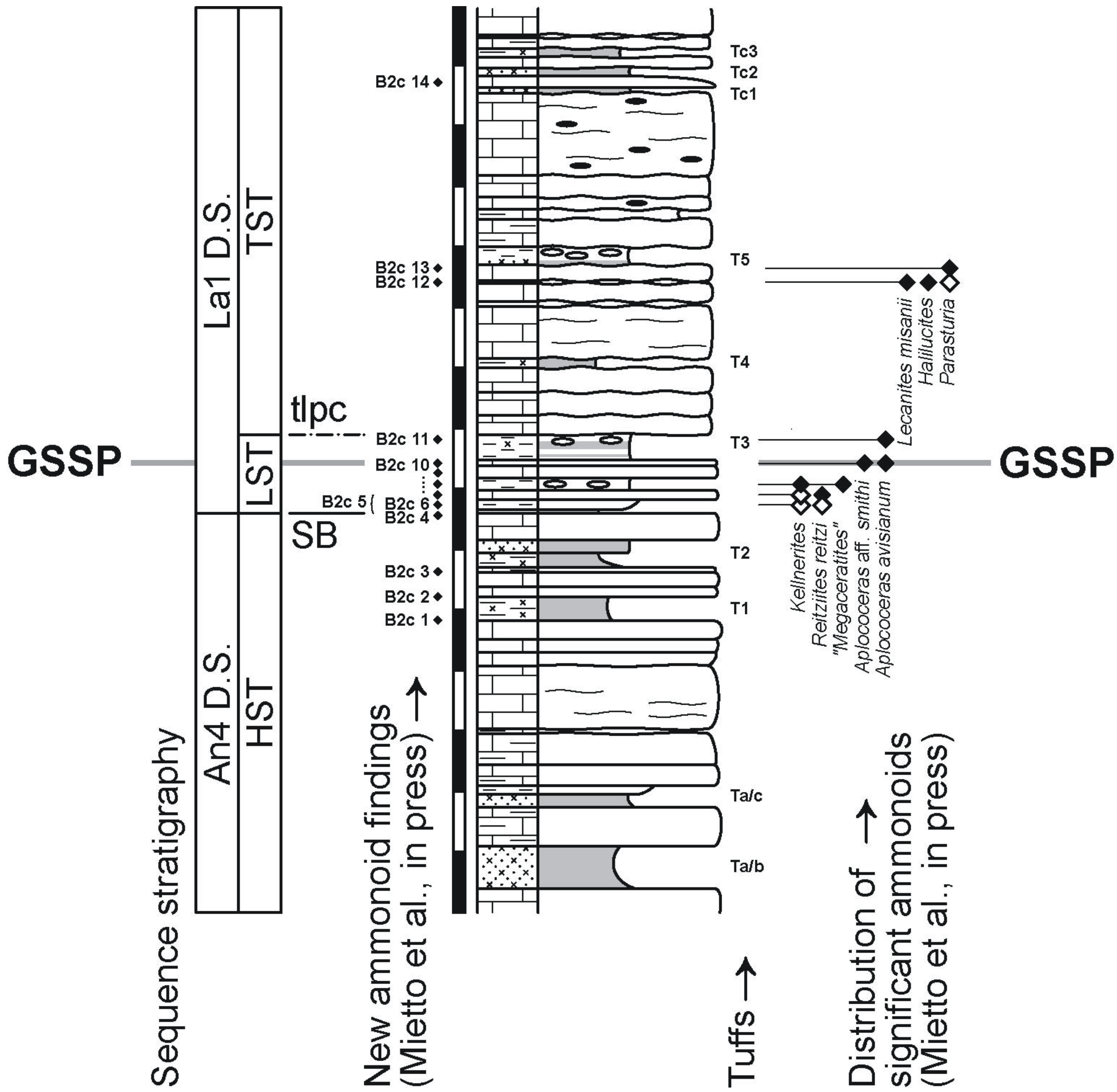

Figure 1. Detailed stratigraphic log of site C at Bagolino, interval including the proposed boundary. Ammonoids (cf. Mietto et al., in press) are only from site C and not from nearby outcrops; open diamonds refer to specimens with open nomenclature. Sequence stratigraphic interpretation is relative to this outcrop, taking in consideration the regional stratigraphic and sedimentologic framework. The proposed boundary is placed at the FO (FAD) of *A. avisianum* at level B2c 10, in a relatively consistent bed within a dark silty interval. Conodont data for this site may be found in Nicora and Brack (1995).

radiometric dates;

- Preto et al. (2001) calculated an average sedimentation rate for a consistent portion of the Latemar platform of 51 m/Myr on the base of orbital tuning. Platform to basin correlations based on biostratigraphy (Preto et al., 2002) and magnetostratigraphy (Muttoni and Kent, 2003) would translate this platform sedimentation rate to less than 1 m/Myr at Bagolino;

- Zühlke et al. (2003) provided an alternative timescale for the Latemar platform, interpreting the elementary cycles as sub-Milankovitch instead of precession-forced. Basing again on biostratigraphic and magnetostratigraphic correlations, the sub-Milankovitch calibration of the Latemar platform translate in Bagolino to an average sedimentation rate of ca. 1.8 m/Myr;

- Maurer (2003) Calculated 3.6 m/Myr for a portion of the Livinallongo / Buchenstein beds in the Seceda core, showing a well preserved Milankovitch signal. This sedimentation rate at Seceda would translate to less than 2 m/Myr at Bagolino.

As the issue of sedimentation rates is still a matter of discussion, it is more correct to state that the sedimentation rate at Bagolino is most probably within the range of 1-20 m/Myr ca.

We confirm the abundance of ammonoids in the Bagolino section. Brack et al. (this volume) point out that only a short barren interval at m 58-60 is observed. Of course, when new data of the authors (Mietto et al., in press) are considered, this problem is somewhat overcomed. The Avisianum Subzone is now documented in this interval.

PRIMARY AND SECONDARY MARKERS

PRINCIPAL CORRELATION EVENT (MARKER) AT GSSP LEVEL

The proposed GSSP at level 57.71 m of Bagolino section, site C (bed B2c 10) is defined with the first appearance of the ammonoid species Aplococeras avisianum (Mojsisovics), as outlined in Fig. 1 (see also Brack et al., this volume: figs 3, 5)

In the same section *Reitziites reitzi* (Böckh) is still present a few cm below (m 57.58); in several other sections of the Southern Alps and Balaton Highland, the ranges of *R. reitzi* and *A. avisianum* never overlap, so that bed B2c 10 can be safely interpreted to document the possible FAD of *A. avisianum*. This is also confirmed (Mietto et al., in press) by the occurrence, in the interval immediately below (beds B2c 8-9), of the typical faunal association of the uppermost Reitzi Subzone sensu Mietto and Manfrin (1995).

For practical purposes, this option is extremely interesting: the index species is commonly found in the Southern Alps in both basinal and platform settings, and is recorded also in Balaton Highland, Hungary.

Due to the coincidence of all morphological characters, including the suture line, the North American species *Aplococeras vogdesi* (Hyatt and Smith) is considered as a junior synonym of *A. avisianum* (Mietto et al., in press) as Assereto (1969) earlier suggested. The marker species thus shows a widespread, intercontinental distribution in the low palaeolatitude (tropical) faunal realm. Furthermore, *A. avisianum* is easy to recognize and usually common, thus its FAD constitutes an excellent marker.

OTHER STRATIGRAPHY

BIOSTRATIGRAPHY

Daonellids

The Avisianum Subzone is characterized by a rich association of species of the *Daonella elongata* group and is on that basis widespread correlatable in the Southern Alps (Brack and Rieber, 1993, Brack et al., this volume: fig. 7). *Daonella cf. elongata* is further found in the Meeki Zone of Nevada (Silberling and Nichols, 1982), another hint for the contemporanity of the two time intervals.

Conodonts

Conodonts have been extensively studied from both the Bagolino (Nicora and Brack, 1995; Brack and Nicora, 1998) as well as many other sections of the Buchenstein basin in Southern Alps (Brack and Nicora 2002). The latest range data for Bagolino (see fig. 2) and surrounding sections are found in Brack et al.'s GSSP proposal (this volume) to which we are referring below. A continous conodont record through the considered time interval is also known from Hungary; the latter closely matches and completes the Italian record. The chosen boundary level is very close to main evolutionary events in the two distinct genera *Neogondolella* and *Paragondolella*. The onset of elongate *neogondolellids* with upturned posterior end of the *pseudolonga/ transita* group postdates rather shortly (just 10-20 cm) the base of the Avisianum Subzone in the Southern Alps (fig. 1) and Hungary (see Vörös et al., this volume). Slightly higher and above the Avisianum Subzone *Paragondolella fueloepi* and *P. trammeri* appear (Brack et al, this volume; Kovacs et al., 1990), both distinct and widespread Tethyan Ladinian guide forms. The apparent later FO of *P. trammeri* at the base of the overlying Secedensis Zone (sensu Brack and Rieber, 1993) in the strongly condensed Hallstatt facies of Epidauros (Greece) is now explained by non-deposition, leading to a stratigraphic hiatus during the Avisianum time interval. Though presently not yet described, *transita* and/or *pseudolonga* could be present in North America too as Ladinian representatives of the groups have already been mentioned by Orchard and Tozer (1997).

Dasycladaceans

The distinct top-Anisian dasycladacean event between *Diplopora annulatissima* and *D. annulata* could be related to a major platform emergence phase during the sea level lowstand at the base of the Avisianum Subzone. Following Gaetani et al. (1981), this event is documented in the Latemar platform at the base of the "Latemar Limestone", i.e., within the lower Avisianum Subzone. Additional work is however needed to substantiate this supposition. If true, it would become an excellent boundary marker tool within the otherwise stratigraphically undividable huge Middle Triassic platform carbonate buildups of the western Tethys.

PALYNOMORPHS

In-depth palynological investigations at Bagolino yielded no results. Preliminary analysis of correlated sections seem to indicate a significant floral change within the Crassus and/or Secedensis Subzones (Hochuli and Roghi, 2002).

The Reitzi Subzone at Val di Centa (Val di Centa Marls) and M. Rite (Ambata Fm., "Daonella Marls" Mb.) is characterized by a palynological association with *Jugaesporites comnilvinus*, *Stellapollenites thiergarti*, *Staropollenites antonescui*, *Strotersporites tozeri*, *Angustisulcites sp. A* (sensu Brugman, 1986), *Cannanoropollis scheuringi* and *Dyupetalum vicentinense* (Roghi, 1995). The same association was found at Seceda (Hochuli and Roghi, 2002) within the Plattenkalke (Avisianum and/or Crassus Subzones). This association corresponds to a classical microflora described in the "*vicentinense-scheuringi* phase" (Brugman, 1986) and in the Assemblage A (Hochuli and Roghi 2002).

The next floral association is documented, after a barren interval, in the Val Gola Section (Val Gola Limestones) within the upper Secedensis (ex Serpianensis) Subzone, and is characterized by the disappearance of some of the previously listed species. The FO of the typical Upper

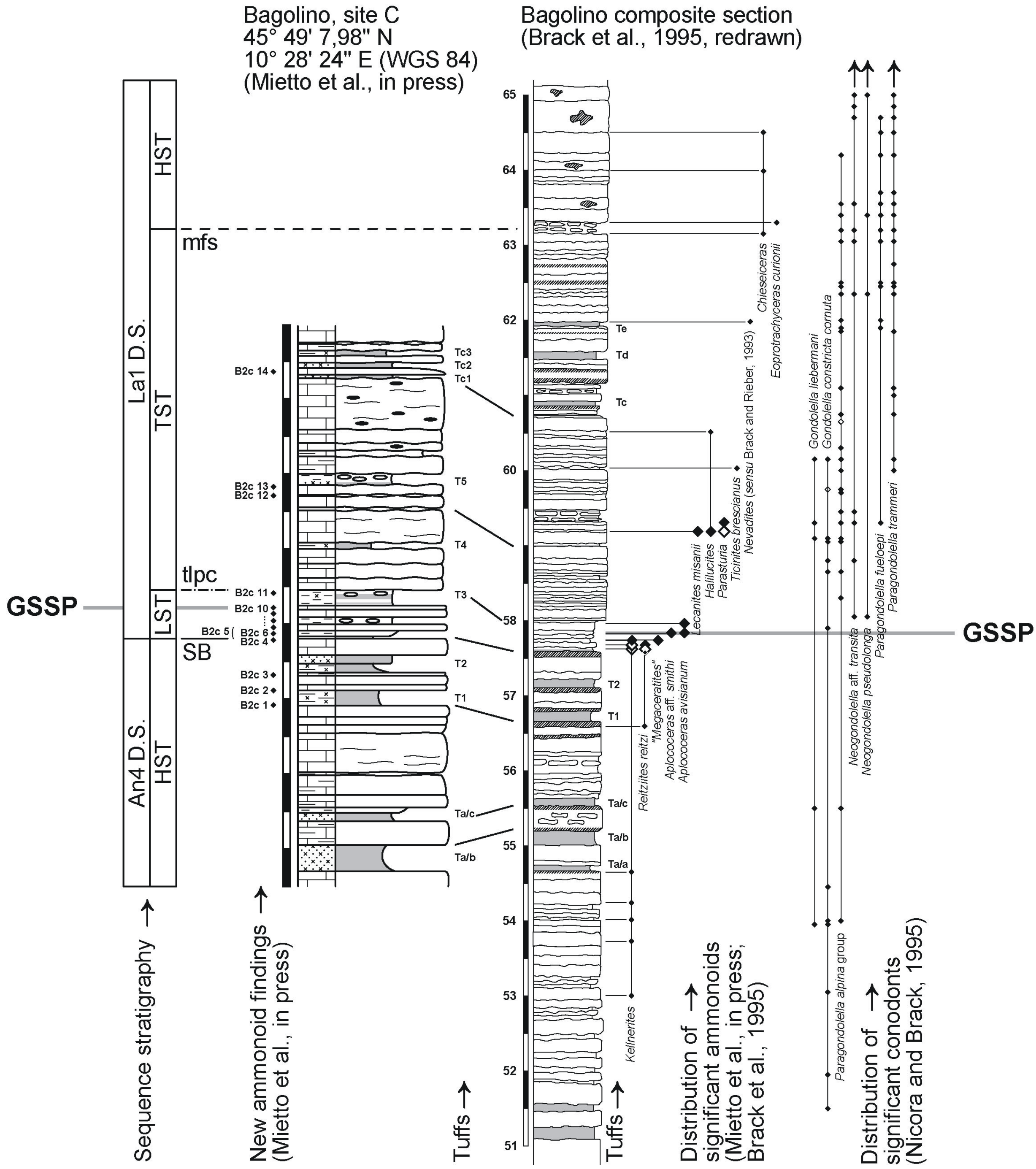

Figure 2. Detailed stratigraphic log of site 2C compared with the composite Bagolino section by Brack et al. (1995). Sequence stratigraphic interpretation is based on site 2C and regional stratigraphy (cf. De Zanche et al., 1993; Gianolla et al., 1998); in the ammonoid distribution, small diamonds refer to ammonoids from Bagolino (unspecified site) of Brack et al. (1995); conodont distribution (all sites) from Nicora and Brack (1995). It should be highlighted that the distribution of conodonts in Bagolino is in some cases not representative of the regional (Southern Alps) distribution (cf. Brack et al., this volume). Open diamonds indicate open nomenclature.

Ladinian to Lower Carnian forms *Camerosporites secatus*, *Duplicisporites sp.*, *cf. Ovalipollis sp.*, and *Sellaspora spp.* is also documented (Hochuli and Roghi, 2002).

Ongoing studies will better define the correlation of this floral change with the standard ammonoid scale. This floral change is reasonably close to the proposed GSSP level, but do not correspond to it, neither with the other proposed GSSPs (Brack at al., this volume; Vörös et al., this volume).

MAGNETOSTRATIGRAPHY

The record of Anisian/Ladinian paleomagnetism is not preserved at Bagolino (Brack et al., this volume). Only the correlated section of Felsoörs, Hungary, has magnetostratigraphy at the proposed boundary level (Vörös et al., this volume). Here, the Avisianum Subzone is presumably confined between the FO of *Latemarites latemarensis* (beds 110) and the FO of *Halilucites* (bed 111a), and is thus probably almost condensed.

Bed 111a show reversed polarity. We suggest this is a real reversal, observed in only one sample due to the extremely low sedimentation rate at Felsöörs, along with a somewhat low resolution sampling. This reversed interval might correspond to the reversed interval found at Seceda within the Plattenkalke (Brack et al., this volume).

Thus, the base of a reversed magnetozone occurs slightly above the proposed GSSP, within the Avisianum Subzone.

SEQUENCE STRATIGRAPHY

Despite the pelagic setting, the Bagolino section fits well with the sequence stratigraphic framework of the Southern Alps (De Zanche et al., 1993; Gianolla et al., 1998). A new careful examination of the Bagolino section revealed a narrow interval (65 cm at site C) characterized by an increased siliciclastic component (mainly silt) which is interpreted as a Lowstand Systems Tract (LST). The Sequence Boundary (SB) lies at m 57.6 in the uppermost part of the Reitzi Subzone sensu Mietto and Manfrin (1995), thus, this SB corresponds to a SB identified in several localities of the Southern Alps (La1 SB in Fig. 1; De Zanche et al., 1993, 1995; Gianolla et al., 1998; An4 SB in Handerbol et al., 1998). At the end of the LST, a sudden decrease of the siliciclastic component and the resumption of the carbonate sedimentation (m 58) represents a tlpc (top lowstand prograding complex) surface. Both the SB and the tlpc are close to the proposed boundary, and constitute an excellent instrument of physical correlation which can be potentially recognized worldwide, also in marginal setting where a reliable biostratigraphy is missing.

The following maximum flooding surface (mfs) corresponds to the so-called “Chiesense groove” (Brack and Rieber, 1986), at m 63.25 ca. This surface is perhaps the major flooding event of the Triassic in the Southern Alps (Gianolla and Jacquin, 1998). From the point of view of sequence stratigraphy, the stratigraphic interval including the “Chiesense groove” has the highest probability to be condensed, and is expected to have the lowest sedimentation rates at Bagolino.

CYCLE STRATIGRAPHY

No cyclostratigraphic data are available at Bagolino, neither they most probably will, due to the relatively low sedimentation rates of the series and the pervasive bioturbation above m 58.

Cyclostratigraphic analyses have been carried out at Seceda and at the Latemar Platform (Goldhammer et al, 1987; Preto et al., 2001; Maurer, 2003; Zühlke et al., 2003). All these studies revealed discrepancies with available radiometric ages, or failed to identify an undisputable Milankovitch signal. We suggest that cyclostratigraphy of Middle Triassic is still in its earliest stage, and its use for time measurement or correlation is still untimely.

None of the cyclostratigraphic studies overlap with any of the proposed GSSPs.

OTHER EVENT STRATIGRAPHY

TEPHRASTRATIGRAPHY

Primary volcaniclastic deposits (tuffs) are present at Bagolino from m 51 to m 72 and above. Some of these tuffs (Tc, Td and Te in Fig. 2) have been traced for kilometers within the Southern Alps (Brack and Rieber, 1993; Brack and Muttoni, 2000).

Palfy et al. (2003) suggest that the lower tuffs (Ta1, Ta2, T1 and T2 in Fig. 1 and 2) in Bagolino could be found as far as Felsoörs, Hungary. We agree with these authors, and suggest that tuffs F103 and F105 in Felsoörs correspond respectively to T1 and T2 (Fig. 1 and 2). These tuffs lie slightly below the proposed GSSP and constitute a good correlation marker at the regional scale.

Apart from these tuffs, many other tuff horizons can be identified in Bagolino, some very close to the proposed boundary (tuffs T3, Fig. 1 and 2). Although they haven’t been yet correlated with other localities, they represent other potential elements of regional correlation.

MARINE-LAND CORRELATION POTENTIAL

Correlation with continental successions can be achieved by palynology or geochronology.

Palynological marine-land correlation is hampered by paleolatitudinal microflore differentation. *Stellapollenites thiergarti*, found in the Southern Alps till the Secedensis Subzone (Hochuli and Roghi, 2002), is an important species present also in the Germanic domain.The LAD of *Stellapollenites thiergarti* in the Germanic basin, in the middle part of the Upper Muschelkalk, define the position of the proposed boundary in the lower part of this unit (Visscher et al., 1993; Brack et al., 1999).

Many high resolution radiometric dates are available from several sections in the boundary interval. Although they obviously need to be assessed, as for example dates from the Reitzi Zone in Hungary (Palfy et al., 2003) appear to be younger that dates of the overlying biozones (Mundil et al., 1996, 2003), they appear to provide a resolution comparable with that of the biostratigraphy in non-marine settings.

GEOCHRONOMETRY

The interval of interest is perhaps the most dated of the Triassic. Many high resolution zircon dates have been published (Mundil et al., 1996, 2003; Palfy et al., 2003), and many others are in progress and might be published soon.

All published dates close to the proposed GSSP range between 240.4 and 242.6, with mostly overlapping confidence intervals. The age of the boundary is likely within this range, but it is still premature to interpolate an age of the GSSP, until some issues about the meaning of these radiometric dates are not resolved (cf. Hardie and Hinnov, 1997; note also that the radiometrically youngest ages, reported in Palfy et al., 2003, are at the stratigraphically lowest level, within the Reitzi Zone, and lie below tuffs yielding radiometrically older zircon dates).

DEMONSTRATION OF REGIONAL AND GLOBAL CORRELATION

Regional correlation

In the Southern Alps, the base of the Avisianum Subzone is recorded within the "Daonella marls" member of the Ambata Fm. of Ru Sec section in Cadore (De Zanche et al., 1995), and in the "Grenzbitumenzone" of Monte S. Giorgio in Switzerland (Rieber, 1973). In Ru Sec section, *Reitziites reitzi* occurs in the uppermost Bivera Fm.

In the Grenzbitumenzone of Mt. S. Giorgio the FO of A. avisianum is to be placed in layer 42 ("Aplococeras cf. misanii" in Rieber, 1973). In the underlying layer 35 is documented the uppermost Reitzi Subzone (sensu Mietto and Manfrin, 1995) represented by "*Ceratitide gen. et sp. indet. a*", the latter found also in the Passo della Fricca section.

As stated in 3A, A. avisianum (and the related biozone) is recorded in both basinal and platform settings, is easy to recognize and common, thus constitutes an excellent marker for regional correlation: the taxon is indeed surely documented in many localities and sections of the Southern Alps, from Carnia to Canton Ticino (Mt. Nebria in Valbruna, Ru Sec in Val Zoldana, Punta Zonia and Auronzo in Cadore, Latemar massif in the western Dolomites, Monte Cislon, Val dei Molini in the Adige Valley, Adanà in Giudicarie: Mietto & Manfrin, 1995, De Zanche et al., 1995; Prezzo: Brack et al., 1995; Monte San Giorgio in Canton Ticino: Rieber, 1973).

Long distance and global correlation

In accordance with the suggestion of Assereto (1969) a fundamental key-element for a long distance correlation is the succession of the various taxa of the ammonoid family *Aplococeratidae* (Manfrin and Mietto, 1995)

In the Southern Alps the most ancient representatives of the family so far found are specimens morphologically similar to *Aplococeras smithi* Silberling and Nichols from Fossil Hill in Nevada; these specimens were found in a level 26 cm overlying the one with the last *Reitziites reitzi* (Böckh) in the Bagolino section (Mietto et al, in press), and in the level with *"Megaceratites" friccensis* (Arthaber) at Fricca Pass near Trento. In the Punta Zonia section (Cadore area) the LO of *A. aff. smithi* co-occurs with the first representatives of *A. avisianum*. Similarly, in Nevada the LO of *A. smithi* is above the FO of *A. vogdesi* (Hyatt and Smith). The latter is treated as a synonym of *A. avisianum*, as suggested by Assereto (1969) and already proved by Mietto et al (in press).

In the Bagolino section, *A. aff. smithi* co-occurs again with the first representative of *A. avisianum* in bed B2c 10, as observed in Nevada. Moreover, it is important to emphasize that at Bagolino, between the LO of *R. reitzi* and the FO of *A. avisianum*, another stratigraphical interval characterised by elements of *"Megaceratites" friccensis* level is present.

In the Southern Alps, *Lecanites misanii* (Mojsisovics) appears in the uppermost Avisianum Subzone, while *A. avisianum* is rarely present in the basal portion of the overlying Crassus Subzone. Based on type specimens comparison, Mietto et al. (in press) reached the conclusion that *Aplococeras parvus* (Smith) in Nevada is a junior synonym of *L. misanii*. In Nevada, *A. parvus* is associated with the first representatives of the genus *Nevadites*.

Therefore, on the basis of these data, a correlation of the boundary *Frechites nevadanus/Parafrechites meeki* beds in Nevada and the boundary Reitzi/Avisianum Subzones (sensu Mietto and Manfrin, 1995) can be suggested. As a consequence, the *F. nevadanus* beds and the *Gymnotoceras blakei* beds are correlated with the Reitzi Subzone, while the *P. meeki* and the *Parafrechites dunni* beds correspond to the Avisianum Subzone.

Outside the Southern Alps and Nevada, *A. avisianum* is confidently documented in the Balkans (Berndt, 1935) and in the Balaton area (Vörös, 1993, 1998; Vörös and Budai, 1993). In the Felsöörs section, which is also proposed as GSSP candidate for the base Ladinian (Vörös et al, this volume), the Avisianum Subzone is documented by the correlated fauna with *Latemarites latemarensis*.

SELECTION PROCESS

Relation of the GSSP to historical usage

The historical background of the Anisian-Ladinian boundary has been elucidated intensively by Balini, 1993; Brack & Rieber, 1994; De Zanche and Gianolla, 1995; Gaetani and Brack, 1993; Kozur, 1995 and Manfrin and Mietto, 1995, and demonstrates how all tentatives of seeking a priority argument to support a GSSP proposal, based on historical grounds, is largely subjective.

Other candidates and reasons for rejection

Following Vörös (2002), three candidates for the base of the Ladinian were mainly discussed to date: the base of the Reitzi Zone sensu Brack and Rieber (1993) (FAD of genus Kellnerites); the base of the Crassus Subzone sensu Mietto and Manfrin (1995), supposed to correspond to the FAD of *Ticinites crassus* and *Nevadites*; the FAD of *E. curionii*. While all of these possibilities might be considered, all have some shortcomings.

The genus *Kellnerites* has never been found outside of the Tethysian domain, and so this proposal has strong limitations with regard to long distance correlations. Furthermore, while *Kellnerites* is well documented both in the Southern Alps and Hungary, the FO of the genus is represented in these two localities by two different species: *K. felsoeoersensis* at Felsöörs (Hungary: see Vörös 1993, 1998) and *K. halilucensis* in Bagolino (Southern Alps: see Brack and Rieber, 1993, 1995). The suggestion of Kovács (2002: Fig. 2, variant 2a) to consider the base of the Ladinian at the base of Reitzi Subzone (FO of Reitziites reitzi at Felsoörs), represent an improvement of the original proposal. However, neither *Reitziites reitzi* nor the genus *Reitziites* have been yet found in the North American province.

The base of the Crassus Subzone corresponds to a time of major turnover for ammonoids, and might thus be the candidate providing the best chances of long distance correlation. However, problems arise when a single faunal event (FAD) must be chosen as principal marker for the base of the Ladinian. In Mietto and Manfrin's (1995) acceptation, the important genus *Nevadites* appear together with *Ticinites crassus*, but both taxa are somewhat rare and never found together. In addition, only Nevadites can be found in North America, and the older North American species (*N. hyatti*) was never found in Europe.

The option at the FO (FAD) of *E. curionii* has several drawbacks, among which we highlight:

- *E. curionii* is not found outside the Southern Alps and Greece. The FO (FAD) of genus *Eoprotrachyceras* is documented by the FO of different species in several localities worldwide (e.g. *E. curionii* in the Mediterranean domain, *E. subasperum* in Nevada and *E. matutinum* in British Columbia, see also Tozer, 1994) and thus apparently constitutes a good marker. Hovewer, there is no guarantee that the FO of the genus occurs at the same time in the different localities, when this FO is not given by the same species.

- The FO (FAD) of *E. curionii* at Bagolino lies at the top of the "Chiesense groove", interpreted in the distal Bagolino section as a mfs (see section 3.B.4). In this setting, this interval is expected to have the minimum sedimentation rates, and might be condensed. The base of the "Chiesense groove", i.e., the ca. 20-cm-thick seam which is the physical expression of the mfs, contains a significantly different ammonoid association, also suggesting possible condensation.

- With respect to other candidates, the FAD of *E. curionii* do not corresponds to a marked faunal turnover, thus hampering the possibilities of long distance correlations.

- Lastly, if the base of the Ladinian will be placed at this event, the Fassanian (i.e., the first substage of the Ladinian) will be extremely reduced, and a large part of the (several hundred of meters thick) Sciliar Dolomite in the Dolomites, traditionally considered a Ladinian carbonate platform, will result to be actually Anisian. This will lead to a great difficulty in the interpretation of bibliography for non-specialists, which is a problem that can be avoided by giving stability to the stratigraphic nomenclature.

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OTHER USEFUL SECTIONS

Other important sections bearing the proposed boundary are Ru Sec in Cadore, Monte S. Giorgio in Switzerland and Felsoörs in Hungary. Due to the good documentation of ammonoids, Felsoörs can be a reference section of the boundary for the Balaton area.

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GSSP (Global Boundary Stratotype Section And Point) PROPOSAL FOR THE BASE OF LADINIAN (TRIASSIC)

A proposal for the GSSP at the base of the Reitzi Zone (sensu stricto) at Bed 105 in the Felsöörs section, Balaton Higland, Hungary

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1. NAME AND STRATIGRAPHIC RANK OF BOUNDARY

Base of the Ladinian Stage (=Anisian/ Ladinian stage boundary) within the Middle Triassic Series.

2. THE PROPOSED GSSP: GEOGRAPHICAL AND GEOLOGICAL DESCRIPTION

Geographic location and access

The village of Felsöörs is located in the northeastern part of the Balaton Highland, a chain of rolling hills north of Lake Balaton and south of the Veszprém Plateau (Fig. 1). The Balaton Highland forms the southern slopes of the broad Transdanubian Range, rising some 200 m above the lake level. Felsöörs is 5 km north of the northern shore of Lake Balaton.

Felsöörs is served by scheduled bus service from towns along the northern shore of Lake Balaton (Balatonalmádi and Alsóörs) and from Veszprém, an important regional centre and seat of Veszprém County. Both Balatonalmádi and Veszprém has railway stations on main lines from Budapest. Felsöörs is accessible on a secondary road from either Balatonalmádi or Veszprém, which in turn are connected to Budapest by main highways 7 then 71, and 7 then 8, respectively. Driving time from Budapest to Felsöörs is approximately 2 hours.

The section lies on the southwest slope of Forrás-hegy (Forrás Hill), above the Malomvölgy (Malom Valley), only 200 m from the edge of the village (Fig. 2). Access is via a newly developed footpath that serves as an educational trail featuring this important geological and paleontological site. The trailhead is signposted on Malomvölgy Street.

The latitude and longitude of the proposed GSSP is 47°01.006’N, 17°56.589’E, the elevation is 220–230 m above sea level. Hungarian topographic map sheet 503-444 (1:10 000 scale, stereographic projection) and tourist map “Balaton” (1:40 000) covers the area of the locality.

Geological setting

The Felsöörs area is located in the north-eastern part of the Balaton Highland that forms the southern flank of the Transdanubian Range’s synclinorium. The area is made up by the following main stratigraphic units (Budai 1991): Upper Permian red sandtsones of fluviatile-lacustrine facies (Balatonfelvidék Sandstone Fm.) overlying the Hercynian anchimetamorphic basement; Lower Triassic shallow marine siliciclastic-carbonate series of mixed ramp facies (“Werfen Group”); Lower-Middle Anisian carbonates of shallow marine ramp facies (Aszófö Dolomite, Iszkahegy Limestone, Megyehegy Dolomite); Middle-Upper Anisian (Felsöörs Fm.), Ladinian (Vászoly and Buchenstein Fm.) and lowermost Carnian (Füred Fm.) limestones of pelagic basin facies; tongues of Lower and Middle Carnian platforms (Budaörs and Sédvölgy Dolomite) which are intercalated into the basin successions (Veszprém Marl); and finally Upper Carnian platform carbonates (Main Dolomite).

The Middle Anisian to Upper Ladinian section at Felsöörs is exposed in three, partly overlapping trenches (Szabó et al., 1980) (Fig. 3). The first trench begins with bedded dolomicrosparite of the Megyehegy Formation (Beds 0-22). The overlying yellowish-grey bituminous, thin-bedded dolomites and dolomitic marls of restricted basin facies (Beds 23-43) represent a transition towards the Felsöörs Formation (“transitional unit”). The next part of the section consisting of grey, bedded limestones with chert nodules (Beds 44-67) and crinoidal-brachiopodal marly limestones (Beds 68-81) belongs to the Felsöörs Formation. At the base of the second trench poorly exposed crinoidal limestones are visible which are probably equivalent to the uppermost beds of the first trench. Above these layers grey, flaser-bedded limestone occurs. It is followed by 1 m thick tuffitic intercalation.

The overlying well-bedded sequence (Beds 87-99/C) consists of 8-20 cm thick, grey limestone layers with 5-30 cm thick, yellow clay interlayers (Fig. 2b). At the top of the second trench an uneven bedding surface has been exposed - the footwall of the overlying tuffaceous succession. In the original third trench, the artificial exposure has been recently enlarged as a cutbank. Here, a 18 m thick tuffitic sequence is exposed (Vászoly Fm.). It consists of greenish-white, locally brownish-yellow K-trachyte tuffs with thin limestone interlayers or lenses ("pietra verde"). The tuffaceous sequence is overlain by pinkish-grey, nodular limestones which are exposed at the end of the trench. Higher up on the hillside, red, cherty limestones crop out representing the Nemesvámos Limestone Member of the Buchenstein Formation.

LOCATION OF LEVEL AND SPECIFIC POINT

The proposed GSSP level is at the base of Bed 105 in the highest, artificially exposed cutbank that is now protected by a wooden cover. Within the sequence of tuffite and interbedded thin limestone layers or lenses, Bed 105 is 38 cm in thickness and it represents three separate layers of nodular limestone in tuffaceous matrix. The nodular limestone yielded an ammonoid fauna characterized by the first appearance of *Reitziites reitzi*. Stratigraphically it is 11 m above Bed 99/C which is exposed as a large bedding plane at the base (southeastern end) of the cutbank.

CONSIDERATION OF STRATIGRAPHIC COMPLETENESS

At the level of resolution afforded by ammonoid biostratigraphy, the Felsöörs section appears complete. In the critical interval, it contains all of the ammonoid biostratigraphic subdivisions (zones and subzones) recognized elsewhere in key sections of the Balaton Highland and the Southern Alps. No hiatus could be detected by any other biostratigraphic or magnetostratigraphic method, or by sedimentological observations. High-resolution radiometric dates with overlapping errors from below and above the boundary level also argue against any significant gap. Sedimentological features suggest that deposition of limestone layers may represent longer time intervals than the thicker volcaniclastic strata.

THICKNESS AND STRATIGRAPHIC EXTENT OF BOUNDARY SECTION

The well bedded higher part of the FelsQörs Formation represents parts of the Trinodosus Zone in which the Trinodosus, Camunum and Pseudohungaricum Subzones were revealed (Vörös et al. 1996). Its thickness is about 8-9 m.

The overlying tuffaceous succession of the Vászoly Formation starts at the top of the exposed bedding surface of

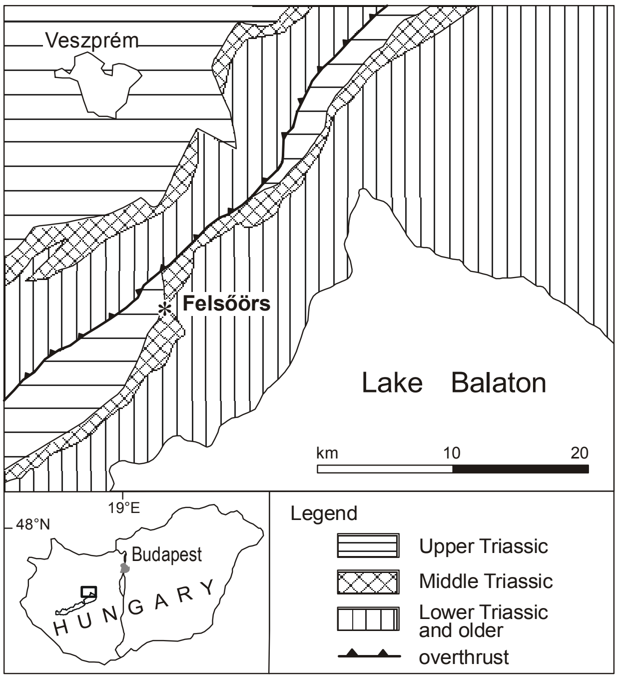

Fig. 1. Location of the Felsöörs section on a simplified geological map of the northeastern Balaton Highland and the Veszprém Plateau. Inset: Location of the study area within Hungary.

Bed 99/C (Fig. 4). The lower part of this sequence consists of greenish-white, sometimes brownish-yellow potassium-trachyte tuffs ("pietra verde", "reitzi-tuff") with thin ochre-yellow cherty limestone interlayers or rows of lenses. The first limestone interlayer (Bed 100/E) in the overlying tuffaceous succession of the Vászoly Formation yielded *Kellnerites felsoeoersensis* proving the Felsoeoersensis Subzone. In limestone interlayers higher up, the Liepoldti and the Reitzi Subzones (the latter marking the base of the Reitzi Zone) have been recorded (Beds 102 and 105, respectively). The whole thickness of the tuffitic succession is about 18 m. Detailed biostratigraphy of this critical part of the section is shown on Fig. 5.

In the higher part of the Vászoly Formation, the carbonate sedimentation predominates again in the form of pinkish-grey, nodular limestones; tuffaceous clay becomes subordinate. The lowermost, still ochre-yellow, limestone beds (110 or 111) are assigned to the Avisianum Subzone of the Reitzi Zone on the basis of a few ammonoids including *Latemarites latemarensis*. The higher beds (111/A–111/K) provided a rich and diverse ammonoid fauna, with a Ticinites-horizon at the top. In the next, massive, cherty limestone bed, *Stoppaniceras* cf. *variabile* appears; whereas the limestone layers in the overlying tuffaceous clay yielded specimens of *Chieseiceras*, *Repossia* and *"Stoppaniceras"* ex. gr. *ellipticum*. This assemblage indicates the Secedensis Zone. The successive appearance of the genera *Hungarites*, *Parakellnerites*, *Ticinites*, *Stoppaniceras* and *Repossia* shows the same order as it was recorded in the South Alpine sections (M. S. Giorgio, Bagolino) by Brack & Rieber (1993).

With diminishing amount of tuffite, a thick, continous se-

Fig. 2. Aerial photograph of the village of Felsöörs and its vicinity, with location of the Felsöörs section marked by an arrow (in left central part of photograph).

quence of red, cherty limestone develops upsection. This typical pelagic, basinal limestone succession (Nemesvámos Member of the Buchenstein Formation) is poorly exposed on the hillside. In October 2002, we started detailed collection for ammonoids in the lower part of this formation. A poorly preserved specimen of *Eoprotrachyceras* cf. *curionii* was found just below Bed 129, indicating the Curonii Zone. No detailed collection was made higher up, but a few poorly preserved pieces of *Arpadites* ? were found in the scree, suggesting the presence of the Gredleri Zone in the reddish cherty limestone. The Upper Ladinian strata are exposed on the NW side of a left tributary valley. These light grey, slightly nodular limestones with clayey interlayers represent the Füred Limestone Formation. Ammonoids (*Clionites* sp. and *Celtites epolensis*), found in loose blocks, suggest the Regoledanus Zone.

Provisions of conservation and protection

The Felsöörs area is part of the Balaton Highland National Park, founded in 1997. The outcrops are one of the most famous, classical geological localities of Hungary and were listed as a geological key section (Haas, 1986) already several years before the establishment of the National Park. In recognition of its special importance, an educational geological trail was developed in 1999. It is protected as a geological conservation site. A 23x3 m wooden cover was built to protect the section that contains the proposed GSSP from weathering and erosion. The footpath and the site is regularly maintained by the Municipality of Felsöörs, in collaboration with the Balaton Highland National Park and the Hungarian Geological Institute.

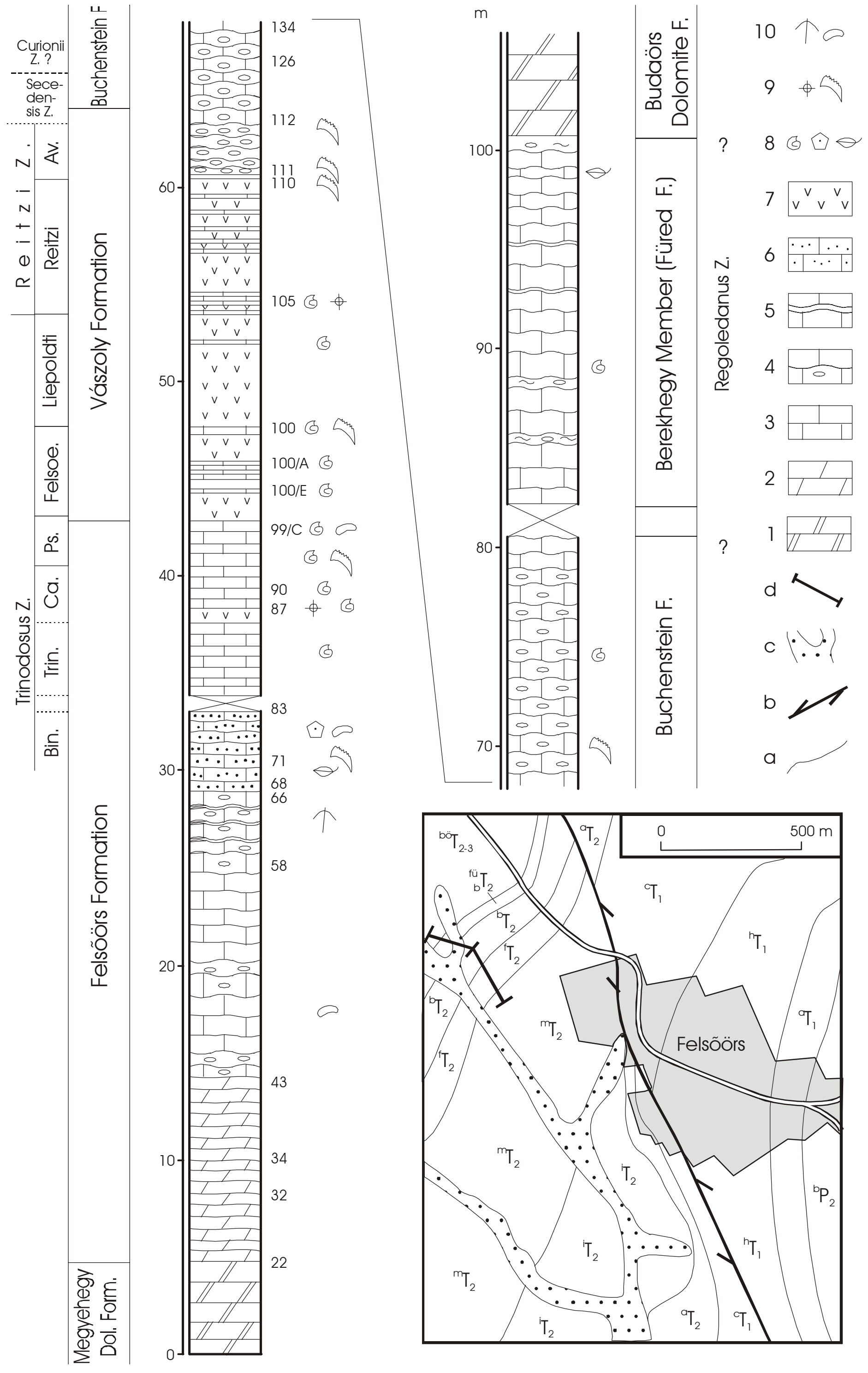

Fig. 3. Stratigraphic column and locality map of the entire section at Felsöörs (slightly modified after Budai et al. 2001). Legend: a - stratigraphic boundary, b - strike-slip fault, c - alluvial deposits, d - geological conservation site, 1 - bedded dolomite, 2 - bituminous dolomite, 3 - bedded, laminated limestone. 4 - cherty, nodular limestone, 5 - flaser-bedded limestone with marl intercalation, 6 - crinoidal limestone, 7 - tuff, tuffite, 8 - ammonoids, crinoids, brachiopods, 9 - radiolarians, conodonts, 10 - sponge spicules, ostracods, bP2 - Balatonfelvidék Sandstone Fm., aT1 - Arács Marl Fm., hT1 - Hidegkút Fm., cT1 - Csopak Marl Fm., aT2 - Aszófö Dolomite Fm., iT2 - Iszkahegy Limestone Fm., mT2 - Megyehegy Dolomite Fm., fT2 - Felsöörs Limestone F., bT2 - Vászoly +Buchenstein Fm., füT2 - Füred Limestone Fm. (Berekhegy Member), böT2-3 - Budaörs Dolomite Fm., Bin. - *Binodosus*, Trin. - *Trinodosus*, Ca. –*Camunum*, Ps. – *Pseudohungaricum*, Felsoe. – *Felsoeoersensis*, Av. - *Avisianum*

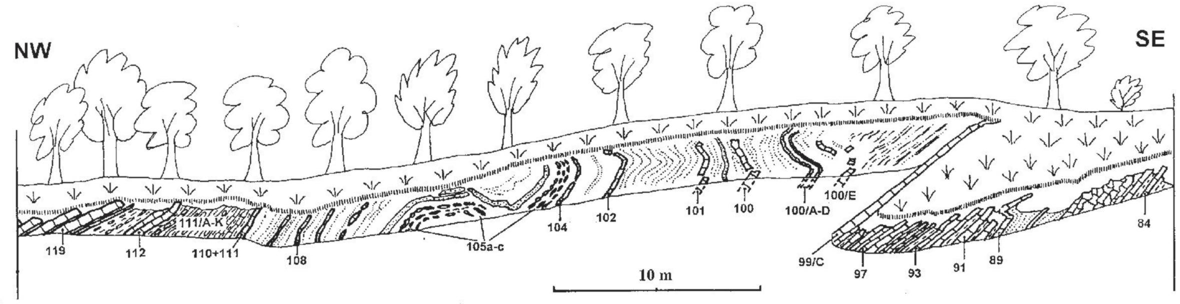

Fig. 4. Panoramic sketch of the upper part of the Felsöörs section after the new excavations of the cutbank in 2000.

PRIMARY AND SECONDARY STRATIGRAPHIC MARKERS AND CORRELATION

PRINCIPAL CORRELATION EVENT (MARKER) AT THE GSSP LEVEL

The proposed GSSP level at Felsöörs section is Bed 105, defined by the first appearance (FAD) of the ammonoid species *Reitziites reitzi* (Böckh, 1872). This species is the index fossil of the Reitzi Zone and its Reitzi Subzone (Vörös et al. 1996). It is a reliable guide fossil and provides excellent correlation with the South Alpine key section Bagolino (FAD at 56.6 m: Brack & Rieber 1993). Moreover, *R. reitzi* is a suitable tool for long-distance correlation between widely separated areas of the Tethys and the western Pacific: it is also recorded from the Himalayas (L. Krystyn, pers. comm.), China (H. Kozur, pers. comm.) and Japan (Bando 1964).

DEFINITION USING OTHER STRATIGRAPHIC METHODS

OTHER BIOSTRATIGRAPHY

Apart from *Reitziites reitzi*, Bed 105 of the Felsöörs section also yielded *Parakellnerites cf. boeckhi* and *Hungarites sp*. This ammonoid assemblage characterizes the Reitzi Subzone of the Reitzi Zone in the section.

Bed 105 also yielded radiolarians of the *Oertlispongus* fauna (Dosztály 1993, Vörös et al. 1996) (Fig. 6). The FAD of the genus *Oertlispongus* marks the most pronounced change (turnover) in the radiolarian faunas of the Triassic and one of the strongest changes in the whole Phanerozoic (Kozur 1995a). This distinct change, that coincides with the FAD of Reitziites, is an important and useful correlation tool. It was recognised not only in the Tethyan but also in the Boreal and Notal realms of the Panthalassa, including the widespread area with radiolarites, where ammonoids are absent and conodonts are rare, represented by indeterminable juvenile forms only (Kozur 1995a, and references therein).

Unfortunately, the Vászoly Fm. in the Felsöörs section is almost barren of conodonts. The upper part of the underlying Felsöörs Fm. (Beds 87 to 99A) is characterized by *Gondolella constricta cornuta* and *G. liebermani*. The conodonts of the Felsoeoersensis and Liepoldti Subzones are well documented by the FAD of *G. constricta postcornuta* in the former subzone in the complementary Vászoly P-11/a section. The Reitzi Subzone is poor in conodonts in all the investigated sections of the Balaton Highland (Kovács et al., 1995). The FAD of *Paragondolella alpina* coincides with the FAD of *R. reitzi*, as documented from the Reitzi Subzone in the Bagolino section (Nicora & Brack 1995) and in the Vászoly P-2 section (S. Kovács, unpublished data). *P. alpina* has a wide distribution within and even outside the Tethys. Also synchronous with the FAD of *R. reitzi* is the FAD of another conodont species, referred to as *G. aff. eotrammeri* by Nicora & Brack (1995) but assigned to *Paragondolella praetrammeri* by Kozur. Regardless of the difference in taxonomic assignment, both Nicora & Brack (1995) and Kozur & Mostler (unpublished data from Bagolino) agree that the FAD of this taxon coincides with the FAD of *R. reitzi* in the Bagolino section.

A major change is recorded in the Avisianum Subzone, beginning in the Felsöörs section at Bed 111, with the appearence of eupelagic elements (*gladigondolelloids*) and typical Ladinian forms such as *G. trammeri* and *G. fueloepi* (the former most probably ranging up to the top of the Archelaus Zone, as documented in the Köveskál section). However, this change is much better documented in the complementary Mencshely section, where the Avisianum Subzone is represented by red crinoidal limestones (beds -6 to -1), rich in conodonts. This event was evidently facies controlled and no data is known from the lower subzones about the earlier history of the evolutionary lineages leading to these stratigraphically important forms. No changes in the conodont fauna is recorded in the higher part of the Vászoly Fm., which includes the Ticinites horizon and the Secedensis Zone.

Bed-by-bed conodont collections were made from the Nemesvámos Mb. of the Buchenstein Fm. (Kovács, 1993, 1994). Beds 120 to 155 yielded a rich eupelagic associa-

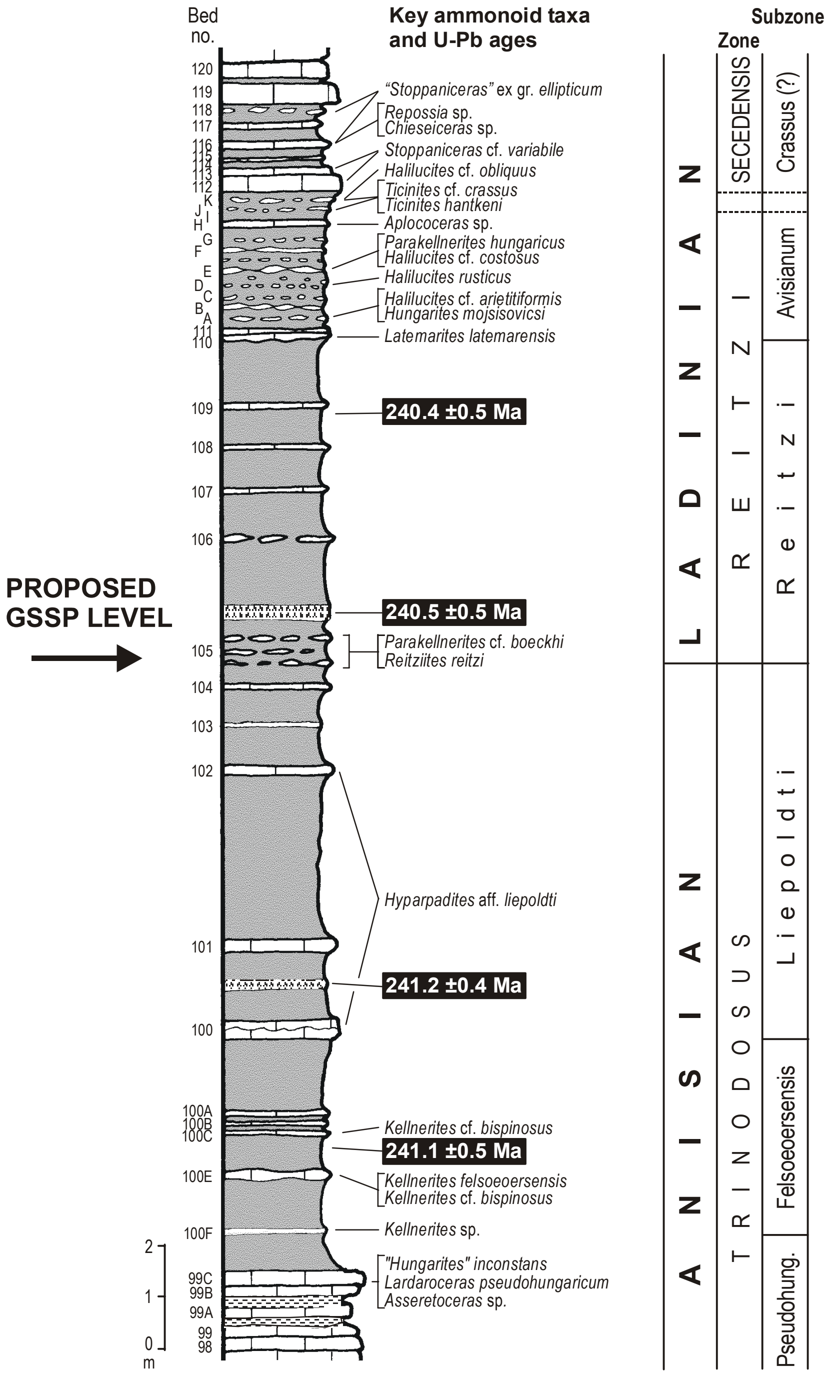

Fig. 5. Measured stratigraphic section at Felsöörs, showing the biostratigraphic subdivision based on occurrences of age diagnostic ammonoid taxa, the U-Pb ages of dated tuff layers, and the proposed GSSP level (modified from Pálfy et al. in press).

tion. The lowest ?*G. praehungarica* was found in Bed 123; in the Southern Alps it is known from slightly below the Curionii Zone (Nicora and Brack, 1995). *"Metapolygnathus" hungaricus*, an index for the upper part of the Curionii Zone and/or the Gredleri Zone, was obtained from Bed 151, which is above the range of ?*G. praehungarica*.

The Felsöörs section contains one of the richest known Triassic palaeopsychrosphaeric ostracod faunas of the world (Kozur 1970, 1991). This cold bottom water fauna has a global distribution in the world oceans with the same composition in Boreal and tropical areas and provides a good correlation tool.

MAGNETOSTRATIGRAPHY

The thermally unaltered conodonts (CAI =1) in the Felsöörs section provide evidence for the lack of thermal overprint, allowing reliable magnetostratigraphic (and chemostratigraphic) studies. The proposed GSSP falls

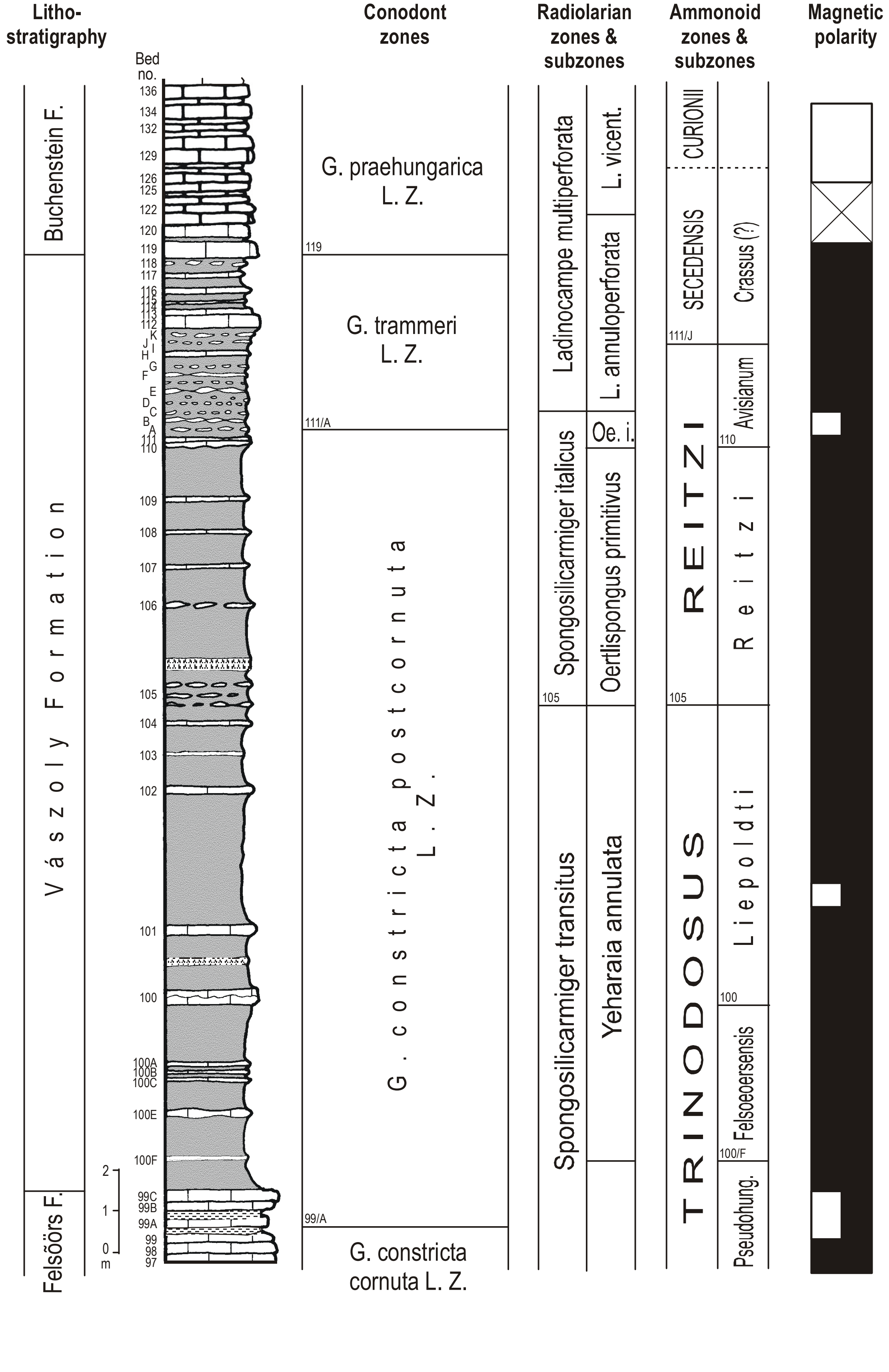

Fig 6. Integrated conodont, radiolarian, and ammonoid biostratigraphy of the Felsöörs section (modified from Márton et al. 1997). Abbreviations: Oe. i. – *Oertlispongus inaequispinosus*; L. vicent. – *Ladinocampe vicentinensis*.

within an extended normal polarity interval. Magnetostratigraphy of the Felsöörs section was summarised and discussed by Márton et al. (1998). Due to irregularly spaced and sporadic sampling at that time, the obtained magnetic polarity column was rather discontinuous. New sampling and recent results complemented the earlier data set and proved that the whole interval of the upper Trinodosus, Reitzi and lower Secedensis Zones

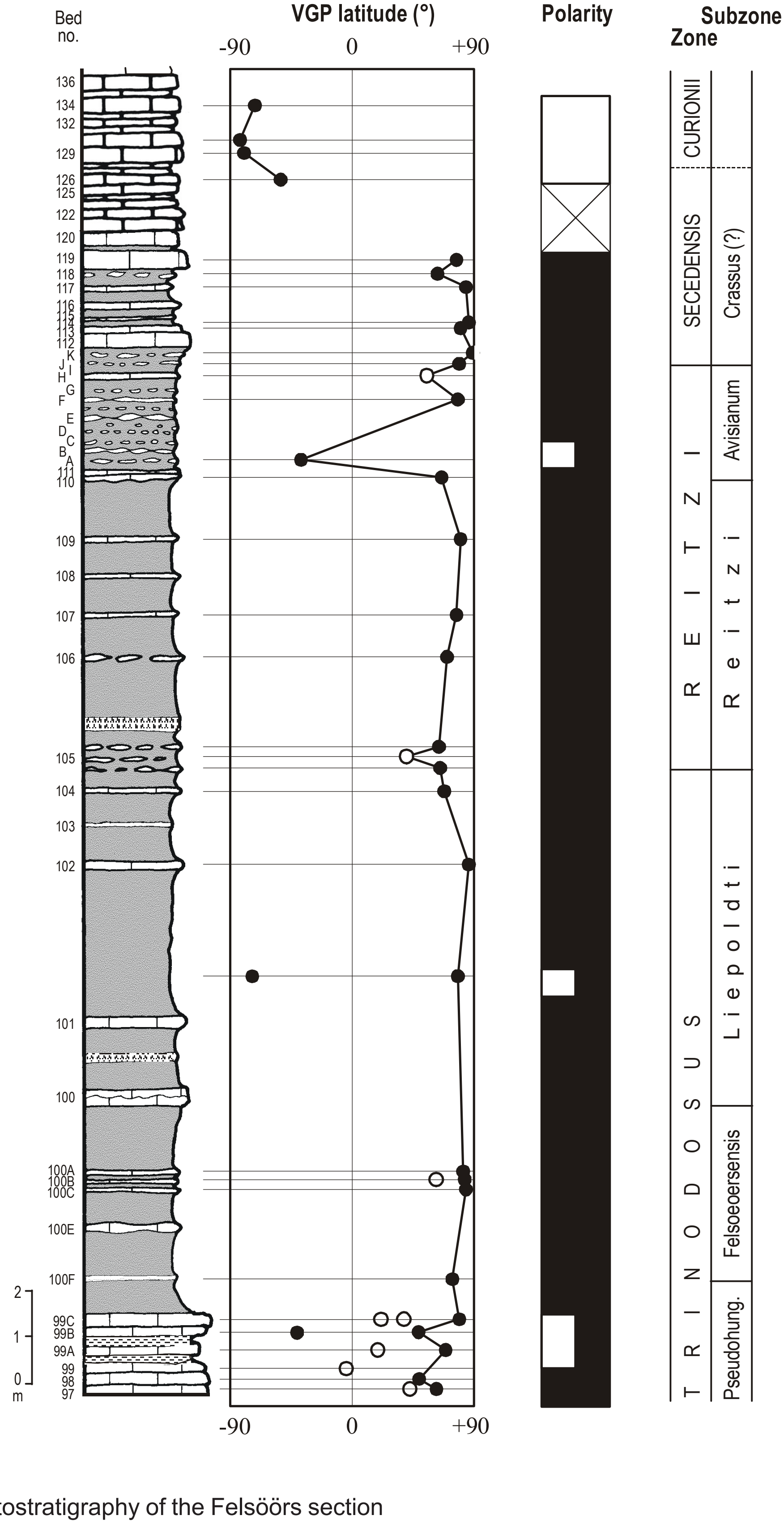

Fig 7. Magnetostratigraphy of the Felsöörs section

is characterised by normal polarity with a few hints to minor reverse episodes (Fig. 7, Vörös et al. 2002).

CHEMOSTRATIGRAPHY

The chemostratigraphy of the Felsöörs section was studied by Korte (1999). Within the Anisian/Ladinian boundary interval, francolite from conodont elements were analyzed for Sr isotope ratios from three samples in the Trinodosus Zone (beds 91, 99 and 100) and seven samples from the Avisianum Subzone of Reitzi Zone and the Secedensis Zone. The obtained values, mostly between 0.70777 and 0.70767, suggest a falling trend of the seawater $^{87}Sr/^{86}Sr$ ratio. It represents the best available dataset for this stratigraphic interval and contributes to the construction of the global Sr reference curve (Veizer et al. 1999). The decrease in the Sr isotopic ratio appears to be an overall trend for the entire Middle Triassic (Korte 1999). The Sr isotope stratigraphy holds global correlation potential, as amply demonstrated in other parts of the stratigraphic column. Specifically, it proves useful in correlation between the Tethys and the Muschelkalk basin in the Middle Triassic (Korte 1999).

Further Sr, together with carbon and oxygen isotopic data, were obtained from brachiopod shells in the Pelsonian crinoidal-brachiopodal limestone of the Felsöörs Fm in the lower part of the section (Korte 1999). Although the $\delta^{13}C$ and the $\delta^{18}O$ curves are too flat to be stratigraphically useful, the paleotemperatures calculated from $\delta^{18}O$ values provide independent isotopic evidence that the area belonged to the tropical climatic belt in the Middle Triassic.

SEQUENCE STRATIGRAPHY

The lower part of the Felsöörs section represents the third sequence within the Anisian of the Balaton Highland (Haas and Budai, 1999). The lower part of the Middle Anisian depositional sequence is composed of the restricted inner ramp facies of the Megyehegy Dolomite Formation. The overlying flaser bedded cherty limestones (Felsöörs Fm.) represent the maximum flooding interval, while the brachiopod-crinoid bearing limestones (Binodosus Subzone, Márton et al., 1997) mark definite shallowing (HST). Dark grey limestones with marl intercalations in the upper part of the section represent the initial stage of the next transgression period (Trinodosus Subzone). Detailed investigation of the ostracode assemblage and ammonoids of the Vászoly Formation (Vörös, 1996) revealed a deepening trend up to the top Reitzi Zone. The proposed GSSP level lies within this transgressive systems tract.

OTHER EVENT STRATIGRAPHY

The Reitzi Zone at FelsQörs is dominated by tuffites. A radiometrically dated, greenish brown weathering, coarse-grained, feldspar-rich crystal tuffite layer of 20 cm thickness lies 45 cm above bed 105. Correlation of individual tuff horizons between distant areas may seem hazardous, nevertheless it is assumed that this layer can be correlated with one of the higher tuffs in the Reitzi Zone, below the tuff labeled Tb in the Bagolino section (Brack and Rieber 1993).

CYCLOSTRATIGRAPHY

No record of cyclic sedimentation is preserved in the section.

MARINE–TERRESTRIAL CORRELATION POTENTIAL

Although no sporomorhs were found in the FelsQörs section, boreholes in the neigbourhood (e.g. Balatonfüred Bf-1) yielded a rich assemblage from the boundary interval (Góczán & Oravecz-Scheffer, 1993) that makes possible the correlation of the marine and continental successions. There is a radical change in the palynomorph association slightly below the top of the Felsöörs Formation, i.e. just below the base of the Reitzi Zone. This is registered by the first occurrence of genera *Cannanoropollis* and *Kuglerina* and a significant change in the species of genus *Triadispora* (Góczán, 1994). Above this event no significant change could be detected in the association up until the basal part of the Longobardian.

GEOCHRONOMETRY

The Anisian/Ladinian boundary interval contains abundant tuff layers that are amenable to radiometric age determination. Zircons extracted from four layers were dated using the U-Pb method (Pálfy et al., in press). Stratigraphically closest to the proposed GSSP is a 15 cm thick, brown weathering, coarse-grained, feldspar-rich crystal tuff layer that lies 45 cm above Bed 105 (Fig. 5). The sample yielded abundant, colourless zircons of excellent clarity. Of the four analysed multi-grain fractions, three intersect the concordia curve and overlap one another, whereas one fraction is discordant suggesting minor inheritance. We use their concordia age of 240.5±0.5 Ma, calculated on the basis of the three concordant fractions, as the best estimate of the crystallization age of the tuff. This estimate is also used for the numeric age of the proposed Anisian/Ladinian boundary. It is consistent with three other U-Pb dates obtained from the Felsöörs section: 241.1±0.5 and 241.2±0.4 Ma from the underlying Felsoeoersensis and Liepoldti Subzones, respectively, and 240.4±0.4 Ma from the higher part of the Reitzi Subzone. These dates are also in agreement with single crystal U-Pb dates from slightly higher Ladinian horizons in the Southern Alps (Mundil et al., 1996).

Further U-Pb dating using single zircons from FelsQörs will be carried out in 2003. The tuff layers can also be dated by the $^{40}Ar/^{39}Ar$ method.

DEMONSTRATION OF REGIONAL AND GLOBAL CORRELATION

The base of the Reitzi Subzone is well defined by the FAD of *Reitziites reitzi* (and other, perhaps synonymous species of *Reitziites*, e.g. *R. cholnokyi*) in many sections of the Balaton area: at Bed 105 in Felsöörs, Bed 5 in Mencshely (Cser-tetQ II) and Bed 10 in Szentkirályszabadja (Vörös 1993, 1998, Vörös et al. 1996) (Fig. 8). The same distinct horizon, with the appearance of *Reitziites* species, was also recorded in Bed 14 at Vászoly (P-11/a), and Bed –9 at Mencshely (Cser-tetQ I), where the occurrence of *Ticinites hantkeni* hints to sedimentary condensation (Vörös 1993, Vörös et al. 1996).

As mentioned above, the FAD of *Reitziites reitzi* is an excellent tool for correlation with South Alpine sections: it was clearly demonstrated in Bagolino (at 56.6 m, Brack & Rieber 1993); *R. reitzi* was also recorded at Pertica, in the topmost layer of the lower section (Brack et al. 1995). Moreover, findings of *R. reitzi* from the Himalayas, China and Japan demonstrate the long-distance correlation potential of this level.

SELECTION PROCESS

Relation of the GSSP to historical usage

The Reitzi Zone at Felsöörs has historical priority as the basal biostratigraphic unit of the Ladinian. The fossiliferous beds at Felsöörs provoked the interest of the scientific community as early as the 1870's when bed-by-bed collections were made and some peculiar ammonoids were described from the "yellow, siliceous limestones of Forráshegy" by Roth (1871), Böckh (1873), and Stürzenbaum (1875). The results were included in the monograph of Mojsisovics (1882) who defined his "Zone des *Trachyceras Reitzi*" partly by the findings from Felsöörs. He placed this zone to the base of his "Norische Stufe" which was later renamed by Bittner (1892) as Ladinian. The content, range and status of Mojsisovics' Reitzi Zone has subsequently changed several times. Its upper part was formally separated as the Curionii Zone. The „Avisianus zone" was established as a replacement or it referred to the underlying unit. The Reitzi Zone was also substituted by the "*Parakellnerites*" and/or the "*Nevadites*" zones and consequently, it was transferred to the Anisian by some authors. The Reitzi Zone was redefined at Felsöörs (Vörös 1993) and, on the basis of a more inclusive interpretation, the FAD of *Kellnerites* was suggested as the base of the Ladinian (Vörös et al. 1996).

The proposed GSSP (Bed 105 of the FelsQörs section) corresponds to the base of the Reitzi Subzone of Vörös et al. (1996). This sensu stricto interpretation of the Reitzi Zone is in agreement with the usage of Vörös & Pálfy (1989), Kozur (1995b) and Kozur et al. (1995), who used the FAD of *Reitziites reitzi* as the base of the Ladinian.

OTHER CANDIDATES AND REASONS FOR REJECTION

Three other formerly suggested candidate levels for drawing the base of Ladinian are rejected here for the following reasons:

Candidate 1, at the first appearance of *Kellnerites* (i.e. Reitzi Zone sensu lato) fulfils the requirements of integrated biostratigraphic approach and is useful for correlation. However, as repeated (partly informal) voting has demonstrated, it seems unlikely to be accepted by the entire community of Triassic stratigraphers.

Candidate 2, at the first appearance of *Nevadites*, has serious shortcomings in terms of biostratigraphic correlation potential because of the debated taxonomy and rare occurrence of *Nevadites* in the Alpine sections, and because no distinct microfaunal changes are observed at this horizon.

Candidate 3, at the first appearance of *Eoprotrachyceras* (i.e. base of the Curionii Zone) is rejected because (1) the alleged advantage of intercontinental correlation on the basis of FAD of the genus *Eoprotrachyceras* is problematic. Numerous other Mesozoic examples illustrate that first appearances of ammonoid genera are often diachronous between Europe and North America. Independent evidence for synchrony of the " *Eoprotrachyceras* datum" between the Tethyas and eastern Pacific is still lacking; (2) the microbiostratigraphic tools of correlation are limited to conodonts, but the FAD of the diagnostic *Budurovignathus truempyi* postdates and ?*Gondolella praehungarica* demonstrably predates the FAD of *Eoprotrachyceras*; and (3) this time horizon would undesirably cut across vast carbonate platform bodies in the Alpine region (major portion of Wetterstein-type carbonate platforms, traditionally regarded Ladinian in age, would thus be transferred chronostratigraphically to the Anisian).

Selected publications

The key references describing various aspects of the stratigraphy of the Felsöörs section are the following (many more relevant papers are listed in the References):

Dosztály, L. 1993. The Anisian/Ladinian and Ladinian/Carnian boundaries in the Balaton Highland based on Radiolarians. Acta Geologica Hungarica, 36 (1): 59-72.

Kovács, S. 1993. Conodont biostratigraphy of the Anisian/Ladinian boundary interval in the Balaton Highland, Hungary and its significance in the definition of the boundary (Preliminary report). Acta Geologica Hungarica, 36 (1): 39–57.

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OTHER USEFUL SECTIONS

There are further sections in the Balaton area (Mencshely, Vászoly, Szentkirályszabadja) which provided important additional information to the knowledge of ammonoid and conodont stratigraphy of the Felsöörs section and which may help in the correlation of the proposed GSSP horizon (i.e. base of the Reitzi Subzone). The sections were described in Vörös (1993, 1998), Vörös et al. (1996).

Mencshely (CsertetQ I. and II.). The lowermost beds of these sections belong to the Anisian Felsöörs Formation (grey limestone beds with clay intercalations). This is followed by ash-grey tuffites of the Vászoly Formation in

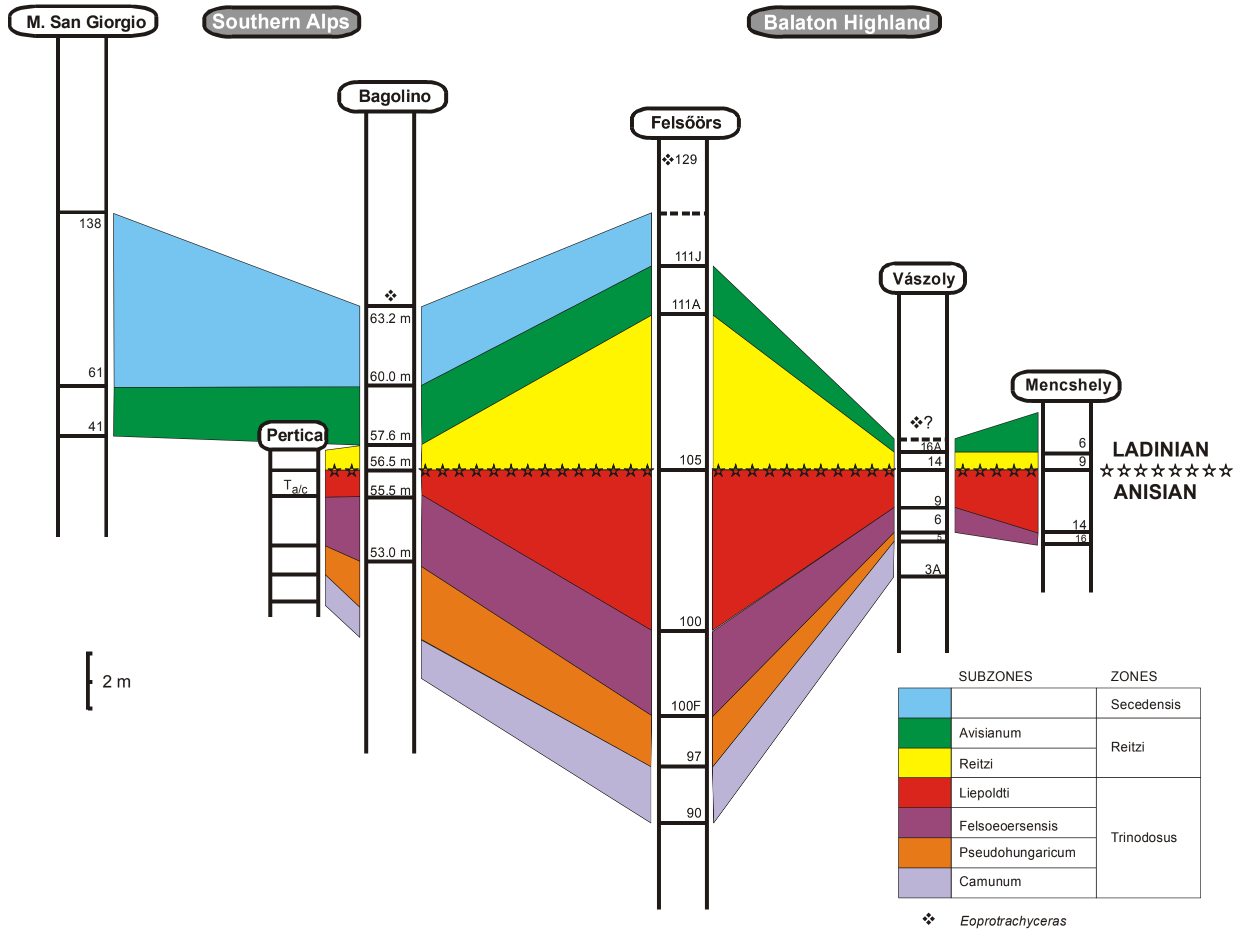

Fig. 8. Correlation of Felsöörs and other key Anisian/Ladinian boundary sections in the Balaton Highland and Southern Alps.

about 4 m thickness, containing a few, thin (8-10 cm) yellow and grey cherty limestone intercalations. The higher part of the tuffitic sequence becomes pinkish and passes into reddish-bown clay with limestone lumps. These crinoidal, tuffitic limestone lumps yielded a very rich ammonoid fauna. With gradually decreasing amount of clay, massive crinoidal limestone beds appear. The uppermost member of the exposed sequence is light-coloured micritic limestone. The sequence accumulated in a basin of low sedimentary rate and represents the Felsoeoersensis to Avisianum Subzones of the Reitzi Zone. The base of the Reitzi Subzone can be pinpointed at Bed –9 in Cser-tetQ I. and at Bed 5 in Cser-tetQ II., by the appearance of *Reitziites reitzi*, *R. cholnokyi*, *Hungarites ? arthaberi*, *Latemarites ? conspicuus* and *Ticinites* cf. *hantkeni*.

Vászoly. From the numerous localities of the Öreg-hegy (Öreg Hill) between the villages Vászoly and Pécsely, the section "P-11/a" was best studied. Here the Anisian Megyehegy Dolomite is followed by yellow tuffites alternating with limestone and massive dolomite layers in 2 m thickness (Vászoly Formation). Above this, the yellowish tuffites become dominant and contain sporadic calcareous lumps. The higher part of this 3 m thick sequence consists of tuffitic clay containing big blocks of yellow crinoidal limestone with plenty of ammonites. The exposed sequence is terminated with massive beds of light-coloured micritic limestone (Vászoly Limestone). The sequence was deposited on the top of a submerged platform (pelagic plateau) and represents the uppermost part of the Trinodosus Zone and the Reitzi Zone (Camunum to Avisianum subzones). The base of the Reitzi Subzone was drawn at Bed 14, where *Reitziites reitzi*, *R. cholnokyi*, *Ticinites* cf. *hantkeni* and *Nevadites ?* cf. *symmetricus* were found, suggesting stratigraphic condensation.

Szentkirályszabadja. The lower part of the sequence consists of thick dolomite beds alternating with yellow clays. Higher up the dolomite becomes thin-bedded and crumbly and contains volcanoclastic admixture; then alternates with limestone, but the crumbly and tuffitic character remains constant throughout the sequence. The uppermost beds are again pure dolomites but since they contain a few poorly preserved ammonite "ghosts" they must have been pelagic limestones dolomitized secondarily. The sequence was deposited during a pelagic episode on a drowned and later revived carbonate platform and represents the the uppermost part of the Trinodosus Zone and the Reitzi Zone (Pseudohungaricum to Reitzi Subzones). The base of the Reitzi Subzone is at Bed 10, where

Reitziites reitzi occurs.

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The proposals for the GSSP of the Ladinian stage: pros and cons of a complex choice

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In the past ten years of activity of the A/L boundary Working Group I did not take part in the interesting discussion that was developed on Albertiana, mostly because I did not have any personal data on this boundary. At the present, however, two formal proposals have been submitted to the Working Group (now renamed as A/L boundary Task Force), so I have decided to express my way of reasoning and to suggest my opinion. I do not have any personal thesis to support or to demonstrate. I have just tried to analyse the two proposals in terms of pros and cons and in term of the practical consequences of the different choices. I have always tried to keep in mind that any decision of the Task Force must be taken with the purpose: a) to create an unambiguous and well defined standard reference, b) to solve or, at least, simplify long lasting problems, and c) to make chronostratigraphic classification easier to understand and easier to use. I have read the proposals and I have done my comments taking also into account that the Task Force must come to a decision soon. After 12 years of activity it is not possible to demand more time for additional research and a ballot is scheduled for September 2003. There is not so much time, so I discuss the problems frankly.

FORMAL CORRECTNESS OF THE PROPOSALS

The two proposals presented to the members of the A/L boundary Task Force (Brack et al., 2003; Vörös et al., 2003, in press on this issue of Albertiana) summarise the result of several years of work on Bagolino-Seceda and Felsoörs sections. Both the proposals are rich in data, however, only Vörös et al. proposal fulfil the formal requirements to be considered for a GSSP selection (Cowie et al., 1986; Remane et al., 1996), while Brack et al. proposal is not formally correct and therefore need some corrections and additions.

The main problem in Brack et al. proposal is that it is not clear where is the Section and the Point of the GSSP. In the proposal it is pointed out that at Bagolino, around Romanterra bridge, there are four main exposures of the boundary interval (section 2.B of the proposal: sites A-D, fig. 2 and 3; see also Brack & Rieber, 1993b, fig. B05, B06, B07, B09, B10), and the eastern end of site B is designated "as main reference outcrop" (sect. 2.C of the proposal) "because of the particularly extended exposure". I see the following problems:

a) The statement on site B is ambiguous. It is not well clear whether site B is proposed for the GSSP, or just as a reference outcrop. Following Remane et al. (1996, p. 78) the term "reference" concerning a GSSP, refers to an auxiliary stratotype point in support of a GSSP that is defined in another place. It does not seem to be the case for Bagolino proposal. The coordinates of the stratotype-section, that are required for the GSSP candidate (Remane et al., 1996, section 5.1 sub 2, p. 80), do not help to solve this ambiguity. Brack et al. provide only the coordinates of Romanterra bridge (Brack et al., 2003, section 2A) and not the coordinates of what they consider the GSSP candidate section. The illustration of the eastern end of site B (Brack et al., 2003, fig. 4) also does not solve the problem, because it reports the indication "GSSP-level", that leaves the question on the definite location of the Point of the GSSP unsolved.

b) If the eastern end of site B has to be considered as the GSSP site in the proposal by Brack et al., then the proposal lacks of the range chart reporting all the fossils collected at this outcrop and showing the first appearance of Eoprotrachyceras curionii, the suggested marker for the base of the Ladinian.

c) The Bagolino section sensu Brack et al. (2003, fig. 3, 5, 6, 7b) cannot be proposed for the definition of the GSSP because it is a composite section. In particular it is based on data from four sites, and five different but overlapping outcrops (there are two outcrops of the lower Buchenstein Fm. at site B: B-west, under the bridge, and B-east, east of the bridge). Figures 5 and 7b also include ammonoid data from other localities in Giudicarie and Trompia Valleys (Prezzo, Pertica and Brozzo).

I have no doubts that Brack et al. correlations between the four sites are correct, and I have no doubts that they have paleontological documentation from site B, but this documentation must be made available. I point out that this information is not available from the literature. In the recent papers on Bagolino ammonoids Brack & Rieber (1986 and 1993a) never separated the information site by site. In particular the quotations of the specimens in the paleontological descriptions and in the plate explanations always refer the specimens simply to "Bagolino", so that there are no ways to infer from the papers the exact site of collection of the specimens. The only information from Bagolino that is illustrated by reference to the site of collection is the conodont distribution (Nicora & Brack, 1995; Brack & Nicora, 1998), but the boundary marker in Brack et al. proposal is an ammonoid bioevent, not a conodont bioevent.

The problem most probably is more formal than essential, but as the GSSP selection is a formal step-by-step procedure, we must follow the formal rules. According to Cowie et al. (1986), a GSSP "is a point in a specific sequence of rock strata", but at Romanterra there are several specific sequences of rock strata in a relatively rather tectonically complicated setting (see Brack & Rieber, 1986, fig. 4). A GSSP proposal at Bagolino must require first the selection of the outcrop and second the indication of the point of the section measured on the outcrop where the event that is proposed to mark the boundary has been detected. In the lack of this information Brack et al. proposal cannot be taken into account for any ballot.

Practical examples of the applications of the rules and guidelines are available also at the web site of the ICS (http://www.micropress.org/stratigraphy/). Up to the present no one GSSP has been established on a composite section while, on the contrary, when there are several outcrops in a small area, the GSSP is defined in a specific outcrop that is illustrated by its detailed and specific range chart. One example, above all: the GSSP of the base of the Triassic is base of level 27c at Meishan section D (Yin et al., 1996; Yin et al., 2001), where at Meishan there are seven outcrops and sections labelled in literature from A to F, and Z.

GENERAL COMMENT ON THE TWO PROPOSALS

In my opinion both the proposals are too much focussed on the ammonoids. The ammonoids are important, because in both the proposals the candidate boundary marker is an ammonoid bioevent, but I would have expected a more detailed discussion of the correlatability of the candidate boundary markers (section 3C in Brack et al., 2003, and in Vörös et al., 2003). In particular I would have expected the indication of some additional micro- or macrofossil bioevents close to the boundary that are useful for regional and global correlation. Some potentially interesting bioevents are mentioned in the illustration of the additional tools (sections 3B), but in the section 3C they are not quoted. Whatever solution we choose for the A/L boundary, we have candidate GSSP markers that are far from being worldwide distributed. The most important ammonoid genera (i.e., *Eoprotrachyceras*, *Nevadites*, *Reitziites*, *Chieseiceras*, *Paranevadites* etc.) are restricted to one-two or at most three marine paleobioprovinces on a total number of five. With this background I think that it is necessary to support the GSSP marker with other additional marker events. The lack of clear indications in section 3C would leave the identification of useful (additional) marker events to the experience of the reader, and this does not really go by the spirit of the selection of a GSSP. Section 3C of the proposals must be improved after discussion within the Task Force.

The GSSP proposal of the first appearance of Reitziites reitzi at Felsöörs

Among the two proposals this is, from the stratigraphical point of view, the proposal closest to the ammonoid faunas I am familiar with. In my opinion there are two pros but also two serious cons in this hypothetical boundary.

The first advantage of this proposal is that the boundary traced at the first appearance of *R. reitzi* would approximate the base of Mojsisovics' Trachyceras reitzi Zone (Oppel zone), so that most of the tethyan ammonoids early attributed to the Ladinian, would remain Ladinian in age. The second pros is that this boundary is very close to the base of the Buchenstein Fm./Group, so that the revised Ladinian sensu Vörös et al., 2003 would be almost coincident with the original Bittner's Ladinisch (Buchensteiner und Wengener Schichten: Bittner, 1893).

In other words this GSSP proposal is nearly in compliance with the original definition of the Ladinian stage, and with the original definition of the first ammonoid zone of the Ladinian. This historical correctness is emphasised by Vörös et al., but I weight it in a different way. A lot of work has been done since Mojsisovics and Bittner's time, and we have many more information and a much better picture of the Anisian-Ladinian faunal succession with respect to what was known to Mojsisovics and Bittner. We are not obliged to force our new data into their old structure. If necessary we have to modify the structure. I do not see any logical reason to support this boundary just because of historical priority. Moreover from a formal point of view, priority cannot be claimed in the selection of a GSSP (Remane et al., 1996, p. 78; A. Baud, comm. to the Task Force members, 2002). In case I think this boundary could be supported because it is the traditional boundary in the Tethys, that is to say it is the boundary more commonly used in practice by stratigraphers for tens of years. Practical usage must be kept in mind when we want to change the definition of a concept that has been used since tens of years. There are no doubts that in literature the Buchenstein Fm./Group has been always attributed to the Ladinian and never to the Anisian. Moreover in the Tethys the A/L boundary has been traced below the first appearance of *Eoprotrachyceras* by all the authors, but by Brack & Rieber (1986, 1993a and 1993b).

In Vörös et al. proposal there are, however, also some serious cons. In my opinion the first is the lack of significant ammonoid faunal change at the suggested boundary, and the second is the scarce correlatability of the candidate marker event.

As regard the ammonoid faunal change, I do not see any major faunal change at the appearance of *R. reitzi*. This bioevent is practically the only change within the interval comprised between the first appearance of *Kellnerites* and the first appearance of *Aplococeras*. The rest of the fauna below and above the first appearance of *R. reitzi* is composed by medium to large sized, relatively compressed, more or less keeled ammonoids like *Hungarites* and *Parakellnerites*, that are very similar to the so called *Hyparpadites*. In my opinion there are more important faunal changes roughly around the first appearance of Ticinites and at the first appearance of *Eoprotrachyceras*.

The significance of the first appearance of *R. reitzi* turns out scarce also from the point of view of the correlatability. The occurrence or *Reiztiites* reported by Vörös et al. (Western Tethys and probably in Spiti, China and Japan) demonstrates that *Reitziites* is restricted to only one of the five

	Bagolino	Felsóörs	Bagolino & Frötschbach	
Ammonoids	*good*	*good*	*good*	*rather poor*
Conodonts	*good*	*very poor*	*good*	*good*
Bivalves	*no record*	*no information*	*no record*	*poor*
Radiolarians	*no information*	*possibly good*	*no information*	*no information*
Ostracods	*no information*	*possibly good*	*no information*	*no information*
Palinomorphs	*?in progress*	*no record*	*?in progress*	*good (*)*
Magnetostratigraphy	*remagnetised*	*doubtful record*	*remagnetised*	*primary*
Chemostratigraphy	*no information*	*good (Sr)*	*no information*	*?no information*
Sequence stratigraphy	*~MFS*	*TST*	*~MFS*	*~MFS*
Cyclostratigraphy	*no information*	*no record*	*no information*	*?no information*
Tephrastratigraphy	*good*	*no information*	*good*	*good*
Geochronometry	*good*	*good*	*good*	*no information*

A B

Figure 1: Quality and significance of the stratigraphic record in some A/L key sections compiled from Brack et al. (2003) and Vörös et al. (2003). A) In both the GSSP candidate sections only some of the stratigraphic tools can be applied. B) The selection of an auxiliary section in the Dolomites (Frötschbach in this example) in support of a GSSP defined at one of Bagolino outcrops, would improve notably the definition and the correlatability of the boundary. In such a case, however, the formal definition of the auxiliary section requires a special care on the selection of the GSSP marker and of the additional marker events. For instance, at the present Brack et al. suggest only a GSSP marker event and no additional markers, so that Frötschbach section cannot be formally correlated and linked to Bagolino composite section, because at Frötschbach the first occurrence of *Eoprotrachyceras* has not been detected. (*) data from Brack & Rieber (1993b, p. 63).

marine Triassic paleobioprovinces. Its first appearance can be recognised only within the Tethyan Paleobioprovince and Japan, but is too much restricted to be selected as GSSP marker. In particular I think that any candidate boundary marker would have to allow direct correlations at least between the Tethyan and the North American successions.

The GSSP proposal of the base of the Curionii Zone at Bagolino

At the base of the Curionii Zone, no doubts, there is one of the major ammonoid faunal changes. In my opinion the best paleontological documentation of the base of Curionii Zone is recorded at Pertica (see Brack & Rieber, 1986, 1993a and 1993b), but at Bagolino the fossil record is more complete. The genus *Eoprotrachyceras* is well defined and relatively easy to recognize, and I do not agree with the opinion that the species *E. curionii* is not well known. Our knowledge of this species might be improved, but it is not so much different from the knowledge we have of the major part of the triassic ammonoids.

Eoprotrachyceras is also common in both the Tethys and North America, so that the base of the Curionii Zone probably might be well correlated with the Subasperum Zone, that is by tradition the base of the Ladinian in North America (Tozer, 1967; Silberling & Tozer, 1968; Tozer, 1981). However, the quality and accuracy of this correlation are not fully solved, because the sections studied by Brack et al. have been sampled with much more detail than the North American sections (Silberling & Tozer, 1968; Silberling & Nichols, 1982). New detailed sampling for ammonoids and conodonts have been carried out in Nevada, but the work is still in progress (Bucher & Orchard, 1995; Orchard, 2002).

If the boundary at the base of the Curionii Zone is easy to correlate with North America, I think there are some drawbacks in its application in the Tethys and in the tethyan successions.

The selection of this GSSP would imply that in the Tethys the time duration of the Lower Ladinian in term of ammonoid zones is reduced from four (Bittner's Buchensteiner Schichten=Reitzi, Secedensis, Curionii and Gredleri Zones sensu Brack, Rieber & Mundil, 1995) to two (Curionii and Gredleri). This means that the new Lower Ladinian is 50% reduced with respect to the original definition and, at the same time, the scope of the

Anisian is expanded. This also means that the tethyan biochronostratigraphic scale is not just refined, but instead it is strongly modified. The main problem is that tethyan stratigraphers have been using a full-size concept of Lower Ladinian since one hundred years. Lithostratigraphers always refer the whole Buchenstein Fm./Group or Buchenstein-like facies to the Lower Ladinian so they use a four-zone equivalent concept of the Lower Ladinian. Biostratigraphers never follow Brack & Rieber two-zone concept of Lower Ladinian, but more commonly they prefer the three-zone to the four-zone equivalent concept (within the ammonoid biostratigraphers: Krystyn, 1983; Leithner & Krystyn, 1984; Vörös & Palfy, 1989; Vörös, 1993; Mietto & Manfrin, 1995).

I would not have problems to accept such a major change in the chronostratigraphic scale, if this change is justified by a significant improvement in the easiness and in the accuracy of dating and/or correlating rocks. Is it so for the suggested boundary? I have the feeling that it would not introduce such an improvement.

If we give a look at the tethyan basinal successions, the application of the Brack et al. boundary is not so much problematic. The boundary has to be drawn a little higher in the successions with respect to the traditional one, then the age of the basinal formations has to be corrected (i.e., the Buchenstein Fm. in Western Dolomites becomes in part Upper Anisian in age). Timing of the basinal evolution has also to be corrected, but these corrections are not so much problematic, because there are some criteria that can be used to detect the Curionii Zone in basinal facies (not yet formally emphasized in Brack et al., 2003, section 3C).

The application of the proposed boundary to the tethyan carbonate platform successions is not that easy. In the lack of ammonoids, very rare in carbonate platforms, I have the feeling that there are no ways to detect the base of the Curionii Zone. Usually the carbonate platform environments are dominated by organisms with low power of time resolution that is also rarely calibrated with ammonoids. If this is true, the consequences are tremendous. In Western Tethys, and in particular in the Dolomites, a lot of Middle Triassic carbonate platforms are at present dated as Ladinian by stratigraphic relationships with basinal formations or by correlation with the very rare platforms whose age is calibrated by ammonoids (mostly belonging to Mojsisovics's A. avisianum Zone: Mojsisovics et al., 1895). If the short Lower Ladinian is introduced, the A/L boundary is rejuvenated by two ammonoid zones, so all of these platforms would have to be attributed to the Upper Anisian-Lower Ladinian or to the Upper Anisian-Ladinian with no chances to discriminate the Upper Anisian from the Lower Ladinian. This is equivalent to say that the age of these platforms becomes undefined. Do we think that such a revision that makes the Ladinian very difficult to be detected in the Dolomites, that is to say in the land where the Ladinian was founded, would be appreciated? Do we think that the reason for this change will be understood by stratigraphers non-member of the STS? Do we think that these stratigraphers will have the feeling that the new scale is better than the old one? I cannot answer for the other members of the A/L boundary Task Force, but personally I cannot answer yes to these questions.

It was said in Veszprem (5-8 September 2002) that the new boundary would have not changed the geological maps, but it would have modified only the age of the formations. This statement is right, but at the same time it is superficial. Chronostratigraphy does not provide only additional information to geological maps, but is a basic approach to time analysis of sedimentary successions. Most of our knowledge on Anisian and Ladinian carbonate platforms is based on the Western Tethys and in particular on the Dolomites, and consists of hundreds of papers, and tens of books. If we modify the age of the Ladinian carbonate platforms of the Western Tethys and of the Dolomites, then we have to change the timing of the evolution of the carbonate platforms, and of the reef communities, that are codified since years. Moreover, this change would consist in the introduction an obscure Lower Ladinian very difficult to handle, while the present chronostratigraphic classification is very useful in separating platforms and different stages in platform recovery and development after P/T crisis.

FINAL COMMENTS ON THE PROPOSALS

Boundaries

In my opinion the even important pros of Vörös et al. solution do not counterbalance the cons, then I do not find their proposal satisfactory. On the other hand also Brack et al. proposal is not convincing. I think it would be necessary to go a little deep into the problem of the consequences of the application of this boundary to carbonate platforms. More in general it would be interesting to know the opinion of carbonate platform specialists on the best boundary solution for the platforms.

Sections

The stratigraphic tools tested at Bagolino (composite) and at Felsóörs sections by Brack et al. and Vörös et al. are summarised in Fig. 1A. Bagolino has a good ammonoid and conodont record, but lacks of palynomorphs and magnetostratigraphy does not work. Felsöörs is practically barren of conodonts, lacks of palynomorphs, and magnetostratigraphy does not correlate with Frötschbach. There are radiolarians and ostracods, but no range chart is provided, so the significance of radiolarians and ostracods for the detection of the boundary is not demonstrated.

In conclusion, none of the two sections show a good and reliable record of all the most important stratigraphic tools. In my opinion, Bagolino is better than Felsöörs, so that a GSSP should have to be defined at one of the outcrops there. However, due to the incomplete documentation at Bagolino, I strongly suggest to support the GSSP section with an auxiliary section selected in the Dolomites providing some information that is not available at Bagolino. For instance Frötschbach section (Fig. 1B) seems to be complemental to Bagolino as regards palinomorphs and magnetostratigraphy.

The formal selection of an auxiliary section in the Dolomites improves the significance of the GSSP section, enhances the potential for long distance and global correlations and, last but not least, links the GSSP section with the type area of the Ladinian stage.

I know that the practical usage of auxiliary sections is admitted by the ICS (Remane et al., 1996) but in practice it is not so much encouraged. However, in the case of the A/L boundary it seems to me that most of the marine fossils do not allow low-high paleolatitude correlations and no one of the candidate sections is useful for the calibration of marine-land correlations.

HOW TO COME TO A DECISION?

Both the proposals submitted to the Task Force have disadvantages: the base of the Curionii Zone is good for North America, but not for the Tethys, while the base of the Reitzi Zone is good for the Tethys, but not for the rest of the world. No doubts this situation is not good for the Anisian/Ladinian boundary Task Force of the STS. After 12 years, the boundary interval has not been restricted, and the two solutions under discussion are separated by a good deal of two ammonoid zones. I am sorry, but this is not the best demonstration of flexibility.

At the present I see only one possibility to solve this embarrassing situation, that is to say to try to come together to a compromise solution. I strongly suggest the Task Force members to think about this possibility. It is obviously difficult to come to a compromise on one of the two proposals, because they are too much different and distant in time, but it would be easier to come to a compromise on an intermediate boundary. More in general, I think that it would be very interesting to test pros and cons of an intermediate boundary solution, and to compare it with the lower and upper ones.

At a first glance, a boundary located more or less around the first appearance of *Nevadites* or of *Ticinites* or just a little below, could be also recognised with *Daonellids* (gr. of *D. elongata*: Brack et al., 2003). Maybe it would be also recognised with magnetostratigraphy (for instance the reversed magnetozone F1r.1r, or base of the normal magnetozone F1n.2r: Brack et al., 2003, fig. 7a). This boundary would be not so distant from the Tethyan and the North American traditional boundaries, so its selection would not force anybody to make strong changes in the stratigraphic scales. This boundary probably would be not so dramatic for dating carbonate platforms as the boundary fixed at base of the Curionii Zone. It could be defined in a way that most or at least part of the Avisianum Zone sensu Mojsisovics (in Mojsisovics et al., 1895) would be kept into the Ladinian.

Last but not least, this boundary would fall in the middle of the most fossiliferous part of the sections studied by Brack et al. (2003, fig. 7a-b). The paleontological documentation they have provided from this interval is simply wonderful, and would represent the best support for the boundary. The upper part of the sections is actually much less fossiliferous (Brack et al., 2003, fig. 7a-b), and the first appearance of Eoprotrachyceras is recognised only at Bagolino and Margon, but not at Frötschbach, Seceda and M.S. Giorgio.

This solution would not be the perfect solution, of course, but after the examination of the pros and cons of the two proposals under discussion I am convinced that there is no perfect solution for the A/L boundary.

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Proposals for the GSSP for the base of the Ladinian Stage: Comment

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INTRODUCTION

The recent discussion of potential candidates for the GSSP of the base of the Ladinian (Balini, 2003, Vörös, 2003) and a formal proposal (Mietto et al., 2003) submitted six months after the deadline (agreed upon in September 2002 by the Anisian/Ladinian boundary working group) induce us to briefly touch a few of the most important aspects raised.

DISCUSSIONS BY BALINI (2003) AND VÖRÖS (2003)

Formal correctness of Bagolino proposal, auxiliary section and request for compromise

The authors apologize for the formal shortcomings in their proposal as indicated by Balini (2003). It was our - apparently erroneous - feeling that the indication of more than one and perfectly correlatable (on a bed-scale) and overlapping sections, all of which lie within a radius of less than 1000 m should not be a disadvantage for a GSSP proposal. If required, the detailed distribution of ammonoids for individual intervals exposed at sites A - D at Bagolino can be made available. In spite of these apparent shortcomings, Balini (2003) eventually concludes "that a GSSP should have to be defined at one of the outcrops there" (i.e. at Bagolino). Moreover, in their proposal, Mietto et al. (2003), refer to our documentation of Bagolino "as reliable section for the base of the Ladinian".

Vörös' (2003) indication that Pèrtica has a better record with respect to the ammonoid species *Eoprotrachyceras curionii* is correct in terms of number of specimens. However, at Bagolino this ammonoid was unambiguously identified on the basis of specimens of similar quality!

Balini's (2003) request for a GSSP defined at Bagolino and complemented with an auxiliary section with magnetostratigraphic data is reasonable and follows our intention expressed in Fig. 7 of Brack et al. (2003). The much better fossil record and extended magnetostratigraphic coverage at Seceda (Muttoni et al., submitted) promotes Seceda rather than Frötschbach as the auxiliary section in the Dolomites.

Balini's (2003) suggestion for searching a compromise on an intermediate boundary may be valid. However, the argument for a compromise alone cannot be a decisive criterion. Although the process of defining a stage boundary has inevitably a political component, in our view, the boundary position should be chosen on the basis of scientific arguments such as the best possible resolution of stratigraphic tools and their correlation potential.

Carbonate platforms

We share Balini's concern on problems in properly recognising the A/L boundary within carbonate platform successions. In our view this has more to do with the insufficient biostratigraphic record in many platform settings rather than with the stratigraphic position of the boundary. In the Dolomites for example, only the boundary proposal at the base of the Reitzi Zone (sensu Vörös et al., pre-2003; and possibly also the revised version 2003) would result in the assignment of (post-Contrin and pre-volcanic) platform carbonates to a single stage (i.e. the Ladinian). All other proposed boundary positions (i.e. the base of the Avisianum subzone, of the Secedensis or the Curionii Zone respectively) would imply that these platforms are Anisian-Ladinian. None of the eventually chosen boundary position will result in an improvement of the information on the age of these platforms!

THE GSSP PROPOSAL BY MIETTO ET AL. (2003)

Interpretation of the Bagolino section and Buchenstein Beds

Although Mietto et al. (2003) conveniently adopt our documentation for Bagolino (Brack et al., 2003 and earlier reports), some of their comments and additions are partly incorrect. We did not indicate the 58-60m interval as barren but only as an interval with scarce faunas. Of course the new ammonoids reported by Mietto et al. (2003) are a welcome addition but the indicated fossils seem to predominantly comprise rather long ranging taxa (e.g., *Aplococeras*, *Halilucites*, *Parasturia*).

The minimum value of 1 m/myr as indicated by Mietto et al. (2003) for rates of sedimentation in the Buchenstein Beds is derived from adopting Preto et al.'s (2001) interpretation of Latemar cycles, even though in a subsequent paragraph the application of cyclostratigraphy for time measurement or correlation in the Middle Triassic is declared as "still untimely".

Mietto et al.'s (2003) interpretation of the Bagolino section in terms of sequence stratigraphy is largely devoid of convincing sedimentological arguments. At Seceda the correlated position of the boundary between sequences An4 and La1 at Bagolino most likely corresponds to a level in the "Lower Plattenkalke". The latter do not show any indication of significant change in the depositional environment (e.g., Maurer & Schlager, 2003). Apart for the abundance of ammonoids, there is no clear evidence for stratigraphic condensation at the level of the "Chiesense groove"(considered as "mfs" by Mietto et al., 2003) and similar thin intervals of limestone nodules in a shaly matrix also occur at other stratigraphic levels throughout the Buchenstein succession.

As a consequence, the potential for far-reaching or even global correlation of stratigraphic sequences in the A/L boundary interval still remains to be proven.

Aplococeras avisianum and A. vogdesi: their differences and suitability for correlation

The ammonoid Aplococeras avisianum is the key element in Mietto et al. (2003) and these authors propose a GSSP with the first appearance of this ammonoid species at Bagolino. For reasons given below (A-C) and based on information from literature and on our own observations on abundant material of *Aplococeras* from the Southern Alps and North America, we disagree with at least three crucial arguments in favour of *A. avisianum*:

1) The interpretation of A. avisianum at Bagolino as "possible FAD" of the species;

2) The claim that *A. avisianum* is commonly found in basinal and platform settings;

3) The interpretation of the North American species *Aplococeras vogdesi* as junior synonym of *A. avisianum*.

A) Sections in NW-Nevada (e.g., Humboldt Range, Augusta Mountains, Tobin Range) are hitherto the only places where the ranges of species of *Aplococeras* can be evaluated with some confidence. Table 1 in Silberling & Nichols (1982) clearly documents the prolonged range of three species of *Aplococeras*, including *A. vogdesi*.

On the basis of the rather isolated finds in pelagic sections and platform carbonates in the Southern Alps (see B) we doubt if at present a FAD can be confidently defined for any species of *Aplococeras* in this area.

B) According to our experience and in agreement with observations on Hungarian sections (Vörös, 2002; Fig. 4), specimens of *Aplococeras* are usually very rare or absent in distal basinal sediments. *Aplococeras* is locally abundant in platform carbonates and in basinal sediments located in proximity to carbonate platforms.

C) In agreement with Silberling and Nichols (1982) and in spite of the large intraspecific variability we consider *Aplococeras avisianum* and *A. vogdesi* to be different species. Contrary to the indications by Mietto et al. (2003) both species show differences in their suture line and morphology. The lateral lobe of *A. vogdesi* is entire (goniatitic suture; e.g., Fig. 37 of Silberling & Nichols, 1982) whereas it is clearly denticulated in *A. avisianum* (e.g., Fig. 17c in Brack & Rieber, 1993). The slope of the umbilical wall and the ornamentation of the two species are different: *A. avisianum* is characterised by umbilical tubercles which are absent in *A. vogdesi* a feature already noted by Hyatt & Smith (1905).

For these reasons and because of the scarcity of taxonomical characters, *Aplococeras avisianum* is not an easily identifiable taxon. Its potential for far-reaching correlation is questionable. As a consequence the species A. avisianum should not be considered for the definition of a GSSP.

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Comment on the A-L Boundary Proposals

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Milan, 14 May 2003

Dear Aymon,

Among the two A/L candidate sections, my preference goes the the one provided with a global means of correlation independent of (ammonoid) biostratigraphy. With independent and global means of correlation I refer essentially to isotope stratigraphy and magnetostratigraphy. Variations in the global carbon cycle and Earth's magnetic polarity reversals occur both in the marine and continental realms. Therefore, a Global SSP should be erected in a level of a section where a recognizable event can be correlated globally by means of, for example, magnetostratigraphy. A marine-based SSP that is globally non-exportable is not a Global SSP.

The Bagolino section was entirely remagnetized probably during the Cenozoic (Muttoni and Kent, 1994). However, lithostratigraphic correlation with the radiometrically-dated Seceda composite sequence of magnetic polarity reversals has been performed (Muttoni et al., submitted).

Felsoors is directly provided with magnetostratigraphy (Marton et al., 1997), however, because this section is largely dominated by unsampled tuff levels, the pattern of magnetic polarity reversals therein retrieved is of poor resolution and limited utility as a correlation tool.

At the present status on knowledge, from a magnetostratigraphic and, in general, global stratigraphy point of view, the best A/L section worlwide is Bagolino.

Sincerely Yours,

G. Muttoni

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On the definition of the base of the Ladinian Stage

E.T. Tozer

Of the three proposals for this definition (Brack et. al., Vörös et al., Mietto et al.), respectively at the base of the *Curionii*, *Reitzi*, and *Avisianus* zones, I recommend acceptance of the *Curionii* datum. This level is characterized by the first appearance of the Trachyceratidae, a significant event in the history of Triassic Ammonoidea, which can be recognized in both North America and Eurasia.

Integrated ammonoid, conodont and radiolarian zonation of the Triassic and some remarks to Stage/Substage subdivision and the numeric age of the Triassic stages

This paper is a contribution to IGCP Project 467

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Abstract: An integrated Triassic ammonoid-, conodont and radiolarian zonation is presented. Ammonoid- and conodont zonations are generally well worked out and well correlatable. The radiolarian zonation is well established in the Middle Triassic, lower and middle Carnian as well as in the upper Norian and Rhaetian.

The Induan (Kiparisova & Popov, 1956) was more than 60 years later established than the Brahmanian (Mojsisovics et al., 1895) and its scope was two times drastically changed. After the latest shift of its lower boundary, the Induan get a perfect synonym of the original Brahmanian and should be therefore rejected, the more, as even its name is incorrect. The Dienerian Substage (Tozer, 1967) is a junior synonym of the Gandarian Substage (Mojsisovics et al., 1895) which should be used for priority reasons. The Gangetian Substage (Mojsisovics et al., 1895) was defined by the *Otoceras*-*Ophiceras* faunas of the Himalaya. The Griesbachian Substage (Tozer, 1967) included originally the Boreal *Otoceras concavum* and *O. boreale* zones which are older than the *H. parvus* Zone and belong therefore to the Permian after definition of the base of the Triassic with the base of the *H. parvus* Zone. Only the upper Griesbachian belongs to the Triassic but should not more used as Triassic substage both for priority reason and for different definition. Also its upper boundary must probably be re-defined. The biostratigraphic priority boundary for the Ladinian with the FAD of *Reitziites reitzi* is preferred against the definition with the FAD of *Eoprotrachyceras curionii*. A compromise boundary is possible (especially the FAD of *A. avisianum*), but this boundary has not the correlation potential of the two other boundaries.

The numerical age of the Triassic stages and substages is discussed.

INTRODUCTION

The ammonoid- and conodont biostratigraphy of the Triassic is well elaborated for the entire Triassic, and also the radiolarian zonation is well known for most of the Triassic. Despite of this fact only the base of the Triassic is finally defined and approved by the International Stratigraphic Commission. In the present paper the correlation of the ammonoid-, conodont- and radiolarian zonation is shown to facilitate the definition of the Triassic stages and substages. However, other fossil groups (e.g. bivalves, especially pelagic bivalves, holothurian sclerites, dasycladaceans, conchostracans, sporomorphs) are also widely used for stratigraphic correlation within the Triassic. Many reliable data about the numerical age of the Middle Triassic are present, but nearly no reliable numerical ages are known for the Upper Triassic, except for the Triassic-Jurassic boundary. However, the numerical ages can be applied also for most of the Upper Triassic by astronomic calibration in the of the Tuvalian to Rhaetian interval in the Newark Basin (e.g., Kent & Olson, 2000). Channell et al. (2002, 2003) correlated the palaeomagnetic subdivision of the Newark Basin with the marine scale and made by this the astronomic calibration also available for the marine Tuvalian and Norian.

REMARKS TO THE PERMIAN-TRIASSIC BOUNDARY

The base of the Triassic at the FAD of *H. parvus* is the only officially confirmed boundary of the Triassic. *H. parvus* occurs both in deep-water deposits without ammonoids (e.g. Sicily, Oman), in ammonoid-bearing moderately deep deposits (e.g. South China, Kashmir, Greenland, Arctic Canada) both of the Tethyan and Boreal realms, and in shallow water deposits without ammonoids (e.g. Southern Alps, Hungary, Salt Range, western North America). For better understanding of the causes of the Permian-Triassic biotic crisis, a very precise correlation of this boundary is necessary also to continental deposits. For this reason and for evaluation of the conditions around the Permian-Triassic boundary (PTB) also sequence stratigraphic, palaeomagnetic, stable isotope and microsphaerule investigations have been carried out around the PTB, and the presence and onset of anoxia, the radiometric ages as well as the Milankovitch cycles have been investigated by many authors, especially in the Meishan GSSP (e.g. Claoue-Long et al., 1991, Yin Hongfu et al., 1992, 1996, 2001, Wang Cheng-yuan et al., 1996, Bowring et al., 1998, Jin Yugan et al., 2000, Mundil et al., 2001), but also in other sections. They yielded not only interesting data for the understanding of the Permo-Triassic crisis, but are also - in combination with biostratigraphic data - a good tool for very detailed correlation. Some remarks are necessary. Magnetostratigraphic investigations in combination with detailed biostratigraphy are very important for correlation. However, at the PTB the trend can be observed to fit the data by compilation into the PTB which was accepted or generally used at the time of publication. The Boundary Clay was generally not investigated in the Chinese section because the soft, weathered and fissile clays are unsuitable for getting samples for reliable investigations. However, the beginning of the normal polarity close to the PTB was often shown at the base of the Boundary Clay. Only in Heller et al. (1988, 1995) was shown a short level of unknown polarity in the Boundary Clay of the Shangsi section. In the other papers the beginning of the normal polarity was shown at the base of the Boundary Clay which was formerly assumed to be the PTB. In the compilation by Jin Yugan et al. (2000) the normal polarity which is even not proven for the Boundary Clay was then assigned to the *H. parvus* Zone in the Meishan and Shangsi sections whereas the reversed polarity which was in all original papers shown for the beds below the Boundary Clay was assigned to the *C. meishanensis* Zone, from where it is nowhere in the world proven. By this again the reversal was fit into the new, internationally adopted PTB without any new data. This is especially dangerous because by this was created the impression that in the GSSP (Meishan) and in other well investigated sections at the PTB (e.g. Shangsi) the reversal coincides with the adopted PTB (FAD of *H. parvus*) what is nowhere in the world the case. This has caused in the Germanic Basin discussions to lower the PTB to the lower part of the upper Bröckelschiefer (uppermost Zechstein), where this reversal occurs.

All reliable palaeomagnetic data in the world have shown that the change from reversed to normal polarity around the PTB occurs distinctly below the PTB which lies within the lower third of a normal Zone. In the section Dorasham II on the Azerbaidzhan side of the Araxes river the normal polarity begins 0.5 m below the top of the *Paratirolites* beds (Zakharov & Sokarev, 1991). In the Jolfa sections on the Iranian side of the Araxes river, this level corresponds to the upper *C. yini* fauna of the uppermost *C. changxingensis*-*C. deflecta* Zone. In the Iranian sections two further zones follow in the Permian red ammonoid-bearing limestones, the *C. iranica* Zone and the *C. praemeishanensis* Zone (missing in the Chinese intraplatform basins) before the *C. meishanensis*-*H. praeparvus* Zone begins at the base of the overlying Boundary Clay. Thus, the beginning of the normal polarity zone around the PTB is undoubtedly within the upper Dorashamian below the *C. meishanensis*-*H. praeparvus* Zone. This is confirmed in other parts of the world. In Scholger et al. (2000) the beginning of the normal polarity Zone is shown in the Bulla section (Southern Alps) distinctly below the FAD of *H. parvus*. This *H. parvus* is even not *H. parvus*, but partly a form, similar to *H. eurypyge* Nicoll, Metcalfe & Wang which begins within the uppermost Permian, partly an indeterminable juvenile form, probably of *H. praeparvus*. In the Shangsi section, the normal polarity zone begins at the base of Bed 28, Bed 27 has unknown polarity and below, Bed 26 has reversed polarity (Peng Yuanqiao et al. (2001). The FAD of *H. parvus* in this section is in Bed 30, about 4.6 m above the beginning of the normal polarity zone. In the Griesbach Creek in Arctic Canada, both the *O. concavum* and the *O. boreale* Zones have normal polarity. The FAD of *H. parvus* in the Arctic is above the *O. boreale* Zone s.s. within the *T. pascoei* Zone. Gallet et al. (2000) have shown in Abadeh (Iran) the beginning of the normal polarity zone around the PTB at the base of the Triassic above a long gap comprising the entire *C. changxingensis*-*C. deflecta* Zone of the upper Dorashamian. However, the upper Dorashamian gap is not present. *C. changxigngensisi*, *C. deflecta*, *C. parasubcarinata* are very common in this section and the upper Dorashamian part is even longer than the lower Dorashamian *C. subcarinata* Zone. *C. yini* is present in the upper part of the *C. changxingensis*-*C. deflecta* Zone. Above this *C. yini* level which lies in the same position as in Meishan, two further conodont zones are present which are missing in Meishan, the *C. iranica* Zone and the *C. praemeishanensis* Zone, the latter of which contains only very few conodonts. Then the *C. meishanensis*-*C. praeparvus* Zone follows in the Boundary Clay as in Meishan. By dissolving of 10 kg samples in very short distances (after re-sampling every 5-10 cm in the critical interval) the FAD of *H. parvus* could be very well established at 1.10 m above the Boundary Beds, that means 1.38 m above the PTB which is indicated by Gallet et al. et the base of the Boundary Beds, as Gallet et al. (2000) ,did not yet use the base of the Triassic with the FAD of *H. parvus*. This may be overlooked in using the paper of Gallet et al. (2000) because in 2000 no other paper used the old PTB at the base of the Boundary Clay and the FAD of *H. parvus* is shown within the upper Boundary Clay and so it appears that the PTB is placed at the FAD of *H. parvus*. This low occurrence of *H. parvus* is not confirmed. All clayey-marly samples from the Boundary Clay have a poor *Hindeodus* fauna with *H. praeparvus* and *H. typicalis*. A thin limestone bed within the upper Boundary Clay has an unusually rich *Hindeodus* fauna which does not contain any *H. parvus*. This species may be misinterpreted for the similar *H. eurypyge*, but even this species is very rare in this bed which is dominated by *H. praeparvus*. As correctly stated by Gallet et al. (2000) no palaeomagnetic investigations were carried out from the unsuitable boundary Clay. Thus, the first sample with normal polarisation is from the first limestone above the Boundary Clay, but also this level lies 1.10 m below the base of the Triassic (see above). It is not quite clear what is the highest sample with reversed polarity in the Hambast Formation because *C. subcarinata* is shown to occur until the top of the Hambast Formation. However, this species is not present in the uppermost metres of the Hambast Formation. Nevertheless, the Gallet et al. (2000) paper is important to show that the normal event begins distinctly below the PTB despite the fact that it is shown to begin at least at the PTB. Correct evaluation of reliable palaeomnagnetic data as in the Gallet et al. (2000) paper needs to revise the stratigraphic subdivision, especially the formerly used PTB. In the Germanic Basin the normal zone around the PTB begins in the lower third of the upper Bröckelschiefer (upper Fulda Formation) of the uppermost Zechstein. This fits well with the biostratigraphically defined PTB at the Oolithbank Alpha 2 of the overlying Calvörde Fm. (Kozur, 1999) of the lowermost Buntsandstein. The beginning of the normal zone in the uppermost Permian is in combination with biostratigraphic data an important tie-point for a very detailed correlation of the marine and continental Triassic.

The new palaeomagnetic data in the Meishan section by Zhu Yanming and Liu Yugan (1999) repeated by Yin Hongfu et al. (2001) are problematical for the magnetostratigraphy around the PTB. In these papers the entire Bed 27 is shown to have a reversed polarity and the normal polarity zone is shown to begin more than 5 m below the Boundary Clay. Both these features cannot be confirmed in many section outside Meishan, also not in the well dated sections of the Central and Western Tethys. Bed 27 comprises more than the upper half of the *C. meishanensis*-*H. praeparvus* Zone and the entire *H. parvus* Zone. Exactly this time interval is well investigated in several sections (Abadeh of Iran, Bulla and Siusi of Southern Alps, Griesbach Creek in Arctic Canada, Germanic Basin, see Gallet et al., 2000, Scholger et al., 2000, Ogg & Steiner, 1991, Szurlies, 2001) and nowhere a reverse interval was found in the *H. parvus* Zone and time equivalents. Moreover, in well dated marine sections, the normal Zone does not begin so deep within the upper Dorshamian *C. changxingensis*-*C. deflecta* Zone, but only in its uppermost part (Zakharov & Sokarev, 1991 in Dorasham II, Gallet et al., 2000 in Abadeh, Scholger et al., 2000 in the Southern Alps).

Stratigraphic importance has also the drop in $\delta^{13}C$ close to the PTB (e.g., Baud et al., 1989, Xu & Yan, 1993, Bowring et al., 1998, Jin Yugan et al., 2000, Yin Hongfu & Zhang Kexin, 1996, Yin Hongfu et al., 2001). In Meishan generally a first minimum is indicated within the Boundary Clay (lower part of Bed 26) and after a short increase in the uppermost part of the Boundary Clay, a second stronger drop occurs in Bed 27 with a minimum just before the base of the Triassic (e.g., Yin Hongfu & Zhang Kexin, 1996, Bowring et al., 1998). The two minima are with –5 to –6 very strong. Only Jin Yugan et al. (2000 y) gave an other picture with only one minimum (around –1) close to the base of the Boundary Beds (basal parts of Bed 25) and no minimum in the *H. parvus* Zone (values between 0 and +1). Korte, Kozur, partly with other co-authors (in press and in prep.) investigated in detail the development in ´ ^{13}C in several sections in Iran which are well dated by conodonts. In two sections (Abadeh and Jolfa) there are two minima, one in the Boundary Clay and an other in the uppermost *C. meishanensis*-*H-praeparvus* Zone, similar to the picture shown by Bowring et al. (1998) and Yin Hongfu et al. (2001) and other papers for Meishan, but the values for the minima do not go below –2. However, the first minimum within the Boundary Clay may be an artifact both in Meishan, Abadeh and Jolfa. Especially in Meishan, the beds contain very few carbonate which is often dominated by carbonate from ostracod shells. This may strongly alter the values for $\delta^{13}C$. In Shahreza and Zal, where the Boundary Clay contain more $CaCO_3$, there is no minimum in the Boundary Clay. In Shahreza, the values vary between +1.27 and +2.12, in Zal so far only one value at the very base of the Boundary Clay with *C. meishanensis* and *H. praeparvus* yielded a value of +1.31. The second minimum at the PTB or a little before can be everywhere found and it is surely not an artefact. It is characterised by a drop to values <0 within the uppermost *C. meishanensis*-*H. praeparvus* Zone, but in pelagic sections not below –2. The minimum lies either a little below the PTB or at the PTB. After a slight in crease in the upper *H. parvus* Zone, there is generally a second drop within the lower *I. isarcica* Zone.

The minimum of the $\delta^{13}C$ values in the uppermost *C. meishanensis*-*H. praeparvus* Zone immediately below the PTB or at the PTB is a good stratigraphic marker. In the Shangsi section this minimum was assumed to be somewhat higher, in Bed 30 (Baud et al., 1989). However, after re-study of the conodonts in this section by Nicoll et al. (2002), the FAD of *H. parvus* was found in Bed 30, indicating that the PTB was drawn in this section too low. Also in this section the first minimum in the Boundary Clay is not present. The re-evaluation of the conodont stratigraphy has shown in this section the outstanding stratigraphic importance of the $\delta^{13}C$ minimum around the PTB.

First testing of the application of the $\delta^{13}C$ minimum for determination of the continental PTB were successful. Dr. Ch. Korte (Bochum) determined $\delta^{13}C_{carb}$ from the Oolithe Bank Alpha 1 (-2.22 to –2.65 in different levels) which is a time equivalent of the lower part of the Boundary Clay, and from the Oolite Bank Alpha 2 (-4,00 to –4.22) which is situated around the PTB. A stromatolitic limestone bed, about 1.35 m above the base of Oolite Bank Alpha 2 yielded the value -3.81. Despite the fact that only 3 levels of limestones are present in this interval, the Oolite Bank Alpha 2 represents the minimum in $\delta^{13}C$ because just in this level is the minimum in $\delta^{13}C_{org}$ (Prof. Dr. H.J. Hansen, pers. comm.).

A further tool for stratigraphic correlation around the PTB is a horizon with rich occurrences of microsphaerules. They were first reported from the Meishan section and other sections in China (e.g., He Jinwen, 1985, Yin Hongfu et al., 1992, Yin Hongfu & Zhang Kexin, 1996), but we have found them also in the Abadeh, Jolfa, Shahreza and Zal sections of Central and NW Iran and in the Bükk Mts. of Hungary. The interval with increased frequency of microsphaerules occur from the uppermost *C. changxingensis*-*C. deflecta* Zone (horizon with *C. yini)* until the *H. parvus* Zone. The richest occurrences are derived from the lower, but not lowermost Boundary Clay. Such microsphaerules were also found in continental beds of the Germanic Basin (Bachmann & Kozur, 2002) with a distinct maximum from the Oolite Bank Alpha 1 up to grey clays about 1.5 m above the base of Oolite Bank Alpha 1. This indicates that the base of the Buntsandstein which is characterised by a distinct climatic change from a dry to wet climate coincides roughly with the base of the Boundary Clay.

By consideration of different tools for stratigraphic correlation, a rather detailed correlation between the marine and continental Triassic around the PTB is possible. In the continental deposits of the Germanic Basin, the Milankovitch cycles are well recognisable. From the beginning of the normal zone below the PTB in the lower third of the upper Fulda Fm. until the PTB in the Germanic Basin at the Oolite Bank Alpha 2 two ~100kyr eccentricity cycle s can be discriminated. From the base of the Buntsandstein (corresponding to the base of the Boundary Clay) up to the PTB only one ~100kyr eccentricity cycle and one 20 kyr precession cycle is present. This is very important for dating of the PTB from radiometric data from Bed 25 (lower Boundary Clay) in the Meishan section (see below).

REMARKS TO THE NUMERICAL AGE OF THE PERMIAN-TRIASSIC BOUNDARY

Two sets of radiometric data were published recently for the PTB at Meishan. Bowring and others (1998) reported 251.4 Ma ± 0.3 for Bed 25 of Meishan (lower *C. meishanensis*-*H. praeparvus* Zone) and 250.7 Ma ± 0.3 for Bed 28 (basal *I. isarcica* Zone). From these data an age of the PTB of about 251 Ma can be concluded. Mundil and others (2001), on the other hand, reported values slightly older than 254 Ma for Bed 25 and 252.5 Ma ± 0.3 for Bed 28, concluding 253 Ma for the PTB. There are problems with both sets. 251 Ma for the PTB seems to be inconsistent with the 247 Ma for the base of Anisian (Lehrmann et al., 2002). 4 myrs for the entire Scythian (Brahmanian + Olenekian stages) is too short considering the Milankovitch cycles of the Germanic Basin as well as the number of biozones and sedimentation rates in the marine Lower Triassic. Approximately 253 Ma for the PTB (Mundil et al., 2001) is a reliable value, when 247 Ma is used for the base of the Anisian. However, Mundil and others mentioned that > 254 Ma for Bed 25 is a very weak value. The time span from the base of Bed 25 to the base of the Triassic (PTB) cannot be >1 myrs. As shown by correlation with the Germanic Basin (Bachmann & Kozur 2002), this interval has a duration of about 0.12 myrs (see above). A solution to this problem may be found in the basic data of Bowring and others (1998). They recorded two data clusters in Bed 25, one at 251.4 Ma ± 0.3 and one at 252.7 Ma ± 0.4. They rejected the older cluster as inherited and used the younger one which fit in their other data. But as correctly stated by Mundil and others (2001), the older data cluster inferred an equally plausible age assignment. If we use 252.7 Ma for Bed 25 and 0.12 myrs for the duration of the *C. meishanensis*-*H. praeparvus* Zone (interval between the event boundary and the biostratigraphic PTB), we get an age of 252.6 Ma for the PTB, close to the value of 253 Ma (Mundil et al., 2001), and a duration of about 100 kyrs for the *H. parvus* Zone, as 252.5 Ma for Bed 28 (Mundil et al., 2001) corresponds to the base of the overlying *I. isarcica* Zone. If we use this estimated PTB of 252.6 Ma and the 247 Ma for the base of Anisian (Lehrmann et al., 2002), we get a duration of 5.6 myrs for the Lower Triassic. This is nearly identical with the Scythian duration estimated by astronomic calibration of the Brahmanian to Lower Olenekian and estimation of the Upper Olenekian (see below).

LOWER TRIASSIC STAGE/SUBSTAGE SUBDIVISION

Most of the Triassic stages were established by Mojsisovics et al. (1895). Only the Rhaetian Stage was introduced already by Guembel (1859, 1861) and overtaken by Mojsisovics et al. (1895). The stage subdivision by Mojsisovics et al. (1895) was generally overtaken for Middle and Upper Triassic and only the Juvavic Stage was re-named into the Norian Stage originally introduced for the Ladinian Stage which was named already by Bittner (1892). However, the Lower Triassic stages were not used, but the Scythian Series, also introduced by Mojsisovics et al. (1895) was regarded as the Scythian Stage for more than 50 years. This was rather well founded as even a Scythian Stage would belong to the shortest stages of the Triassic (compare the duration of the Lower Triassic with the other stages, see figs 1-3). However, in the former Soviet Union and in North America prevailed for long time the opinion that one stage for the Lower Triassic would have a too long duration. Unfortunately, the paper of Mojsisovics et al. (1895) was not taken into consideration and thus not the Lower Triassic stages established by Mojsisovics et al. (1895) were used but new stage names were introduced, the Induan and Olenekian by Kiparisova & Popov (1956) and the Griesbachian, Dienerian, Smithian and Spathian by Tozer (1965). This was the more curious as the Brahmanian Stage, the lowermost stage of the Triassic (introduced by Mojsisovics et al., 1895) is the originally best defined stage of the Triassic.

The Induan and Olenekian were originally defined by Kiparisova & Popov (1956) with faunal successions in the Boreal realm, but the Salt Range was taken as the type of the Induan which got its name from the Indus river. By this even the name of the Induan is incorrect, the correct name would be Indusian. The base of the Induan was defined by the base of the Boreal *Otoceras* faunas that means with the base of later established *O. concavum* Zone which is not present in the Salt Range (gap). The top of the Induan was placed in the type area Salt Range at the top of the Ceratite Sandstone which was erroneously correlated with pre-Olenekian Boreal faunas. However, the ammonoid fauna of the Ceratite Sandstone comprises the largest part of the Lower Olenekian (Smithian Substage). This was recognised by Kiparisova & Popov (1964), and they who excluded the Ceratite Sandstone from the Olenekian. This was the first big change in the scope of the Induan.

By the final definition of the base of the Triassic (finally ratified by the IUGS Executive Committee in March, 2001) with the first appearance datum (FAD) of *Hindeodus parvus*, first proposed by Kozur & Pjatakova (1976) and later followed by Yin Hongfu et al. (1988), the lower part of the Induan became Permian by definition. After this second revision of the Induan, a large part of the original Induan belongs now to the Permian and Lower Olenekian. After these two big revisions, it corresponds now perfectly to the Brahmanian established by Mojsisovics et al. (1895) more than 60 years before the introduction of the Induan. Therefore, there is no reason, furthermore to use the "remnant Induan" instead of the Brahmanian which has the priority and must not be re-defined.

The Brahmanian was defined by Mojsisovics et al. (1895) by the *Otoceras*-*Ophiceras* faunas of the Himalaya (Gangetian Substage) and the Lower Ceratite Limestone

My		Stage/Substage		Ammonoid Zone		Conodont Zone		Radiolarian Zone
247	LOWER TRIASSIC = SCYTHIAN	OLENEKIAN	Late Olenekian (Spathian)	Neopopanoceras haugi		Chiosella gondolelloides		Hozmadia ozawai
						Triassospathodus sosioensis		
				Prohungarites-Subcolumbites		Triassospathodus triangularis		
				Procolumbites		Triassospathodus homeri		
				Columbites parisianus		Icriospathodus collinsoni		
				Tirolites cassianus		Triassospathodus hungaricus		
			Early Olenekian (Smithian)	Anasibirites kingianus		Neospathodus waageni-Scythogondolella milleri		Radiolarians unknown
				Flemingites flemingianus		N. waageni-Scythogond. meeki		
						Chengyuania nepalensis		Stigmosphaerostylus turkensis
250,7		BRAHMANIAN (="INDUAN")	Gandarian (Dienerian)	Prionolobus rotundatus		Neospathodus dieneri		
				Pleurogyronites planidorsatus		Sweetospathodus kummeli		
			Gangetian	Ophiceras tibeticum		Clarkina postcarinata		Radiolarians unknown
						C. carinata	H. postparvus-H. sosioensis	
						Isarcicella isarcica		
252.5				Otoceras woodwardi-Ophiceras bandoi		Hindeodus parvus		
252.6				Otoceras fissisellatum	T. pascoei			
252.7	LOPING.	DORASH.	Upper Dorashamian	Hypoph. changxingense	Otoceras boreale	Clarkina meishanensis - H. praeparvus		
				Pleuronodoc. occidentale		Clarkina praemeishanensis		

Figure 1: Lower Triassic stages, substages, ammonoid, conodont and radiolarian zonations

and Ceratite Marls (Gandarian Substage) of the Salt Range. The *Otoceras*-*Ophiceras* faunas of the Himalaya are younger than the Boreal *Otoceras* faunas (Krystyn & Orchard, 1996, Kozur, 1996, 1998a, b). They begin with the *H. parvus* Zone. As the biostratigraphic base of the Triassic was originally not defined by the FAD of the genus *Otoceras*, but with the FAD of *O. woodwardi* (*Otoceras* was in the late 19th Century used in a much wider sense then today, including Dzhulfian and Dorashamian Otocerataceans), the FAD of *H. parvus* is close to the original base of the Triassic at the base of the *O. woodwardi* Zone. The Boreal *O. concavum* Zone and *O. boreale* Zone s.s. do not contain *H. parvus*, but *H. praeparvus* and *H. typicalis*. *H. parvus* begins in the uppermost Boreal *Otoceras* faunas within the *T. pascoei* Zone (Kozur, 1998a, b). Thus, in contrast to the Induan the lower boundary of the Brahmanian must not be changed. The same is true for the upper boundary. The Ceratite Marls have a rich conodont fauna of the upper *N. dieneri* Zone (*N. cristagalli* Zone sensu Sweet, 1970). The overlying Ceratite Sandstone belongs to the Lower Olenekian *Flemingites flemingianus* ammonoid zone and was never included into the Brahmanian, in contrast to the original Induan which was defined by inclusion of the Ceratite Sandstone (*Flermingites flemingianus* Zone) .

The Gangetian can be used as lowermost substage of the Triassic without change of its original scope (see above). The base of the Himalayan *Otoceras*-*Ophiceras* faunas coincides with the base of the *H. parvus* Zone (Krystyn & Orchard, 1996, Kozur, 1998a, b). The following Gandarian begins with the *Sweetospathodus kummeli* Zone. By this the Gangetian comprises the lowermost substage of the Triassic in the present scope. When the term Griesbachian (introduced 70 years later than the Gangetian) is used for the lowermost substage of the Triassic, this would require a total revision of the Griesbachian by removing of the entire lower half of this substage which belongs to the Permian according to the definition of the base of the Triassic. For this reason the term Gangetian is preferred against a totally revised Griesbachian which has, moreover, not the priority. The Ellesmerian Substage (Kozur, 1972) has the same scope as the Gangetian, but is a junior synonym of the Gangetian.

The Gandarian in its original definition begins with the *Gyronites* ammonoid faunas of the Lower Ceratite Limestone which contain at its base conodonts of the *Sweetospathodus kummeli* Zone, which marks the base of the upper substage of the Brahmanian. Tozer (1978, p. 32) pointed out that “Gandarian is an approximate synonym of Dienerian.” It has to be pointed out that the Dienerian is the junior synonym of Gandarian which was established 70 years before the Dienerian. In the interest of stability in the stratigraphic nomenclature, such clear priority should be in all cases regarded in favour of the senior synonym, in this case in favour of the Gandarian. Moreover, the Gandarian was established on the Perigondwana margin of the Tethys, the Dienerian in the Boreal realm. If possible (priority, well defined and applicable), stages/substages established in the highly diverse Tethyan faunas should be preferred against stages/substages established in low diversity Boreal faunas. The Gandarian base in the Tethys is best to place at the base of the *S. kummeli* Zone in the Salt Range (base of the *P. planidorsatus* Zone s.s.) in agreement with the original definition of the Gandarian. This coincides with the Dienerian base in the Boreal realm where the Dienerian was originally defined by the boundary between the *Bukkenites strigatus* Zone and the *Proptychites candidus* Zone. According to Orchard & Tozer (1997) *S. kummeli* occurs in the *P. candidus* Zone of the Arctic Canada and begins roughly at the base of this zone. *Bukkenites* from the underlying *B. strigatus* Zone occurs also within the Perigondwanan Tethyan *Ophiceras* faunas, but only in condensed deposits (Krystyn & Orchard, 1996). However, *S. kummeli* does not occur in this level and, therefore, it should not yet present in the Perigondwanan *Bukkenites* faunas. An other Dienerian base is used by Krystyn & Orchard (1996). They assigned their ammonoid association between the upper *O. tibeticum* Zone (with *Bukkenites*) and the *P. planidorsatus* Zone s.s. with *S. kummeli* into the lowermost Dienerian. This Dienerian base is lower than the Boreal type Dienerian base. The ammonoid fauna of association 5 is very poor, no specimen can be determined in species level and in 4 out of 5 genera even the generic determination is questionable. The conodont fauna of this level with last *H. typicalis* is a typical Gangetian fauna and *S. kummeli* is not yet present. According to its conodont fauna (Krystyn & Orchard), this horizon should belong to the Gangetian, also in the interest of the correlation with the Boreal fauna.

The base of the Olenekian is well defined by the base of the *Flemingites flemingianus* ammonoid Zone. In this level the ancestor form of *Paragondolella* Mosher begins with *Chengyuania nepalenis* (Kozur & Mostler) in pelagic deposits, a little later is the FAD of *Neospathodus waageni*. In shallow water deposits the characteristic *Pachycladina* begins in this level and *Claraia* disappeared. This boundary can be well correlated with continental deposits by conchostracans which occur in brackish intercalations of marine beds, e.g. in the Werfen Beds of Hungary and in marine sections with ammonoids in northeastern Siberia. At the base of then Olenekian, the characteristic *Cornia germari* fauna (spined conchostracans) with *Estheriella* (radially ribbed conchostracans) disappeared and the *Magniestheria subcircularis*-*M. truempyi* fauna begins. *M. truempyi* was found in Madagascar at the base of the Olenekian between *Claraia*-bearing beds below and the *F. flemingianus* beds above. As in the entire Brahmanian of the Germanic Basin the Milankovitch cycles are well recognisable and no distinct gaps are present in the basin facies of the Germanic Basin, the duration of the Brahmanian can be well fixed (see below).

Remarks to the numerical age of the Lower Triassic stages

Radiometric data are only present around the PTB and from the base of the Anisian. As pointed out above, a duration of 5.6 myrs is assumed for the Lower Triassic. the numeric age of the Lower Triassic stages can be only estimated by investigation of the Milankovitch cycles. As they can be much better recognised in continental beds, the astronomic calibration was carried out in the continental sequence of the Germanic Basin. The correlation of the continental beds in the Germanic Basin with the marine scale was mainly carried out by conchostracans (e.g., Kozur, 1993, 1999, Kozur & Mock, 1993). During the Brahmanian, the conchostracan zonation is as detailed as the ammonoid- and conodont zonations in pelagic marine deposits (Kozur & Seidel, 1983). The Brahmanian-Olenekian boundary marks the most pronounced faunal turnover in the conchostracan faunas. The biostratigraphic control for the Milankovitch cycles in the Germanic Basin is very good.

Szurlies (2001) subdivided the Calvörde Formation, the lowermost formation of the Germanic Buntsandstein, into 10 cycles, interpreted as ~100 kyrs Milankovitch eccentricity cycles. However, his cycle 4 comprises two ~100 kyrs cycles, which means 11 Milankovitch eccentricity cycles are present in the Calvörde Fm. The biostratigraphic PTB at Oolite Alpha 2 lies within the lowermost part of cycle 2, only one precession cycle above its base, leaving about 10 cycles (approximately 1 myrs) for the Brahmanian part of the Calvörde Fm. The overlying Bernburg Fm. comprises up to 11 eccentricity cycles in the basin centre (borehole Halle-Süd, Solling Mts., in the latter area found by studies of Kozur and Lepper, in prep.). Cycle 11 corresponds to the well dated Lower Olenekian *Magniestheria truempyi* and the lowermost part of the *M. quellaensis-L- radzinskii* conchostracan zones. This number is between the view of Szurlies (2001), who recognised maximally 10 cycles (but had not investigated any section with the two youngest conchostracan zones of the Bernburg Fm.), and that of Röhling (1993), who discriminated maximally 14 cycles in the basin centre (including Solling Mts.) which are apparently not all eccentricity cycles. The youngest Brahmanian faunas occur in cycle 9, resulting in 1.0 + 0.9 = 1.9 myrs for the total Brahmanian. By this the base of the Olenekian is estimated with 250.7 Ma.

The base of the Olenekian (base of the *M.* ? *subcircularis* Zone) is close to the base of cycle 10, and is marked by the most prominent change within the Lower Triassic conchostracan faunas (Kozur & Seidel, 1983). Thus, the two upper cycles of the Bernburg Fm. belong to the Lower Olenekian (Smithian). The overlying Volpriehausen Formation has a typical Smithian conchostracan fauna which is well correlated with the marine scale (Kozur & Mock, 1993). As in the uppermost Volpriehausen Fm. the first Upper Olenekian (Spathian) element (*M. deverta*) appears in the conchostracan fauna, and the upper part of the first cycle in the overlying Detfurth Fm. has already a rich Spathian conchostracan fauna, the top of the Smithian can be assigned to the top of the Volpriehausen Fm. It consists of up to 14 cycles (about 1.4 myrs). Thus, 1.6 myrs of the Smithian are represented by sediments in the Germanic Basin. However, there is a short gap between the Bernburg and Volpriehausen Formations. The gap had a short duration as no faunal change can be observed between the topmost Bernburg Fm. and the Volpriehausen Sandstone. Both belong to the *M. quellaensis-L. radzinskii* Zone. Thus, the gap is much shorter than one conchostracan zone which have an average duration of about 400 kyrs during the Brahmanian-Smithian interval. Thus, we assign approximately 200 kyrs for the gap between the Bernburg and Volpriehausen Formations (including the local Quickborn Sandstone which partly filled the gap in the centre of the Germanic Basin). Thus, we get a total duration of the Smithian of 1.6 + 0.2 = 1.8 myrs. From this results a numeric age of 248.9 Ma for the base of the Upper Olenekian (Spathian).

In the Upper Olenekian (Spathian) of the Germanic Basin there are several gaps, which currently prevent a time estimation based on Milankovitch cycles. However, it can be concluded from marine sections that the Spathian has a similar duration as the Smithian or it is a little longer. This is in good agreement with the above mentioned estimation of 248.9 Ma for the base of the Spathian which gives a duration of 1.9 myrs for the Spathian using the 247 Ma for the base of the Anisian.

MIDDLE TRIASSIC – THE PROBLEM OF THE ANISIAN-LADINIAN BOUNDARY

As shown in the Veszprém conference 2002, there is a good agreement between most ammonoid workers and all conodont workers to place the base of the Anisian at the base of the *Chiosella timorensis* Zone. *C. timorensis* (Nogami) has evolved in a phylomorphogenetic cline from *C. gondolelloides* (Bender). This cline can be traced in all pelagic deposits of the Tethys, the Circum-Pacific realm and North America. At this boundary distinct changes can be observed also in other fossil groups, e.g. holothurian sclerites which allow correlation into slightly hypersaline deposits, such as in the Germanic Basin. 247 Ma were reported for the base of the Anisian (Lehrmann et al., 2002).

An open question is the Anisian-Ladinian boundary, the problem has to be solved by agreement. From the *P. trinodosus* Zone up to the lower *E. curionii* Zone the conodonts are in a phase of slow phylomorphogenetic changes which does not allow a very detailed stratigraphic subdivision by conodonts of this level. Moreover, some of the stratigraphically important forms have an occurrence restricted to Tethys or Tethys and western Panthalassa, and do not occur in North America and by this beside the relatively low stratigraphic value of conodonts for this stratigraphic interval also correlation problems with conodonts are present. Only ammonoids and radiolarians of the Anisian-Ladinian boundary level can be well used for a high –resolution biostratigraphy. For ammonoids, this is also the case for many other stratigraphic levels within the Triassic. Radiolarians have in the upper Anisian-Ladinian interval their strongest stratigraphic resolution power in the entire Mesozoic. The reason for this is the recovery pattern after the Permian-Triassic biotic crisis. Radiolarians belong to the strongest affected fossil groups. They almost disappeared at the PTB and only very few radiolarians are present from the uppermost Dorashamian *C. meishanensis-H. praeparvus* Zone until the top of the Smithian. During this time even a world-wide radiolarite gap is present, an unique feature since the Ordovician. For unknown reasons, the recovery of the radiolarians began very late, contemporaneous with the beginning of the recovery of the warm water benthos and of the land plant communities, whereas nekton and nektobenthonic aminals, like ammonoids and conodonts recovered fast, after the short *H. parvus* conodont Zone (after about 100kyrs). The recovery of the radiolarians began at the base of the Late Olenekian (base of the Spathian), but the diversity remained low. However, in Panthalassa the first radiolarites re-appeared in the Spathian. The radiolarian diversity remained low during the lower Anisian and be-

My	Series	Stage	Substage	Ammonoid Zone	Ammonoid Subzone	Conodont Zone	Conodont Zone (Nicoraella)	Radiolarian Zone	Radiolarian Subzone
	UPPER TRIASSIC ?	CARNIAN ?	Julian ?	Trachyceras aonoides		Gladigondolella tethydis-?		Tetraporobrachia haeckeli ?	
			Cordevolian	Trachyceras aon		Paragondolella polygnathiformis I.Z.		unnamed radiolarian zone	
237				Daxatina canadiensis-Frankites sutherlandi		Budurovignathus diebeli-Paragondolella polygnathiformis		Tritortis kretaensis	
	MIDDLE TRIASSIC	LADINIAN	Longobardian	Frankites regoledanus		Budurovignathus supralongobardica		M. cochleata	T. kretaensis dispiralis
238				Protrachyceras archelaus		Budurovignathus mungoensis			Spongoserrula fluegeli
237.9									Spongoserrula rarauana
									Pterospongus priscus
238.8				Protrachyceras gredleri		Budurovignathus hungaricus		Muelleritortis firma	
			Fassanian	Eoprotrachyceras curionii	E. recubariense	Budurovignathus truempyi		unnamed radiolarian fauna	
239.5					E. curionii	Paragondolella ? trammeri-Neogondolella aequidentata		Ladinocampe multiperforata	Ladinocampe vicentinensis
			Ladinian base (base of the reitzi or of the curionii zones) not decided by the ISTS	Nevadites secedensis					
241.2				Reitziites reitzi	Aplococeras avisianum	Paragondolella ? trammeri trammeri-Paragondolella alpina			Ladinocampe annuloperforata
								Spongosilicar. italicus	O. inaequispinosus
240.4 240.5 241					Reitziites reitzi	Paragondolella alpina – Paragondolella trammeri praetrammeri			Oertlispongus primitivus
241.1		ANISIAN	Illyrian	Kellnerites felsoeoersensis	K. felsoeoersensis	Neogondolella mesotriassica		Spongosilicar. transitus	Yeharaia annulata
					L. pseudohungaricum				Tiborella florida
				Paraceratites trinodosus	Asseretoc. camunum	Neogondolella constricta		Tetraspinocyrtis laevis	
					Semiornites aviticus				
					Schreyerites abichi	Paragondolella bifurcata		no dated radiolarians	
			Pelsonian	Schreyerites binodosus			Nicoraella germanica-Nicoraella kockeli	Parasepsagon robustus	
				Balatonites balatonicus	B. balatonicus			Baratuna cristianensis	
					B. shoshonensis	N. shoshonensis			
				Nevadisculites taylori		Paragondolella bulgarica		Paroertlispongus diacanthus	
			Bithynian	Agdharbandites ismidicus			Nicoraella germanica		
				Nicomedites osmani					
				Lenotropites caurus				Hozmadia gifuensis	
				Silberlingites muelleri					
			Aegean	Pseudokeyserlingites guexi		Neogondolella ? regalis		Stigmosphaerostylus ? phattalungensis	
247				Japonites welteri		Chiosella timorensis			

Figure 2: Middle Triassic stages, substages, ammonoid, conodont and radiolarian zonations

came distinctly higher during the Pelsonian. In the Illyrian an explosive radiation of radiolarian taxa began. In the same time, radiolarites became again widespread throughout the world. This explosive radiation of radiolarians continued from the *P. trinodosus* Zone to the *A. avisianum* Zone. The radiation of radiolarian taxa became much slower during the *N. secedensis* Zone and was very low in the *E. curionii* Zone. A second phase of rapid radiation occurred throughout the Longobardian and, to a somewhat lower rate, in the Cordevolian. During the two phases of explosive radiation very much, partly very short-living radiolarians appeared and also the extinction rate was rather high. Thus, a very detailed biostratigraphic subdivision can be made with radiolarians, as detailed as with ammonoids and much more detailed than with conodonts of this stratigraphic level. By this and the fact that in the Middle Triassic radiolarites are very widely distributed in the Tethys and in Panthalassa, in which ammonoids will be never found and conodonts occur only sporadically, the upper Anisian and Ladinian radiolarians have an outstanding stratigraphic importance. For priority and traditional reasons, the upper Anisian and Ladinian stratigraphic units, among them the Anisian-Ladinian boundary should be defined by ammonoids, but the radiolarians should be taken into consideration very seriously. For this reason, ammonoids and radiolarians should be common in a GSSP candidate for the base of the Ladinian.

Presently two levels for the boundary are discussed, the base of the *Reitziites reitzi* Zone s.s. (FAD of *R. reitzi*) and the base of the *Eoptrotrachyceras curionii* Zone. Brack et al. (2003) summarized the advantages for using the FAD of base of the *E. curionii* Zone in the Bagolino composite section (Southern Alps, Northern Italy) as GSSP for the base of the Ladinian and Vörös et al. (2003) did the same for using the FAD of *R. reitzi* (base of the *R. reitzi* Zone s.s.) in the Felsöörs section (Balaton Highland, Hungary) as the base of the Ladinian. Both sections have advantages and some disadvantages of different degree. The advantage of the Bagolino section is that throughout the section rich ammonoid faunas and moderately rich conodont faunas are present. The conodonts are not especially well suitable for definition and correlation of the Anisian-Ladinian boundary level, but the ammonoids are most important. The FAD of *Eoprotrachyceras curionii* is said by all ammonoid workers as a marker which can be traced throughout the Tethys and low latitude ammonoid faunas of western North America in contrast to the FAD of *Reitziites reitzi* which has a much more restricted occurrence. However, this is not correct. *R. reitzi* occurs from the western Tethys until Japan. *E. curionii* is only known from the western Tethys, especially from the Southern Alps, and it was not yet reported east of Greece. For good reasons, stages are defined in GSSP with the FAD of a species which is requested to have a wide regional distribution. This is not the case for *E. curionii*. In North America two other species occur, *E. subasperum* in Nevada and *E. matutinum* in British Columbia (Tozer, 1994). It is not very probable that all these three species begin exactly in the same level, at least, it cannot be proven. Neither conodonts nor radiolarians show any change at the FAD of *E. curionii*. Thus, really, *E. curionii* is a very restricted species, much more restricted than *R. reitzi*.

The disadvantages of Bagolino and the *E. curionii* datum are that no radiolarians are present and that the section is thermally altered. No direct ammonoid-radiolarian correlation can be carried out in the Bagolino section, a serious disadvantage, if we regard the above mentioned importance of radiolarians in this stratigraphic level (see above). The thermal alteration (CAI = 4-5) prevent any reliable magnetostratigraphic investigation in this section. Moreover, also stable isotope investigations are not so easy to carry out in thermally altered sections and there is a danger that the data may be not reliable. Thus, the physico-chemical stratigraphic investigations can be either not carried out (mangetostratigraphy) in the Bagolino section or they must be regarded with reserve (stable isotope investigations). Thermally altered sections should not be chosen as GSSP, if alternative, unaltered sections are present. Physico-chemical stratigraphic data in combination with biostratigraphic data will be more and more important in future investigations and it is therefore not good to choice a GSSP with thermally altered beds in which also in future such investigations can partly not carried out, partly cannot be carried out under optimal conditions. In this connection a discussion in Veszprém was made that the high thermal alteration of the Bagolino section is not a serious disadvantage because a good correlation with unaltered sections can be made, where palaeomagnetic investigations can be carried out. This is not an appropriate discussion of the advantages and disadvantages of a GSSP candidate. By this kind of argumentation any section can be elevated in the rank of a very suitable GSSP without disadvantages. For instance, the disadvantage of the Felsöörs section that only very few conodonts are present around the FAD of *R. reitzi* would be no longer a disadvantage because the FAD of *R. reitzi* can be well correlated with sections in the Southern Alps which contain moderately common conodonts in this level. The above discussion is the more inappropriate as there is an other discussion that the palaeomagnetic data of FelsQörs cannot be used because they were made only from limestone intercalations in tuffs (see below). In the end, this lead to a picture that Bagolino (in which palaeomagnetic investigations cannot be carried out because of thermal alteration) is better suitable for palaeomagnetic correlations (through other sections) than Felsöörs (where such investigations can be carried out, CAI = 1).

A more formal disadvantage of the proposal to use the FAD of *E. curionii* as base of the Ladinian is that the Fassanian would be a very short substage, comprising only one ammonoid zone or two zones, if the gredleri Zone is put into the Fassanian and not into the Longobardian. This is too few for a substage (about 1 m.y.). In the same time, the Illyrian would be very much expanded. This would mean a reduction of the Fassanian used since more 100 years by more 50 %. This is not a refining or slight modification but a very strong change in the traditional scope of the Fassanian. Directly connected with the strong reduction of the traditional Fassanian by using the FAD of *E. curionii* for definition the base of the Ladinian is the fact that this boundary lies high above the appearance of the typical Ladinian *Diplopora annulata* dasycladacean association. Very thick Middle Triassic carbonate platforms with dasycladcean algae are widespread in the Tethys and among them, the Ladinian association with *D. annulata* is well distinguished from the Anisian association with *Oligoporella*, *Physoporella* and *D. annulatissima*. The beginning of the *D. annulatissima* association is well dated by ammonoids in the Germanic basin (Kozur, 1974). The *D. annulatissma* association begins at the base of the Middle Muschelkalk and ranges through much of the Middle Muschelkalk which contains also in its upper part Anisian dasycladaceans (Kozur, 1974). Immediately below an ammonoid fauna from the basal Illyrian is present and also *Neogondolella bifurcata* begins, whereas *N. bulgarica* and *Nicoraella kockeli* disappear. The FAD of the *D. annulata* association is not so well dated, but lies in all cases far below the FAD of *E. curionii*. By this the typical Ladinian *D. annulata* association would be to an Anisian–Ladinian association. According to Bystrický (1964 and later papers), the *D. annulata* association begins in the *R. reitzi* Zone, but it is not clear, whether at its base or inside this zone. A similar problem exits with the sporomorphs. The Ladinian *vicentinense-scheuringi* phase (Brugman, 1986) begins close to the base of the *Kellnerites felsoeoersensis* Zone. From all discussed base of the Ladinian, the FAD of *R. reitzi* is closest to and the FAD of *E. curionii* most distant from this event.

On the other side, the conodont ranges in the Bagolino section can be somewhat improved by own investigations. Brack et al. (2003) discriminate only the *P. alpina* group. The species *P. alpina* (Kozur & Mostler) has in our material its FAD in the same bed in which *R. reitzi* begins. This species is also present in North America (Orchard, pers. comm. Veszprém Meeting 2002), where it occurs in the upper Rotelliformis and Meeki Zones, and has therefore a good correlation potential. It is not correct that only *N. praehungarica* (Kovács), which begins in the upper *N. secedensis* Zone has a correlation potential between the Tethys and North America as pointed out by Brack et al.. (2003). *P. alpina* has the same correlation potential. The same is true for *N. aldae* which is very common in North America, where it begins in the upper Meeki Zone. It is common in the more open sea development in the Tethys, but unfortunately not present in Bagolino. The FAD of this latter species in the Tethys is not yet well dated. It lies between the base of the *R. reitzi* Zone and the base of the *E. curionii* Zone, most probably in the upper *A. avisianum* Zone and does therefore not support either of the two discussed Anisian-Ladinian boundaries. Under *P.* aff. *eotrammeri* (Krystyn) several taxa were united by Brack et al. (2003), among them *P. trammeri praetrammeri* which begins in Bagolino immediately above the FAD of *R. reitzi*. The FAD of this species is important for the Tethys, but not for the open sea development.

The base of the *Reitzi* Zone with the FAD of *R. reitzi* in the Felsöörs section in Hungary was used as proposal for the base of the Ladinian (*Reitzi* Zone sensu Kozur, 1995a, b, corresponding to the original *Reitzi* Zone) by Vörös et al. (2003). *Trinodosus* Zone, *Felsoeoersensis* Zone, *Reitzi* Zone and *Avisianum* Zone occur in a continuous succession with good ammonoid control. Above this level ammonoids are rare. Conodonts are very common in the Pelsonian, rare in the *Trinodosus* Zone and very rare in the *Felsoeoersensis* and *Reitzi* Zones. From the *Avisianum* Zone onward, conodonts are moderately common in about the same amount as in the Bagolino section. The advantage of this section is good ammonoid control, the very good radiolarian control and the absence of thermal alteration which allows both palaeomagnetic and stable isotope studies (Vörös et al., 2003, Korte, 1999). Radiolarians are common and well preserved from the *Trinodosus* Zone up to the *Avisianum* Zone and occur both in the limestones and in tuffs. Above this level well preserved radiolarians can be extracted only from the common chert nodules. Also deep water ostracods are common. A further advantage is the very low thermal alteration (CAI = 1) which allows both palaeomagnetic and stable isotope investigations.

Ammonoids. conodonts, radiolarians, ostracods, and stable isotopes are well studied in this section. In Márton et al. (1997) not all limestone beds were palaeomagnetically investigated, but in Vörös et al. (2003) data from all limestone beds were present. As indicated by radiolarians, the tuffs were deposited very rapidly and the time is in the limestone beds. Only at the base or within the limestone beds changes in radiolarian faunas can be observed, whereas the tuffs have the same radiolarian fauna as the underlying limestone bed. Therefore the investigation of all limestone beds gives a very dense palaeomagnetic control. The beds in the critical interval have largely normal polarity. Only in the upper *Felsoeoersensis* Zone and in the lower *Avisianum* Zone a short reversed interval is present. Thus, also the palaemagnetic investigations are in a good stage in thje FelsQörs section.

The FAD of *R. reitzi* has a good correlation potential because exactly in the same level the first primitive *Oertlispongus*, *O. primitivus* appears and with this species also the genus *Oertlispongus*, one of the most prominent Ladinian genera and the basic form of numerous Fassanian and Longobardian advanced Oertlispongidae. In the immediately underlying beds, as in the entire *Felsoeoersensis* Zone the immediate forerunner of *Oertlispongus primitivus* are present within the genus *Pseudoertlispongus* which were erroneously put into the genus *Oertlispongus* by Dosztály (1993) and therefore the *Oertlispongus inaequispinosus* Zone was shown in Hungarian publications (e.g. Márton et al., 1997) in a wrong place. *Oertlispongus inaequispinosus* is a more advanced form than *O. primitivus* and has its FAD only in the *Avisianum* Zone. At the base of the *Reitzi* Zone (contemporaneous with the FAD of *R. reitzi*) a strong faunal turnover in the radiolarian faunas occurred (Kozur 1995a). Numerous Illyrian guideforms disappeared and numerous Ladinian forms appeared which partly ranges up to the upper Fassanian or Longobardian. This faunal turnover is not local or facies-controlled because it can be also found within radiolarite sequences throughout the Tethys, and in Panthalassa (Japan, Philippines). It can be also correlated with high latitude radiolarian faunas from the Omolon Massif (NE Siberia) and New Zealand (Kozur, 1995 a).

The FAD of *R. reitzi* has also a high potential for correlation with continental beds by the base of the *Dijkstraisporites beutleri* Zone, a megaspore Zone which is present both in the marginal marine and continental beds of the Germanic Basin and in the Pricaspian depression where it characterises the entire Ladinian. The FAD of *D. beutleri* can be well correlated with the base of the *Ceratites compressus* ammonoid zone, but the correlation with the Tethys is not quite clear. *Chirodella tiquetra* begins in the Germanic Basin a little below the FAD of *Dijkstraisporites beutleri* and *C. compressus*, *Neohindeodella triassica aquidentata* begins in the *C. compressus* Zone. In the Felsöörs section both species begin in the *Avisianum* Zone of the Felsöörs section. Unfortunately, the *Reitzi* Zone of the Felsöörs section is very poor in conodonts and therefore it cannot be excluded, that these species begin in the Tethys already during the *Reitzi* Zone. In older deposits they are not yet present. Characteristic miospores of the *Reitzi*- and *Avisianum* Zone are *Kuglerina* meieri, *Cananoropollis scheuringi* and *C. brugmani* (Góczán & Oravecz-Scheffer, 1993). They are typical Ladinian sporomorphs which ranges through much of the Ladinian. Their first appearance, however, is close to the base of the *Felsoeoersensis* Zone, that means earlier than the base of the *Reitzi* Zone. Nevertheless, from all levels for the base of the Ladinian, the FAD of *R. reitzi* is closest to this sporomorph event. In the same level some typical Illyrian foraminifers disappeared, like *Meandrospira dinarica* and several Ladinian forms appear, like *Oberhauserella ladinica, Pseudonodosaria loczyi* and "*Pilaminella*" *gemerica* appeared, but this event may be facies-controlled. Nevertheless, some of these foraminifers occur also in the shallow-water platform carbonates. Also this foraminifer event is somewhat older than the *Reitzi* Zone, but again the FAD of *R. reitzi* is closest to this event among the candidates for the base of the Ladinian..

The disadvantage of the *R. reitzi* boundary is that the index species can be only recognised in the Tethys and in Japan, but not in North America. However, as discussed above, *R. reitzi* is much wider distributed than *E. curionii*. A further disadvantage is that conodonts are very rare in the *Reitzi* Zone. However, conodonts are of subordinate importance for the definition of the Anisian-Ladinian boundary because only gradual changes within smooth *Neogondolella* and *Paragondolella* occur, which are difficult to determine even for conodont specialists.

As a whole, the correlation potential for the *R. reitzi* boundary is much higher than that of the *E. curionii* boundary, if we regard all faunal and floral element. A correlation with the high latitude fauna is possible by radiolarians (Kozur, 1995b) and the FAD of *R. reitzi* is close to a distinct changes in palynomorphs (both megaspores, base of the *D. beutleri* Zone and miospores, base of the *Cannanoropollis scheuringi* association).

In the St. Christina Meeting September 2003 a vote will be made in the Anisian-Ladinian Boundary Working Group between the FAD of *R. reitzi* and the FAD of *E. curionii* for definition of the base of Ladinian. If both proposals will not get 60 % of the votes as in former votings, a compromise proposal should be chosen. The former proposal of the base of the *N. secedensis* Zone is unsuitable because at this boundary no change can be observed in conodonts and radiolarians and therefore the correlation potential is very low. The former view of Krystyn (1983) that this boundary is characterised by a distinct change in conodonts is caused by strong condension in the Epidaurus section, where at least the *Avisianum* Zones is condensed into the *Nevadites* fauna. The base of the *N. secedensis* Zone has the lowest correlation potential from all proposed Ladinian boundaries and, therefore it cannot be used as a compromise boundary.

An other compromise boundary would be the base of the *A. avisianum* Zone. This level was used for many years by Kozur (e.g. 1972, 1974, 1975, 1980) and correlated with the base of the *N. pseudolonga* Zone. This boundary was permanently critisized mainly by ammonoid workers and seems, therefore, from the view of the ammonoid workers not a very good boundary. According to Assereto (1969) *Aplococeras vogdesi* is a junior synonym of *A. avisianum*. If this view would be correct, *A. avisianum* would be the only stratigraphically important species which is present in both Tethys and in North America. However, this view is not accepted by all ammonoid workers and the similarity of the two species may be only caused by the scarcity of taxonomic characters in the genus *Aplococeras*. An other disadvantage of *A. avisianum* is that this species is very rare or absent in distal basinal facies, like in Felsöörs, where the presence of the *Avisianum* Zone is indicated by the *Latemarites* fauna. In terms of conodonts this boundary is not well correlatable but as pointed out earlier, conodonts are not important for definition of the Anisian-Ladinian boundary, as the real big change in conodont fauna, the FAD of *Budurovignathus truempyi*, is only in the middle part of the *E. curionii* Zone. The FAD of *P. trammeri* in the *Avisianum* Zone is a rather facies controlled event as the very similar *P. trammeri praetrammeri* is already present in the lower *Reitzi* Zone and the difference between the two subspecies is not distinct. With *N. pseudolonga*, a Ladinian type of *Neogondolella* with slightly forward shifted basal cavity and upturned posterior lower margin appears in the *Avisianum* Zone. Also *N. transita* begins in this level or slightly higher, but many different *Neogondolella* species have been assigned to *N. transita* and its junior synonym *N. excentrica*. As the FAD of *N. pseudolonga* shows an important step in conodont evolution, Kozur (1980) discriminated the *N. pseudolonga* Zone with a base around the base of the *Avisianum* Zone, but *N. pseudolonga* is often so rare that it is not a good index fossil. it was not reported from North America. An important conodont species for correlation is *N. aldae* which has its FAD in the upper Meeki Zone in North America, but it is not known, where exactly it begins within the *Avisianum* Zone (rather only in its upper part). In intra shelf basins such as Bagolino, this species was not yet found. The changes in the radiolarian fauna at the base of the *Avisianum* Zone is not so pronounced as at the base of the *Reitzi* Zone because no turnover in the fauna occurs and most of the typical Ladinian genera begin already at the base of the *Reitzi* Zone. However, the base of the *Avisianum* Zone is recognisable by radiolarians. In the *Avisianum* Zone of FelsQörs is the FAD of *Oertlispongus inaequispinosus*, an advanced *Oertlispongus* with wide distribution in the Tethys and western Panthalassa. Also some other species appear in this level and a little higher is the FAD of *Ladinocampe*. A rough correlation is also possible with *Daonella elongata* which occurs in the middle *Meeki* Zone of North America. As the FAD of *A. avisianum* is not much higher than the FAD of *R. reitzi*, the base of the *Avisianum* Zone is close to the priority base of the Ladinian. Many authors regard the *Avisianum* Zone even as a Subzone of the *Reitzi* Zone. The FAD of *A. avisianum* is therefore close to the above discussed sporomorph boundary, not as close as the FAD of *R. reitzi*, but not too much apart. The same is true for the beginning of the Ladinian *D. annulata* dasycladacean association. A little above the base of the *Avisianum* Zone in the FelsQörs section a short reversed interval is present within the normal Zone. If this short reversed interval can be also found in other sections it would be a good correlation marker. Summarizing it can be stated that the correlation potential of the *Avisianum* Zone is not as good as that of the *Reitzi* Zone, but correlation in different facies is possible. As a "political" compromise, it would be acceptable, if no other (better) compromise boundary will be found.

Numerical age of the Middle Triassic

As mentionerd aboce, the basem of the Anisian was dated with 247 Ma (Lehrmann et al., 2002). Numerous reliable radiometric data are known from the upper Anisian to Ladinian interval measured in the Southern Alps by Mundil et al. (1996, 2003) and Brack et al. (1996, 2003) and in the FelsQoörs section by Pálfy et al. (2003). The oldest data are from the lower and upper *Felsoeoersensis* Zone with 241.1 ± 0.5 Ma and 241.2 ± 0.4 Ma indicating a very short duration of this zone what is also indicated by radiolarians which are almost unchanged throughout the *Felsoeoersensis* Zone. The lowermost *Reitzi* Zone yielded a value of 240.5 ± 0.5 Ma, the upper *Reitzi* Zone a value of 240.4 ± 0.5 Ma. Somewhat higher values were measured by Mundil et al. (1996, 2003) in the Southern Alps for the *Avisianum* Zone (*Latemarites* fauna) of the Latemar platform (242.6 ± 0.7 Ma) and of 241.2 +0.8/-0.6 Ma for the base of the *Secedensis* Zone. For the *Gredleri* Zone they reported 238.8+0.5/-0.2 Ma. In this level Pálfy et al. got a very similar value (238.7 ± 0.6 Ma) for the boundary *Gredleri*/*Archelaus* Zones. Both set look reliable, but the South Alpine set is about 1-2 myrs older for the *Avisianum*-*Secedensis* level. It is difficult to decide, which set is right. Taking into consideration the 247 Ma for the base of the Anisian, an age around 241 Ma for the base of the *Reitzi* Zone is more probable than an age around 242-243 Ma, which would result from the South Alpine set. Values around 238 Ma for the *archelaus* Zone (Mundil et al., 1996, 2003) speak for the base of the Carnian around 237 Ma.

UPPER TRIASSIC STAGES

The Carnian was long time defined by the FAD of *Trachyceras* and suvbdivided into 3 substages, the Cordevolian, Julian and Tuvalian (Mojsisovics et al., 1895). Later the Cordevolian and Julian was partly united to the Julian s.l. (Krystyn, 1980). This was not a good decision both for questions of priority and common use and from the faunistic viewpoint. the Cordevolian contain in all fossil groups a mixture of Carnian forms with genera and partly species which range up from the Ladinian. In the Julian the Ladinian types are no longer present. In ammonoid faunas *Trachyceras* and *Daxatina* occur together with *Frankites*, in conodont faunas *Paragondolella polygnathiformis*, a very characteristic guideform of the entire Carnian occurs together with the Ladinian genus *Budurovignathus* and in the Neotethys with advanced Pseudofurnishius which also ranges up from the Ladinian, in pelagic bivales the genus *Haloibia* is present and occurs together with *Daonella* which ranges up from the Middle Triassic, in radiolarians the first Upper Triassic and younger Saturnalidae are present together with the last Oertlispongidae which dominate the Ladinian, and similar Carnian-Ladinian mixed faunas are present at holothurian sclerites and ostracods. These mixed faunas have often lead to wrong assignment of ammonoid faunas. Thus, the *Frankites sutherlandi* Zone was generally assigned to the Ladinian because it did not contain *Trachyceras*, but Kozur (1976) assigned it to the Carnian assuming that its upper part (*Daxatina* fauna) is a time-equivalent of the (lower) Cordevolian *Trachyceras* faunas. He pointed out that *Trachyceras* has a diachronous FAD, related to the palaeolatitude, and is therefore not suitable to define the base of Carnian.

Broglio Loriga et al. (1999) proposed to use then FAD of *Daxatina canadiensis* in the locality Prati di Stuores Wiesen Section (Dolomites, Italy) as base of the Carnian. They have shown a clear overlap of *Frankites* and *Trachyceras* as assumed by Kozur (1976). This boundary is close to that proposed by Kozur (1976) and is here accepted. However, studies in more pelagic sections must show, where begin the typical Carnian faunal elements, like *P. polygnathiformis* and *Halobia*. They seem to begin within the *F. regoledanus* Zone, which is here assigned to the uppermost Ladinian, but there is a clear overlap of *Frankites apertus*, generally regarded as guide form of the *F. regoledanus* Zone, *Daxatina* and *Trachyceras* (Broglio Loriga et al, 1999).

The FAD of *Daxatina canadiensis* as base of the Carnian has a good potential for correlation with the continental facies. *Patinasporites densus* and *Vallasporites ignacii* begin a little above the FAD of *Daxatina* cf. *canadiensis* in the Prati di Stuores section. In the Germanic Basin, *V. ignacii* begins somewhat below the base of the "*Estheria* Beds" of the upper Grabfeld Formation, whereas *P. densus* begins in the upper "*Estheria* Beds". At the base of the "*Estheria* Beds" the conchostracan *Laxitextella multireticulata* begins which occurs according to Kozur & Mock (1993) and Kozur (1999) in the "Kalkschieferzone" of the uppermost Meride Limestone, indicating a level around the base of the Carnian.

Rather problematic is the Carnian-Norian boundary because around this boundary the metapolygnathid conodonts split into two main lineages, a North American and a Tethyan-western Panthalassa lineage. Faunal invasions of North American forms occur in the Tethys, e.g. *Metapolygnathus communisti* which always begins with advanced forms in the Tethys, without transitional forms to its forerunner *P. polygnathiformis noah*. Such transition forms are illustrated from the *Communisti* Zone of North America (Orchard, 1991a). This zone seemingly does not contain real *M. communisti* with strongly forward-shifted basal cavity (both with respect to the platform and to the end of the keel; the pit in *M. communisti* is situated in or before the middle of the platform). Especially characteristic are the juvenile forms of *M. communisti* which have the pit at the anterior platform margin. This is unusual because all other juvenile metapolygnathids have the pit in more posterior position than in adults. Perhaps these juvenile forms are in reality an independent species (*M. parvus*). Real *M. communisti* are illustrated from North American material only from the *E. primitia* Zone together with advanced (real) *E.*

My		Stage/Substage		Ammonoid Zone/Subzone Standard		Conodont Zone/Subzone Tethys/Western Pacific		Conodont Zone/Subzone North America	
199.6	UPPER TRIASSIC	Rhaetian	Upper Rhaetian	Chor. marshi	Choristoceras marshi	Misikella ultima		Norigondolella sp.	
					Chor. ammonitiforme	Misikella posthernsteini	Misikella koessenensis	Misik. posthernsteini	
			Lower Rhaetian	"Ch." haueri	Vandaites stuerzenbaumi			Orchardella mosheri	
					"Choristoceras" haueri		Misikella hernsteini-Misikella posthernsteini		
205 ?				Cochloceras suessi					
207 ?		Norian	Sevatian	Sagenites reticulatus		M. hernsteini-P. andrusovi		Mockina bidentata	
				Sagenites quinquepunctatus		Mockina bidentata	Subzone 2		
				Halorites macer			Subzone 1		
211								Orchardella serrulata	
			Alaunian	Mesohimavatites columbianus		Mockina postera		Mockina postera	
								Orchardella elongata	
						Orchardella ? spiculata		Orchardella ? spiculata	
				Cyrtopleurites bicrenatus		M. medionorica		Orchardella multidentata	
216			Early Norian	Juvavites magnus		Epigondolella triangularis-Norigondolella hallstattensis		Epigondolella triangularis	
				Malayites paulckei		Epigondolella quadrata		Epigondolella quadrata	
225				Stikinoceras kerri		E. ? primitia-M. communisti		Epigondolella ? primitia s.l.	
226		Carnian	Tuvalian	Klamathites macrolobatus		Epigondolella pseudodiebeli		Metapolyg. "communisti"	
				Tropites welleri		Epigondolella nodosa		Epigondolella nodosa	upper
									middle
						Paragondolella carpathica	upper		lower
							lower		
				Tropites dilleri		P. postinclinata-P. polygnathifor.		Paragondolella polygnathiformis	
231			Julian	Austrotrachyceras austriacum		Gladigondolella tethydis-Paragondolella polygnathiformis			
				Trachyceras aonoides					
			Cordevolian	Trachyceras aon		Budurovignathus diebeli-Paragondolella polygnathiformis			
				D. canadiensis-F. sutherlandi					

Figure 3:Upper Triassic stages, substages, ammonoid zonation, Tethyan and North American conodont zonations

primita (Carter & Orchard, 2000). Thus, seemingly the *M. communisti* Zone of North America has only the forerunners of *M. communisti*, a new species in the transitional field between *Paragondolella* and *Metapolygnathus* (illustrated "*M. communisti*" in Orchard, 1991a). As real *M. communisti* occurs only in the *E.* ? *primitia* Zone or insignificantly earlier, the North American *Communisti* Zone has to be abandoned. This range is also confirmed by the range of *M. communisti* in Europe. In the northern Tethys it occurs in a very short interval, which begins a little before the FAD of *Norigondolella navicula* and ends just before the *E. quadrata* Zone (Krystyn, 1980 and own data) and co-occurs with rare *E.* ? *primitia*. As *E.* ? *primitia* has to be restricted to the advanced forms in the former scope of this species and true *M. communisti* and advanced *E.* ? *primitia* occur together in North America (Carter & Orchard, 2000), the *M. communisti* Zone and the *E.* ? *primitia* Zone fall largely together. In the Neotethys *M. communisti* is more common than in the northern Tethys (Muttoni et al., 2001, own data from a section NE of Pietra di Salomone in the Sosio Valley, Sicily). It occurs together with common *E. primitia* s.s. (see below), and in the upper range also a few *E. quadrata* occur. One form illustrated by Muttoni et al. (2001, Fig. 10, 4a) under *M. communisti* looks like transition form between *M. communisti* and *E.* ? *primitia*, whereas on the other hand in the northern Tethys there are forms which look transitional between *E.* ? *nodosa* and *E.* ? *primitia.* Orchard (1983) illustrated the intraspecific variability of *E.* ? *primitia* in North America in the scope as the species is until now used. It is clearly to seen that 3 different species belong to *E.* ? *primitia*. True *E.* ? *primita* (holotype refigured in Orchard, 1991 b) are slender with marginal denticles on the anterior platform, and the platform is posteriorly not narrowed. Their pit is strongly forward-shifted in the same manner as in true *M. communisti*. This form occurs in the *S. kerri* Zone of North America which belongs according to Tozer (1984) to the basal Norian and the conodonts obviously confirm this view. More primitive forms with subterminal pit (e.g. Orchard, 1983, Fig. 2F) and rather nodes than platform denticles which are mostly transversally elongated (e.g. Orchard, 1983, Fig. 2, Figs. A-C) are an independent species which seems to be identical with *E. pseudodiebeli* or may partly belong to a new taxon, transitional between *E. nodosa* and *E. primitia*. This form is common in the uppermost Carnian of the Tethys and North America. A third form (e.g. orchard, 1983, Fig. 2 M, N, O, Q are rather different in having a very narrow posterior platform, mostly with a pointed posterior. There forms, which are not present in the Tethys, represent a new form restricted to North America. They represent the basic forms of the North American genus *Orchardella*.

The above mentioned taxonomic problems and uncertainties about the origin of some conodont species around the Carnian-Norian boundary are a big obstacle for definition this boundary with conodonts. For this reason a definition by ammonoids (base of the *S. kerri* Zone) is preferred. Close to this boundary a distinct faunal turnover can be observed in the conodont fauna, to which belong the FAD of *N. navicula*, the FAD of *M. communisti* s.s. (probably a little below the base of the *S. kerri* Zone, within the uppermost *Macrolobatus* Zone), and the FAD of *E.* ? *primitia* s.s. (probably a little below this boundary, within the uppermost *Macrolobatus* Zone). By correlation of this boundary with the magnetostratigraphic scale of the continental Newark Basin (Channell et al., 2003), this boundary lies insignificantly below E7r sensu Kent &, Olson (2000). Therefore, this boundary can be well correlated with the continental scale. It lies at the end of the lower third of the Conewagian (Adamanian) land vertebrate faunachron (LVF) in the level, where the typical upper Carnian *Paleorhinus* of the Otischalkian and lower Adamanian LVF became extinct.

The only base of the Rhaetian which can be well correlated between the Tethys and North America is the FAD of the conodont *Misikella posthernsteini* proposed for the first time by Kozur (1996). This species evolved in a phylomorphogenetic cline From *M. hernsteini*. The FAD of *M. posthernsteini* is at or close to the base of the *Cochloceras suessi* ammonoid Zone which can be well correlated with the *Paracochloceras amoenum* Zone. Therefore this Rhaetian boundary coincides with the base of the *C. suessi* Zone in the Tethys, the base of the *Paracochloceras amoenum* Zone in North America and roughly with the base of the *Orchardella mosheri* conodont zone in North America. This North America Rhaetian boundary was first established by Carter (1993) and also applied by Kozur (1996) and Orchard & Tozer (1997). *M. posthernsteini* occurs in shallow water and pelagic limestones, as well as in shales and radiolarites of the Tethys and in western Panthalassa. It is absent on the North American shelf and occurs in North America only in terranes (Orchard, 1991b). As the *Cochloceras suessi* Zone and the *Paracochloceras samoenun* Zone can be correlated, the *M. posthernsteini* datum, can be well correlated with North America by ammonoids. This base of the Rhaetian is also recognisable by radiolarians (Fig. 4, Carter, 1993). This Rhaetian is also characterised by the disappearance of the bivalve *Monotis* and Norian brachiopods, such as *Hallorella*, *Hallorelloidea*, *Austriellula*, *Pedixella*, *Crurirhynchia camerothyris*, as well as by the appearance of Rhaetian brachiopods, such as *Austrirhynchia cornigera*, *Labella suessi, Oxyclopella oxycolpos*, *Rhaetina pyriformis*, *Zugmayerella koessenensis*. But for many of these forms the exact appearance in correlation with the ammonoid and conodont zonations is not yet precisely known.

Numeric ages of the Upper Triassic

Almost no radiometric data are known from the Upper Triassic. A well dated radiometric age is 199.6 ±=.4 Ma for the Triassic-Jurassic boundary (TJB, Pálfy et al. 2000). Kent & Olson (2000) took a similar age for the continental TJB in the Newark Basin (202 Ma) and calculated the following by astronomic calibration with Milankovitch cycles: base Rhaetian 208 Ma (Rhaetian duration 6 myrs), base Norian 217 Ma (Norian duration 9 myrs) and base Carnian about 232 Ma (Carnian duration 15 myrs). The value obtained for the base Carnian does not fit with the 237 Ma based on the dense set of radiometric data in the Southern Alps. This is, however, not due to the method of astronomic calibration, but by errors in the current correlation of the continental Newark sequence with the marine scale. Channel et al. (2002, 2003) used the same method, but assigned an age of approximately 200 Ma for the TJB and correlated the palaeomagnetic scale of the Newark sequence (Kent & Olson, 2000) with the marine Upper Triassic palaeomagnetic scale. They recognised that the base of the Carnian at the base of the Stockton Fm., as assumed by Kent & Olson (2000), corresponds actually with a level slightly above the base of the Tuvalian, for which they calculated a value of 231 Ma. This fits nicely with the vertebrate stratigraphy by Huber et al. (1993), who correlated the base of the Stockton Fm. with the lower Tuvalian as well. It also fits with the 237 Ma for the base of the Carnian, as 6 myrs duration for Cordevolian + Julian is a realistic value.

The base of the Norian was changed by Channell and others (2002, 2003) from the lower part of the Passaic Fm. to the middle part of the Stockton Fm. at 226 Ma. This gives the Tuvalian a duration of 5 myrs. The base of the Rhaetian was left at about the same level as shown by Kent & Olson (2000), but in the Newark Basin it is biostratigraphically not well constrained. Unfortunately, the palaeomagnetic correlation is also weak, as the marine section of Silická Brezová (Slovakia) ends in the uppermost Norian, immediately below the Rhaetian, and only in the Scheiblkogel section (Austria) palaeomagnetic data are known from the immediate base of the Rhaetian(Gallet et al., 1996). Most of the marine Rhaetian has not yielded any palaeomagnetic data. Channell and others (2003) tentatively placed the lowermost possible base of the Rhaetian at 207 Ma. Along with the considerably lowered base of the Norian in the Newark Basin, this yields a minimum duration of the Norian of about 19 myrs, and a maximum duration of the

Stage	Subst.	Ammonoid Z./Subz. Standard		bivalves	Conodont Zone/Subzone Tethys/Western Pacific		Conodont Zone/Subzone North America	Radiolarian Zone Tethys/W-Pacific	Radiolarian Zone North America	
RHAETIAN		C. marshi	Choristoceras marshi	Rhaetav. contorta	Misikella ultima		Norigondolella sp.	n. gen. n.sp. A	Globolaxtorum tozeri	
			Choristoceras ammonitiforme		Misikella posthernsteini	Misikella koessenensis	Misikella posthernsteini			
		Chorist. haueri	Vandaites stuerzenbaumi				Orchardella mosheri	Praecitriduma mostleri	Proparvic. moniliformis	Subassembl. 2d
			Choristoceras haueri			Misikella hernsteini-Misikella posthernsteini				Praecitriduma mostleri
		Cochloceras suessi						no well dated radiolarians		Praemesosaturnalis decilobum
NORIAN	SEVATIAN	Sagenites reticulatus		Monotis	Misikella hernsteini-Parvigondolella andrusovi		Mockina bidentata	Betraccium deweveri	Betraccium deweveri	
		Sagenites quinquepunctatus			Mock. bidentata	Subzone 2				
		Halorites macer				Subzone 1	Orchard. serrulata			
	ALAUN.	Mesohimavatites columbianus			Mockina postera		Mockina postera	no well dated radiolarians	Ellipsoxiphus silberlingi	

Figure 4: Correlation of upper Norian and Rhaetian radiolarian zones with the ammonoid and conodont zonation

Rhaetian of about 7 myrs (Fig. 3). The duration of the Carnian in the scale by Channel et al. (2003) is 11 myrs.

Interesting is a dating by Gehrels et al. (1986) from a rhyolite in SE Alaska (225 Ma) which is either of uppermost Carnian or of early Norian age. This fits well with the 226 Ma assumed by Channel et al. (2003) for the base of the Norian. However, an exact new biostratigraphic dating is necessary for this rhyolite.

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Triassic tetrapod footprint biostratigraphy and biochronology

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Three time-successive Triassic tetrapod footprint assemblages can be recognized, the chirothere assemblage of Olenekian-Ladinian age, the dinosauriform assemblage of Ladinian age and the dinosaur assemblage of Carnian-Rhaetian age. A fourth footprint assemblage, based on earliest Triassic dicynodont footprints from Gondwana, may also be present. The Triassic tetrapod footprint record thus resolves three (possibly four) time intervals, so it has less than 50 percent of the temporal resolution of the body fossil record.

INTRODUCTION

The fossil record of tetrapod footprints extends from the Upper Devonian to the Neogene. For this majority of the Phanerozoic, which encompasses the entire tetrapod body fossil record, at many places the only tetrapod fossils known are footprints. This means that footprints provide important data on vertebrate distribution in space and time. Furthermore, unlike invertebrate ichnologists, who view their trace fossils primarily as evidence of behavior, not necessarily of the presence of specific biological taxa, vertebrate ichnologists long ago decided to treat tetrapod footprints as proxies of biological taxa. Because of this, drawing inferences about tetrapod distribution in time and space is a significant goal of the study of tetrapod fossil footprints (e.g., Lockley, 1998). Biostratigraphic correlations and biochronological subdivisions based on tetrapod footprints (Haubold and Katzung, 1978 termed this "palichnostratigraphy") thus have been common, especially in the late Paleozoic and early Mesozoic. Here, I evaluate the utility of tetrapod fooprints in Triassic biostratigraphy and biochronology. My conclusion is largely negative, that tetrapod footprints are generally not very useful in Triassic biostratigraphic correlation and biochronological subdivision.

Triassic tetrapod tracks are known from North America, South America, Europe, North Africa, Australia, Antarctica and South Africa (Fig. 1). The Triassic track record is archosaur and synapsid dominated and includes the oldest dinosaur tracks. The oldest footprints attributed to mammals are also of Late Triassic age, but they are too rare to be of biostratigraphic utility (Sarjeant, 2000).

Much has been written about Triassic tetrapod footprint biostratigraphy, especially based on the European and North American records. Most ambitious are the publications of Demathieu (1977, 1982, 1984, 1994; Demathieu and Haubold, 1972, 1974, and others), who recognized the presence of three different Triassic footprint assemblages in Europe that I recognize here. These are here named the chirothere assemblage of Olenekian- Ladinian age, the dinosauriform assemblage of Ladinian age and the dinosaur assemblage of Carnian-Rhaetian age (Fig. 2). A fourth footprint assemblage, based on earliest Triassic dicynodont footprints from Gondwana, may also be present.

EARLIEST TRIASSIC

Dicynodont tracks from the Karoo basin in South Africa (Watson, 1960), the Fremouw Formation of Antarctica (MacDonald et al., 1991) and the Sydney basin in Australia (Retallack, 1996) are the oldest Triassic tetrapod footprints. Retallack (1996) attributed these tracks to the body-fossil genus *Lystrosaurus*, which defines a classic biochron of earliest Triassic (Induan) age (Lucas, 1998). However, at present, the putative tracks of *Lystrosaurus* are rare, and their attribution to *Lystrosaurus* is not certain, so their biostratigraphic value is limited.

EARLY TRIASSIC-EARLY MIDDLE TRIASSIC (CHIROTHERE ASSEMBLAGE)

The best known Triassic footprint assemblage is of late Early to early Middle Triassic (Olenekian-Anisian) age (Fig. 2) and has a Euramerican distribution. This is a chirothere- (archosaur-) dominated assemblage that also persists during most of the Middle Triassic.

Study of this assemblage is nearly as old as vertebrate ichnology itself. Thus, Sickler (1834, 1835) described tracks from the upper part of the Buntsandstein (Olenekian) near Hildburghausen (Thuringia, Germany), and Kaup (1835a, b) named them *Chirotherium barthii* and *Chirotherium sickleri*, which were the first published binomens of tetrapod tracks. This occurrence was in strata now assigned to the Solling Formation.

In Germany, stratigraphically higher and similar track assemblages occur in the uppermost Buntsandstein (Röt Formation) and have been published on extensively (e.g., Willruth, 1917; Soergel, 1925; Rühle v. Lilienstern 1939; Schreiber, 1956; Krebs, 1966; Haubold 1971; Demathieu and Leitz, 1982; Haderer et al., 1995; Ebel et al., 1998). The Röt yields a diversity of archosaur ichnogenera, including *Chirotherium*, *Isochirotherium, Synaptichnium, Brachychirotherium* and *Rotodactylus*. Equivalent

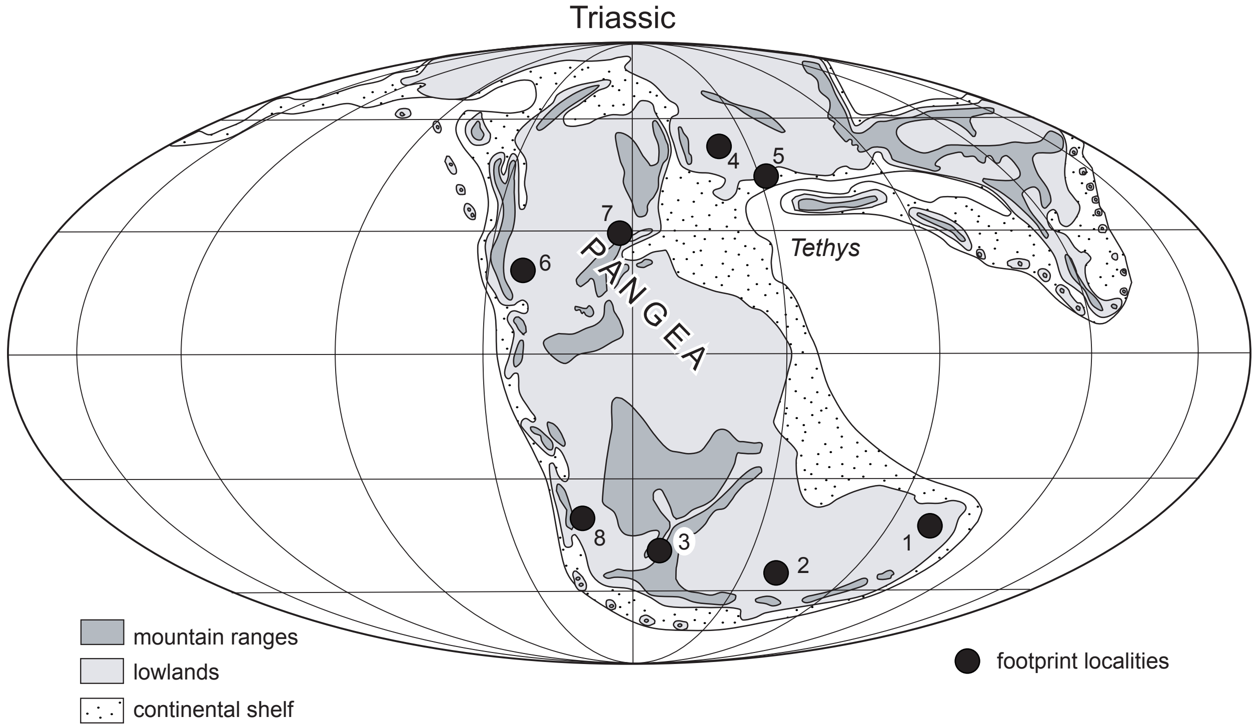

Figure 1. Distribution of principal Triassic tracksites on Triassic Pangea. Locations are 1, Sydney basin, Australia; 2, Karoo basin, South Africa; 3, Antarctica; 4, Germany-France-Belgium, 5, northern Italy; 6, Chinle basin, western United States; 7, Newark basin, New Jersey; 8, Argentina. Base map after Wing and Sues (1992).

ichnofaunas outside of Germany come from France (Provence, Massif Central, Alpes Maritimes) and the Vosges of the French-German-Belgian borderland (e.g., Charles, 1949; Demathieu and Durand, 1975; Demathieu and Leitz, 1982; Orzag-Sperberg, 1966; Demathieu, 1977, 1984). The Buntsandstein ichnofaunas have a demonstrated age range of late Olenekian through early Anisian (Nonesian-Perovkan: Lucas, 1998; Lucas and Schoch, 2002).

In the western United States (Arizona-New Mexico), the Moenkopi Formation has a strikingly similar ichnofauna of early Anisian age, mostly tracks assigned to *Chirotherium* (including *C. barthii* and *C. sickleri*), *Isochirotherium* and *Rotodactylus*, as well as the synapsid track *Therapsipus* (Peabody, 1948; Hunt et al., 1993b; Nesbitt and Angielczyk, 2002; Lucas et al., 2003). In Italy, there are some *Rhynchosauroides* tracks in the Olenekian Werfen Formation (Mietto, 1986). Early Anisian rocks in Italy yield archosaur tracks referred to a variety of ichnogenera, including *Rhynchosauroides*, *Chirotherium*, *Brachychirotherium*, *Synaptichnium*, *Parasynaptichnium* and *Isochirotherium* (e.g., Abel, 1926; Mietto, 1987; Sirna et al., 1994; Avanzini et al., 2001a; Avanzini and Lockley, 2002).

LATE MIDDLE TRIASSIC (DINOSAURIFORM ASSEMBLAGE)

In Germany and the Netherlands, in the Anisian interval of the Muschelkalk, tetrapod ichnofaunas in carbonate tidal flat facies are dominated by the ichnogenera *Rhynchosauroides* and *Procolophonichnium* (Demathieu and Oosterink, 1983, 1988; Diedrich, 1998, 2000, 2002a, b). Chirothere tracks are rare at these localities. This is a distinct ichnofacies correlative to the red-bed chirothere assemblage.

Evidence from Europe (especially France) suggests that chirothere-dominated footprint assemblages continue in red-bed facies into rocks as young as Ladinian. Thus, marginal siliciclastic equivalents of the Muschelkalk in Germany and from the French Middle Triassic yield a chirothere-dominated ichnofauna, including the ichnogenera *Isochirotheriu, Synaptichnium, Sphingopus, Brachychirotherium* and *Rotodactylus* (e.g., Demathieu, 1966, 1970, 1971; Demathieu and Gand, 1972, 1973; Courel and Demathieu, 1973, 1976; Gand, 1976, 1977, 1978, 1980; Gand and Pellier, 1976; Gand et al., 1976). Middle Triassic red beds in Italy (Avanzini and Neri, 1998; Avanzini, 1999; 2002; Avanzini et al., 2001a; Avanzini and Leonardi, 2002), Great Britain (Sarjeant, 1967, 1970, 1996) and Spain (Demathieu et al., 1978) also have a similar ichnofauna. In Argentina, chirothere tracks dominate the Lower and Middle Triassic records in San Juan, Mendoza and La Rioja provinces (e.g., Huene, 1931; Rusconi, 1951, 1967).

In these Middle Triassic assemblages, which are both Anisian and Ladinian (Perovkan-Berdyankian: Lucas, 1998) in age, the only biostratigraphic datum to distinguish them from the earlier chirothere assemblage is the

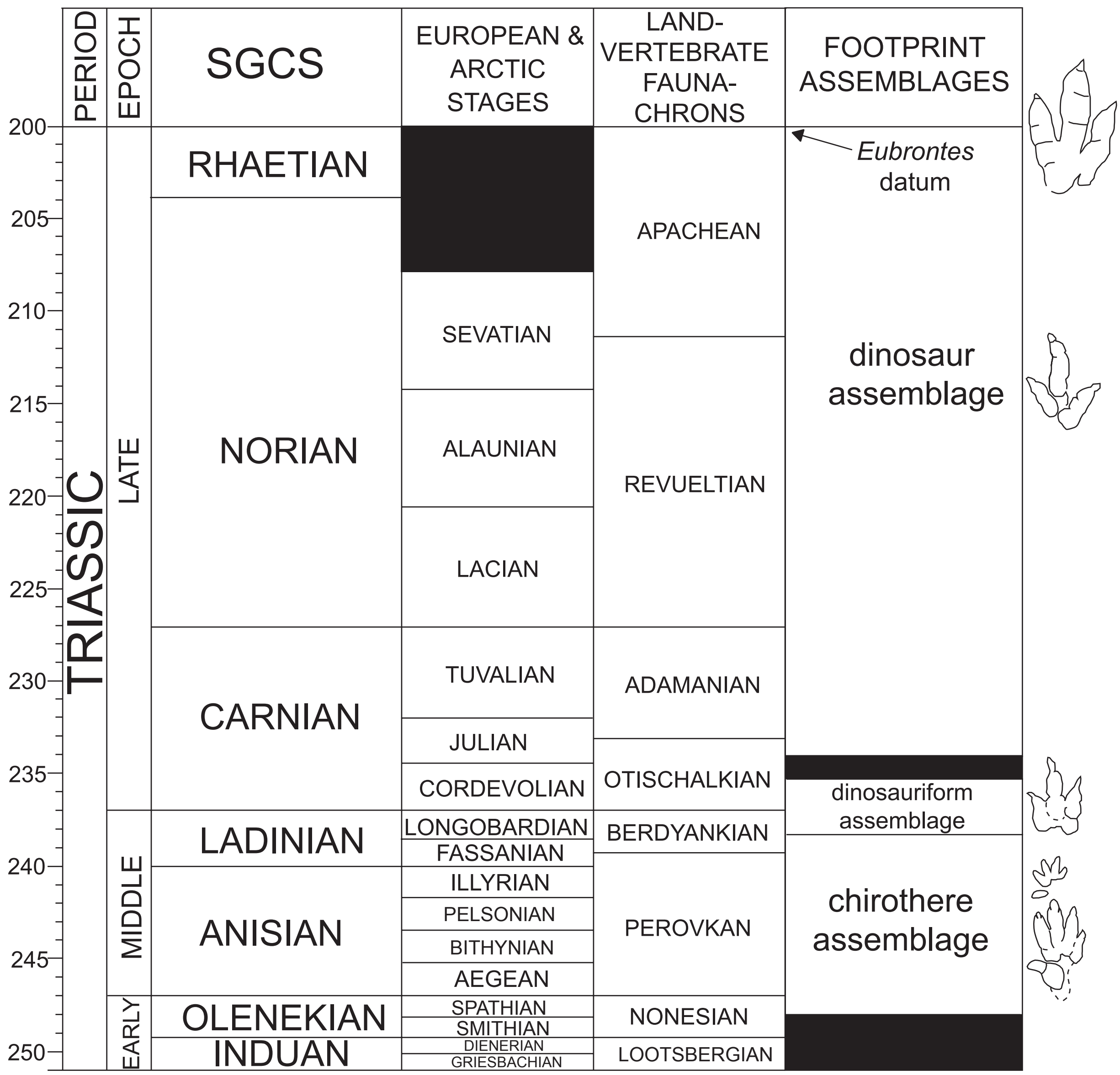

Figure 2. Temporal distribution of Triassic track assemblages.

Ladinian lowest occurrence of dinosaur or dinosaur-like (dinosauriform) tracks (Fig. 2). Apparent tridactyl, bipedal tracks have long been known from Middle Triassic strata in Europe and attributed to dinosaurs by various workers (see review by Demathieu, 1989). One way to evaluate these tracks has been to claim that they are simply extramorphological variants of chirothere tracks (some are) and that the oldest dinosaur track does not predate the oldest dinosaur body fossil, which is Carnian (e.g., King and Benton, 1996; Lucas, 1998).

However, a more sophisticated analysis of this problem by Haubold (1999; Haubold and Klein, 2000) argues that there was a lengthy and complex evolutionary transition from the dinosauriform foot/gait to the dinosaur foot/gait well documented in the Triassic of the German section. Thus, in Germany, track surfaces of the Benker Sandstein up to the Löwenstein Formation (Gipskeuper) and in the Lower Steinmergelkeuper have chirotherian-like, pentadactyl pes imprints and quadrupedal trackways assigned to the ichnogenus *Parachirotherium*. Tridactyl *Atreipus*- and *Grallator*- like tracks have their lowest occurrence in the Benker Sandstein (Rehnelt, 1950, 1952, 1959, 1983; Weiss, 1976, 1981) and increase in abundance up section. Haubold and Klein (2000) identify these tracks as "*Parachirotherium-Atreipus-Grallator*" and conclude that they represent dinosauriform trackmakers.

Regardless of how these tracks are identified, the lowest occurrence of tridactyl dinosaur or dinosaur-like (dinosauriform) tracks appears to be Ladinian and may form a valuable biostratigraphic datum. I thus recognize the appearance of dinosauriform tracks in the later Middle Triassic as marking a distinct footprint assemblage of this age (Fig. 2).

LATE TRIASSIC (DINOSAUR ASSEMBLAGE)

The Late Triassic footprint record is distinct from older Triassic footprint assemblages in its near domination by *bona fide* dinosaur tracks (Fig. 2). These are generally assigned to the ichnogenera *Grallator*, *Atreipus*, *Pseudotetrasauropus* and *Tetrasauropus*. *Brachychirotherium* records begin earlier in the Triassic, but it is the common and characteristic Late Triassic chirothere footprint ichnogenus.

Late Triassic tetrapod footprint assemblages dominated by these ichnogenera are known from the lower Stormberg Group (Molteno and lower Elliott formations and equivalents) of southern Africa (e.g., Ellenberger, 1970; Olsen and Galton, 1984; Raath et al., 1990; Raath, 1996), the upper Keuper in Germany and equivalent strata in Switzerland and Great Britain (e.g., Beurlen, 1950; Heller, 1952; Haubold, 1971, 1984; Demathieu and Wiedmann, 1982; Olsen and Baird, 1986; Haderer, 1988, 1990, 1991; Lockley et al., 1996; Karl and Haubold, 1998, 2000; Lockley and Meyer, 2000; Gand et al., 2000), the Upper Triassic portion of the Newark Supergroup in eastern North America (e.g., Lull, 1953; Olsen and Baird, 1986; Silvestri and Szajna, 1993; Szajna and Silvestri, 1996; Olsen et al., 1998) and the Chinle Group in the American Southwest (e.g., Baird, 1964; Conrad et al., 1987; Hunt et al., 1993a; Lockley and Hunt, 1995; Lockley et al., 2001; Lucas et al., 2001).

In Morocco, the Carnian interval of the Argana Group yields a similar footprint assemblage that includes *Rhynchosauroides*, *Brachychirotherium*, *Atreipus* and *Grallator?* (Biron and Dutuit, 1981). The South American Late Triassic footprint record is from Argentina (Brazilian records are doubtful: Leonardi, 1994). Prosauropod, small theropod, synapsid (both small cynodont and large dicynodont) and chirothere (*Brachychirotherium*) tracks are known from Upper Triassic strata in Río Negro, San Juan and La Rioja provinces (e.g., Casamiquela, 1964; Bonaparte, 1969; Arcucci et al., 1995, 2000; Marsicano and Barredo, 2000). Late Triassic theropod tracks are also known in Australia from the Sydney basin in New South Wales and the Callide basin in southeastern Queensland (Molnar, 1991; Thulborn, 1998).

There have been attempts to identify two temporally successive Late Triassic footprint assemblages. Thus, Olsen (1980) identified three footprint assemblages in the Newark Supergroup of eastern North America, two of Late Triassic age and one of Early Jurassic age. More detailed stratigraphic data have shown that the two Late Triassic assemblages should be combined into one characterized primarily by *Brachychirotherium*, *Gwynnedichnium*, *Grallator*, *Atreipus* and *Rhynchosauroides*. (Silvestri and Szajna, 1993; Szajna and Silvestri, 1996; Lucas and Huber, 2003). Olsen and Huber (1998) raised the possibility that an older, distinctive footprint assemblage may be present near the base of the Newark Supergroup, but when extramorphological variation is considered, this assemblage consists of characteristic Late Triassic ichnotaxa, including *Apatopus*, *Grallator* and *Brachychirotherium*. Haubold (1986) followed Olsen's (1980) zonation, applying it to the European and South African records. However, current ichnotaxonomy and understanding of stratigraphic distribution makes it clear that only one Late Triassic footprint assemblage can be identified in these regions (Lucas and Hancox, 2001; Lucas and Huber, 2003).

Lockley (1993) and Lockley and Hunt (1994, 1995) also presented a similar zonation for the upper Chinle Group and the Glen Canyon Group in the western United States. They identified four successive zones: (1) *Brachychirotherium* and small grallatorid zone of the upper Chinle Group (Rock Point sequence of Lucas, 1993); (2) medium-size grallatorid assemblage of the Wingate Sandstone; (3) *Anomoepus-Eubrontes* zone (with *Batrachopus*) of the upper Wingate-Moenave-Kayenta; and (4) *Otozoum-Brasilichnium* zone of the Kayenta-Navajo. However, subsequent collecting and stratigraphic data demonstrate that assemblages 1 and 2 are a single assemblage dominated by *Grallator* and *Brachychirotherium*. The separation of assemblages 3 and 4 is also not supported by new data.

TRIASSIC-JURASSIC BOUNDARY

In North America, Europe and South Africa, the tetrapod ichnofauna changes at the Triassic-Jurassic boundary. Best documented in the Newark basin by Silvestri and Szajna (1993) and by Szajna and Silvestri (1996), some characteristic Late Triassic ichnogenera disappear (*Apatopus*, *Brachychirotherium* and *Gwyneddichnium*), several ichnogenera continue through the boundary (e.g., *Rhynchosauroides*, *Grallator*, *Anchisauropus*, *Batrachopus*) and some new ichnogenera appear (*Eubrontes*, *Anomoepus* and *Ameghinichnus*). To anyone who knows these assemblages firsthand, the most striking change is from the Late Triassic absence to the Early Jurassic abundance of large theropod (*Eubrontes*) tracks, which I term the *Eubrontes* datum (Fig. 2).

This sudden appearance of *Eubrontes* has generally been viewed as an evolutionary event, reflecting the evolutionary first appearance of larger theropods (such as the ceratosaur *Dilophosaurus*) at the beginning of the Jurassic (e.g., Lockley and Hunt, 1995; Olsen et al., 1998). The most recent example of this is Olsen et al. (2002a, b), who argued for a dramatic size increase in theropod dinosaurs at the Triassic-Jurassic boundary as evidenced by the sudden appearance of large theropod tracks (ichnogenus *Eubrontes*) in the earliest Jurassic strata of the Newark Supergroup. They interpreted an increase in size that resulted from a rapid (thousands of years) evolutionary response by the theropod survivors of a mass extinction as "ecological release" (Olsen et al., 2002a, p. 1307). They admitted, however, that this hypothesis can be invalidated by the description of *Dilophosaurus*-sized theropods or diagnostic *Eubrontes giganteus* tracks in verifiably Triassic-age strata (Olsen et al., 2002a).

Indeed, large, *Dilophosaurus*-size theropods have been known from the Late Triassic body-fossil record since the 1930s; these are *Liliensternus* from the Norian of Germany (estimated length of ~ 5 meters) and *Gojirosaurus* from the Norian of the USA (estimated length ~ 5.5 m) (Huene, 1934; Welles, 1984; Carpenter, 1997). *Dilophosaurus* has an estimated length of 6 meters, and the foot of *Liliensternus* is 92 percent (based on maximum length) the size of that of *Dilophosaurus* (Rowe and Gauthier, 1990, fig. 5.10). Clearly, theropods capable of making *Eubrontes*-size tracks were present during the Norian, and the sudden abundance of these tracks at the beginning of the Jurassic cannot be explained simply by rapid evolution to large size of small theropods following a mass extinction.

Furthermore, tracks of large theropod dinosaurs (ichnogenus *Eubrontes*) have long been known from the Upper Triassic of Australia. Staines and Woods (1964) originally reported these tracks, and they have subsequently been discussed and/or illustrated by Hill et al. (1965), Bartholomai (1966), Molnar (1991) and Thulborn (1998). These tracks are from the Blackstone Formation of the Ipswich Coal Measures near Dinmore in southeastern Queensland, a unit of well-established Triassic age (late Carnian: Balme and Foster, 1996). The largest tracks are 43 cm long and 38 cm wide, and a trackway has a stride length of 2 m. They closely resemble tracks of *Eubrontes giganteus* from the Newark Supergroup described by Olsen et al. (1998). This Triassic record of *Eubrontes* further invalidates the "ecological release" hypothesis of Olsen et al. (2002a, b).

The Triassic record of *Eubrontes* from Australia calls into question the validity of using the lowest occurrence of *Eubrontes* to define the base of the Jurassic. The presence of Norian theropod body fossils large enough to be *Eubrontes* trackmakers also does this. I thus consider the *Eubrontes* datum to be of questionable long term validity; *Eubrontes* tracks await discovery in the North American or European Upper Triassic

BIOSTRATIGRAPHY AND BIOCHRONOLOGY

A global Triassic biochronology based on tetrapod body fossils recognizes eight biochronological units (Lucas, 1998). The Triassic tetrapod footprint record resolves three (possibly four) time intervals (Fig. 2), so it has less than 50 percent of the temporal resolution of the body fossil record. Thus, the Triassic footprint record resolves geologic time very poorly in comparison to the body fossil record.

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Associations of bivalves of Iberian Peninsula (SPAIN): Ladinian

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Abstract - In the levantine area of Spain the Ladinian bivalves are recorded in the upper Muschelkalk in relation with the germanic Triassic type facies of the Iberian peninsula . We establish two associations with paleoecological implications:

1.- “Fauna de Teruel” Association (F-T A), mainly formed by Tethysian (Alpine) species and some cosmopolitan species, the rest belong to Sephardic domain, the southern border of the Tethys. This association is related with a very shallow marine environment.

2.- “Daonella-Posidonia” Association (D-P A) is related with a platform marine environtment. *D. lommeli* dates the Middle-Upper Ladinian (Longobardian).The Iberian Peninsula was located in the western part of the Tethys Basin.

During the Triassic the marine transgression began in the Early Anisian onlapping the land-masses of Central Europe, the Iberian Peninsula, and North Africa. The fluvial and lacustrine red beds of the Early Triassic (Buntsandstein Facies) changed to shallow-water marine carbonates (Muschelkalk Facies). These conditions prevailed during the Middle Triassic. The last marine transgression took place at the end of the Late Triassic. The Iberian Peninsula was located in the western part of the Tethys Basin, along its eastern border there were several sub-basins (Pyrenean, Catalonian, Ebro, Iberian and Betic) open to the E of the Tethys sea and separated by high, faulted Paleozoic blocks. The heights were drowned by the sea during the late Ladinian and a single basin was formed. The Middle - Late Triassic (Anisian - Norian) of the Iberian Peninsula has three carbonate intervals interpreted as prograding carbonate ramps: 1.- Lower Muschelkalk (Anisian), 2.- Upper Muschelkalk (Anisian-Ladinian) and 3.- Imón Dolomites Formation (Norian). This intervals are separated by two siliclastic evaporitic intervals interpreted as sebkha and saline deposits: Middle Muschelkalk Facies (Late Anisian - Early Ladinian) and Keuper Facies (Karnian - Early Norian) (López-Gómez, A *et al* 2002). It is a Germanic Triassic type with intercalations of continental and marine facies. The Middle Triassic sediments of the Catalonian Ranges, SE Iberian Ranges and External Betic Ranges have similar facies, from bottom up: 1.- a lower carbonate unit with bioclastic limestones, algal mats and marls, 70-120 m. Thick, 2.- a middle red siliclastic - evaporitic interval of variable thickness, up to several hundred meters and 3.- an upper carbonate unit with bioclastic and oolitic limestones, algal buildups and shallowing-upwards marl-limestones sequences, 100 - 140 m. thick. In the fig.1 is showed the correlation between the units of the upper Muschelkalk of the Iberian Ranges, Catalan Coastal Ranges and Pyrenees.

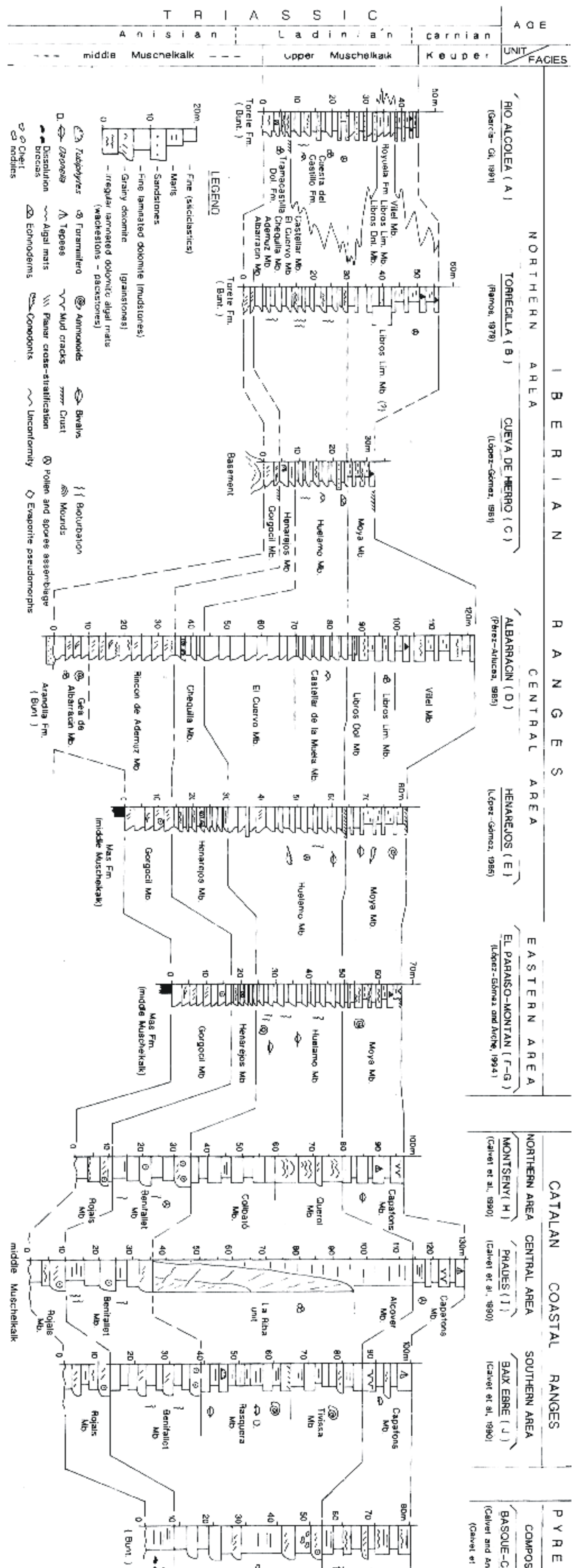
The fossil record is very scarce and poorly preserved. Works done in Spain over a century (1853-1958) were only limited geographical scope. The paleobiological concepts were then not established, these works contain many taxonomic problems. A general paleontological marine Triassic work of Spain, based mainly in bivalves, was made by Márquez-Aliaga (1985) and Márquez- Aliaga & Martínez (1996), and the comparations with other regions as Italy, England, Germany and Bulgaria and taphonomic and taxonomic studies were pointed out by Budurov *et al* (1993). As result, a drasticall reduction of species diversity for the spanish marine Triassic fossils was geting on. The comparative studies show that 73% are found in both the Alpine (Tethysian) and Germanic (Northern) provinces, 12% of the spanish species are purely Alpine (Tethysian) and the rest of the species were considered autochtonous of the Iberian Peninsula. The Sepharadic province was defined by Hirsch (1977) as the epicontinental southern border of the Tethys sea from Arabia to the Iberian Peninsula, different from the deeper northern border, the classic Alpine area. The correlation between the autochtonous species (sensu Márquez-Aliaga, 1985 and 1995) from Spain, Jordany and Israel show how the marine fossil taxa migrate from the eastern to the western part of the province between the Anisian and the Ladinian (Fig.2). The Ladinian faunas have greater specific diversity both in the Catalonian Coastal Ranges and Iberian Ranges.

CONCLUSIONS

In the Ladinian of eastern area of the Iberian peninsula, we establish two associations of bivalves, related with paleoecological implications:

The first is recorded in the upper part of the upper Muschelkalk in a very shallow marine environment: 1.- “Fauna de Teruel” Association (F-T A): mainly formed by Alpine (Tethysian) species: *Neoschizodus laevigatus* (GOLDFUSS), *Bakevellia costata* (SCHLOTHEIM), *Pseudocorbula gregaria* (MUNSTER), *Modiolus myoconchaeformis* (PHILIPPI), *Enantiostreon difforme* (SCHLOTHEIM), *Leptochondria alberti* (GOLDFUSS). The rest of species belong to the Sephardic domain of the Tethys: *Costatoria kiliani* (SCHMIDT), *Placunopsis teruelensis* WURM, *Gervillia joleaudi* (SCHMIDT).

The second is recorded in the middle part of the upper Muschelkalk in a platform marine environment: 2.-


TRIASSIC
Anisian
Ladinian
carnian
AGE
middle Muschelkalk
Upper Muschelkalk
Keuper
UNIT
FACIES
IBERIAN RANGES
NORTHERN AREA
CENTRAL AREA
EASTERN AREA
CATALAN COASTAL RANGES
NORTHERN AREA
CENTRAL AREA
SOUTHERN AREA
PYRENEES
COMPOSITE
RIO ALCOLEA (A)
TORRECILLA (B)
CUEVA DE HIERRO (C)
ALBARRACIN (D)
HENAREJOS (E)
EL PARAISO-MONTAN (F-G)
MONTSENY (H)
PRADES (I)
BAIX EBRE (J)
BASQUE-CADI (K)
LEGEND

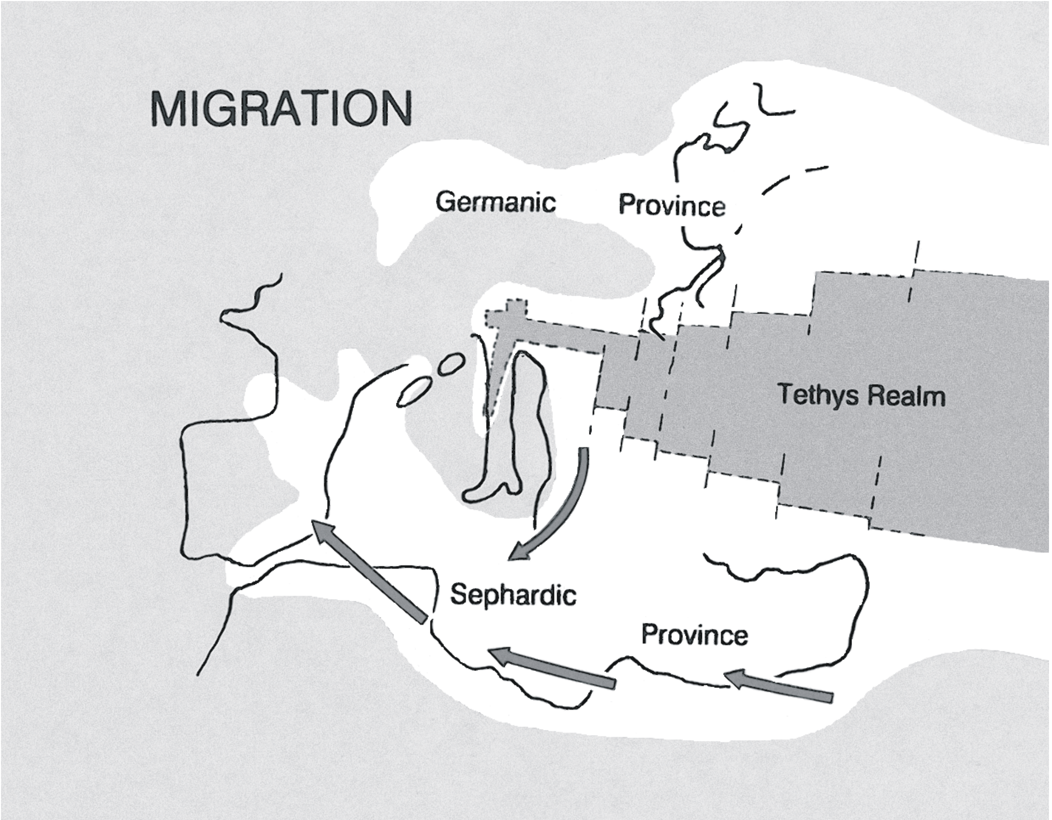


Figure 2. Migration route of Alpine (Tethysian) and Sephardic bivalve species (pro-part of Márquez-Aliaga *et al*, 1986)

“Daonella-Posidonia” Association (D-P A): “*Posidonia” wengensis* (WISSMANN) y *Daonella lommeli* (WISSMANN).

The nektonic bivalve *D. lommeli* dates the Middle-Upper Ladinian to the upper Muschelkalk carbonate unit of the Iberian and Catalonian Coastal Ranges in Spain.

ACKNOWLEDGEMENTS

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Figure 1 (previous page). Synthesis and possible correlation between the units of the upper Muschelkalk of the Iberian Ranges, Catalan Coastal Ranges and Pyrenees. Source: López- Gómez, et al, 1998.

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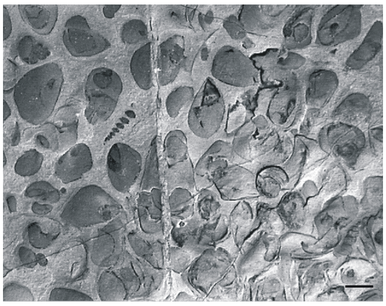
Plate 1 (next page). Two bivalve assemblages from the Ladinian of Iberian Peninsula. A: "Fauna de Teruel" assemblage: 1. *Pseudocorbula gregaria* (MUNSTER), Libros (Iberian Range), 2. *Modiolus myoconchaeformis* (PHILIPPI), Henarejos (Iberian Range), 3. *Neoschizodus laevigatus* (GOLDFUSS), Mallorca (Balearic Islands), 4. *Leptochondria alberti* (GOLDFUSS), Henarejos (Iberian Range), 5. *Enantiostreon difforme* (SCHLOTHEIM), Henarejos (Iberian Range), 6. *Bakevellia costata* (SCHLOTHEIM), Libros (Iberian Range), 7. *Costatoria kiliani* (SCHMIDT), Riopar (Betic Range), 8. *Gervillia joleaudi* (SCHMIDT), Henarejos (Iberian Range), 9. *Placunopsis teruelensis* WURM, Henarejos (Iberian Range). B: "Daonella-Posidonia" assemblage: 10. *Posidonia wengensis* (WISSMANN) accumulation of several specimens, Cabo Cope (Betic Range). 11. *Posidonia wengensis* (WISSMANN), Cabo Cope (Betic Range). 12. *Daonella lommeli* (WISSMANN), Montral-Alcover (Catalonian Coastal Range).



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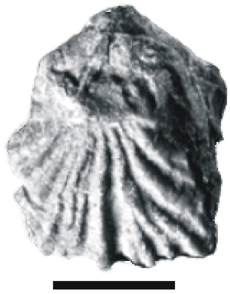

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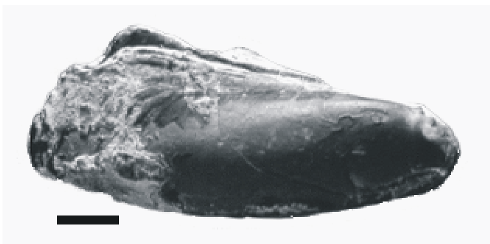

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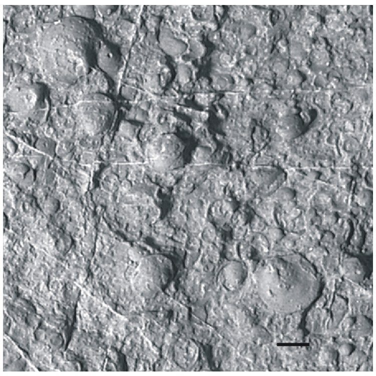

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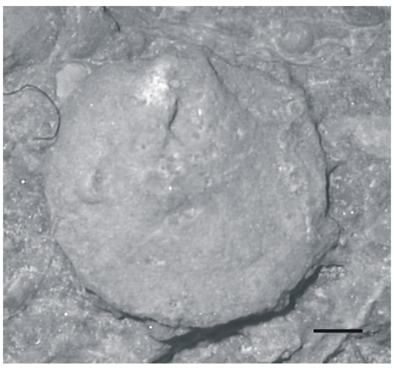

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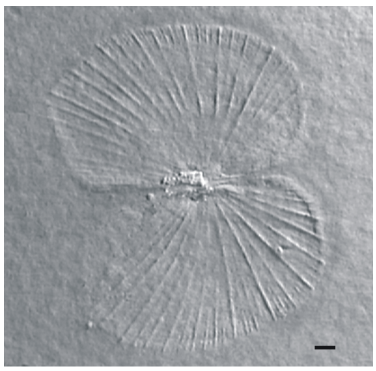

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Interpretation of the Boreal *Otoceras* Beds: Permian or Triassic?

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The Permian-Triassic boundary now has a Global Stratotype section and Point (GSSP) (Yin et al. 2001). In faunal terms it is defined by the appearance of the conodont *Hindeodus parvus*. In stratigraphic terms it is the base of bed 27c at Meishan, China.

Permian-Triassic (PT) boundary beds are well developed in the Sverdrup Basin, on Ellesmere and Axel Heiberg Islands in Arctic Canada (Tozer, 1961; 1967). Permian strata are overlain unconformable by the Triassic Bjorne and Blind Fiord formations (or groups) Tozer, 1961, p.8) .The Blind Fiord beds contain a sequence of ammonoid faunas starting with the *Otoceras concavum* and *Otoceras boreale* zones. These, and the overlying *Ophiceras commune* and *Bukkenites strigatus* zones, constitute the type section for the Griesbachian Stage (Tozer, 1967, 1994). At the type locality for the Griesbachian Stage the base of the Blind Fiord beds rest unconformable on Permian strata. The *Concavum* and *Boreale* zones were interpreted as Triassic. This interpretation is based on the resemblance between the suture lines of the boreal *Otoceras* species with that of *Otoceras fissisellatum* Diener, from the *Otoceras woodwardi* Zone of the Himalayas. The *Woodwardi* Zone is currently regarded as Lower Triassic (Orchard and Krystyn, 1998) as it has been intermittently since the time of Griesbach (1880). The fauna of the *Woodwardi* Zone, unlike that of the *Concavum* and *Boreale* zones, includes *Ophiceras* and this has led Baud (2001, p. 4) to suggest that the Boreal *Otoceras* zones are older than the *Woodwardi* Zone. Orchard and Krystyn (op. cit) and Shevyrev (2000, pp.56, 57) similarly place the *Woodwardi* Zone above the base of the Triassic.

It cannot be denied that Ammonoid chronology at the Permian- Triassic boundary is imperfect owing to the fact that what appear to be the youngest Permian ammonoids (e.g. those of the Dorashamian of Iran) are not known in sequence with the Triassic *Otoceras* beds of the Himalayas. In spite of this difficulty, and recognizing that the boreal occurrences are probably at least in part older than those in the Himalayas, the overall similarity between the boreal and Himalayan *Otoceras* is taken to justify regarding *Otoceras* as a genus characteristic of early Triassic time. Otocerataceans, classed as Araxoceratidae, occur in undoubted Permian strata, but the suture lines of Araxoceratidae differ from those of *Otoceras* from the Woodwardi, *Concavum* and *Boreale* Zones in being devoid of well-individualized ceratitic auxiliary lobes.

A different interpretation for the Griesbachian *Otoceras* zones has been proposed by Henderson and Baud (1997), Baud and Beauchamp (2001) and Baud (2001). They record conodonts from several levels at a section at Otto Fiord, Ellesmere Island. Those from the *Concavum* Zone are not specifically identified but are interpreted as indicating a Changhsingian (latest Permian) age. From the Boreal Zone they record *Hindeodus parvus*, the index for the basal Triassic, an occurrence confirmed by Orchard and Krystyn (1998, p. 352). Baud and Beauchamp (op. cit) redefine the Griesbachian as a substage, comprising only the *Commune* and *Strigatus* zones.

Interpretation of the boreal *Otoceras* zones as Changhsingian is not convincing. No comparable ammonoids are known in Changhsingian deposits. I maintain that the evidence from the ammonoids, now coupled with the occurrence of *Hindeodus parvus* in the Boreale zone, supports the original interpretation of these zones as Triassic (Tozer, 1988). This is also the interpretation of Dagys and Ermakova (1996), and Shevyrev (2000). Kummel (1972, p. 374) considered that *Otoceras concavum* and *O. boreale* were synonyms. Zacharov (2002) does the same and in consequence enlarges the scope of the *Boreale* Zone to embrace the *Concavum* zone. However both, Kummel and Zacharov, do not question assignment of these *Otoceras* beds to the Triassic.

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A candidate for a terrestrial Permian-Triassic boundary stratotype

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The border area of Yunnan and Guizhou, SW China, which lied to the east of the Kang Dian Oldland, provides terrestrial Permian-Triassic strata. After relentless research, we succeeded in finding a few good terrestrial Permian-Triassic boundary strata sections—Zhejue, Chahe and Mide sections. Among them the Zhejue is the best.

The Zhejue section can be correlated with marine sections step by step. In eastern Yunnan and western Guizhou, sedimentary facies continuously distributed in order of land-littoral-shallow sea from west to east. The Permian-Triassic biostratigraphic boundaries in the marine strata, in the middle and west parts of Guizhou, can be easily recognized according to their abundant marine fossils, and can be correlated with the Meishan section in high resolution. These intermediate sections serve to connect the terrestrial section with Meishan. It is important that the "Boundary Clayrock" formed by event activity, which distributes in marine Permian-Triassic boundary bed, also exist in terrestrial area, providing valuable material for accurate dating of geological age. It is also remarkable that we have found "Boundary Beds" widely distributed in the terrestrial and transition Permian-Triassic boundary section. Their vertical framework is similar with that of marine strata, i.e., "three beds" pattern (clayrock—limstone or clastics—clayrock). Furthermore the terrestrial Permian -Triassic boundary can be correlated to marine section in other areas of South China and to terrestrial Permian Triassic boundaries in North China (Xinjiang Province) mainly by sporopollen.

Analysis of fossil plants, sporo-pollen, bivalves, etc., indicate that:

1. The plant types in lowerest Triassic are the same as those of the upper Permian. *Gigantonoclea, Taeniopteris* and *Paracalamites* can be easily found.

2. There was an extinction event during the Permian-Triassic transition. Evidences are that diversity and quantity were suddenly decreased at the base of Lower Triassic.

3. There existed a mixed biota in the terrestrial layers of earliest Triassic, although the layer is thicker than the marine strata (generally about several meters). It is characterized by Permian relicts together with Mesozoic pioneers.

4. The sporopollen can be well correlated between terrestrial strata and marine strata. Many identical genera of the sporo–pollen can be found both in terrestrial strata and in synchronous marine strata.

1-2 horizons of boundary clayrock have been found near the terrestrial Permian-Triassic boundary in the research area. The mineral compositions are illite-montmorillonite(20-80%) and kaolinite(35-80%). The kaolinite content is more than that of the marine P-T boundary clayrock (only 1.1-10.1%)

Zircon, apatite, hexagonal dipyramid high–temperature quartz, and accessory mineral of acidic rocks have been found in the terrestrial P-T boundary clayrock of the Chahe section and Mide section.

There are a lot of transparent hyaline spherules and black metal spherules. Physical characteristics of the spherules show that they were formed in molten status. These spherules may be partly formed by impact.

It is suggested that terrestrial P-T boundary clayrock in the research area may have been formed by mixed functions of volcanism, possible impact and normal deposition.

The P-T biostratigraphic boundary of Zhejue section is located within the dirty siltstone (Bed 55) between the two clayrock beds. Following are the evidences:

1. Sporo-pollen assemblage is obviously different above and below of Bed 54(first boundary clayrock). "*Vittatina"* is found in bed 56 (the second boundary clayrock); it is also found in Bed 30(above second boundary clayrock) of the Meishan section.

2. Diversity and quantity of plant fossils above Bed 54 suddenly decreased. Below Bed 54, they are abundant.

3. Susceptibilities are obvious different. High susceptibility records suddenly increase above Bed 54, and as a whole gradually increase upwards.

4. Carbon isotope show sudden change above the base of Bed 54.

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British Triassic Palaeontology: Supplement 28

G. Warrington

Since the completion of the writer's previous supplement (No.27; ALBERTIANA, 27: 82) on British Triassic palaeontology, the following works relating to aspects of that subject have been published or have come to his notice:

Bridge, D. McC. & Hough, E. 2002. Geology of the Wolverhampton and Telford district. *Sheet description of the British Geological Survey*, 1:50 000 Series Sheet 153 (England and Wales). Keyworth, Nottingham: British Geological Survey, vi+75pp.

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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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