

LADINIAN/CARNIAN BOUNDARY SECTIONS IN SPITI (TETHYS HIMALAYA, INDIA)

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

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

The correlations of the sections emphasize that:

- a) Key beds or distinct lithologic intervals can be correlated and traced for tens of kilometers.
- b) Thickness of Kaga Fm. and of marly intercalations in the Chomule Fm. decreases from Muth to Lalung, i.e., from the present SW to the present NE.
- c) The distribution of fossils in the studied sections is rather constant, with minor changes from section to section mostly due to local difficulty in sampling (cleavage or unextractability).
- d) From the biostratigraphic point of view the Upper Ladinian is quite well documented by the occurrence of the ammonoids *Meginoceras meginiae*, *Maclearnoceras* sp. and Frankites. Frankites also overlaps with *Daxatina*, but the first occurrence of typical Carnian ammonoid *Trachyceras* is of difficult location due to rather poor preservation of the specimens.
- e) The first occurrence of the *Paragondolella/Metapolygnathus polygnathiformis* is recorded at the middle of the range of Frankites, i.e. together with what are normally regarded as Ladinian ammonoids.
- f) *Halobia* seems to overlaps the range of *Daxatina*, and possibly also the range of Frankites.

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

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

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

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

THE PHILOSOPHY OF BOUNDARY STRATOTYPES: THE UPPER TRIASSIC EXAMPLE

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

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

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

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

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

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

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

RHAETIAN AND LATE NORIAN MAGNETOSTRATIGRAPHY AND ITS RELATIONSHIP TO BIOSTRATIGRAPHIC ZONATIONS IN NW EUROPE.

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

LATE TRIASSIC CONODONTOPHORIDS FROM NORTHEASTERN ASIA (SYSTEMATIC COMPOSITION, BIOSTRATIGRAPHY, CORRELATION)

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

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

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

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

Stratigraphic range of the Late Triassic conodontophorids in northern Siberia.

Omulevsky Uplift

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

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

Novosibirsk islands

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

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

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

Biostratigraphy and correlation

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

Carnian Stage Lower Carnian Substage

Paragondolella foliata beds

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

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

Norian Stage Lower Norian Substage

Norigondolella "navicula" beds

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

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

Norian – Rhaetian Stages
Middle Norian Substage – Rhaetian Stage

Norigondolella steinbergensis beds

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

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

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EVOLUTIONARY LINEAGES IN UPPER TRIASSIC PLATFORM CONODONTS AND THEIR IMPORTANCE FOR THE DEFINITION OF THE CARNIAN-NORIAN BOUNDARY

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

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

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

The Norian-Rhaetian boundary – new data from a Tethyan key section in Austria.

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

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

RECOGNITION OF LATE TRIASSIC MARINE STAGE BOUNDARIES IN NONMARINE STRATA

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ALTHOUGH GSSP'S HAVE NOT BEEN DECIDED FOR THE MARINE STAGE BOUNDARIES OF THE LATE TRIASSIC TIMESCALE (BASES OF CARNIAN, NORIAN, RHAETIAN AND HETTANGIAN STAGES), BIOSTRATIGRAPHERS WORKING IN NONMARINE TRIASSIC STRATA HAVE LONG IDENTIFIED AND CORRELATED TO THESE BOUNDARIES. THEIR CONCLUSIONS RELY PRIMARILY ON PALYNOSTRATIGRAPHY AND VERTEBRATE BIOSTRATIGRAPHY AND, MORE RECENTLY, ON A RAPIDLY GROWING MAGNETOSTRATIGRAPHIC DATABASE. NEVERTHELESS, CORRELATION OF ALL LATE TRIASSIC STAGE BOUNDARIES INTO THE NONMARINE TRIASSIC SECTION CONTINUES TO BE PLAGUED BY UNCERTAINTY AND IMPRECISION:

1. The Carnian base (~ base desatoyense zone) is particularly difficult to identify in nonmarine strata because of a lack of corresponding palynostratigraphic change, a paucity of vertebrate fossil assemblages that closely bracket this boundary and a lack of magnetostratigraphic data.
2. In contrast, a change in palynofloras and an extensive and closely bracketing vertebrate fossil record allow relatively confident placement of the Norian base (~ base kerri zone), though recent (and arguably unreliable) correlations of Tethyan marine to nonmarine magnetostratigraphy challenge these correlations.
3. The Rhaetian base (however defined) correlates to a palynological turnover in Europe, but is currently invisible to vertebrate biostratigraphy; its published placement in the Newark Supergroup is conjectural, if not demonstrably incorrect, and has been used to argue for a 7-million-year-long Rhaetian.
4. Many workers believe the Hettangian base (~ base planorbis zone) has been approximated by palynostratigraphy and vertebrate biostratigraphy, particularly relying on placement of that boundary in the Newark Supergroup just below the base of the CAMP basalts. However, if the palynological change in the Newark section is equated to the base Rhaetian change in Europe (which it resembles), and the presence of the footprint ichnogenus *Eubrontes* in the Australian Triassic indicates that the LO of *Eubrontes* is not the base of the Jurassic, then the Hettangian base in the Newark section should be moved up to above the base of the CAMP basalts.

A POTENTIAL CANDIDATE SECTION FOR THE DEFINITION OF THE CARNIAN/NORIAN BOUNDARY: THE PIGNOLA SECTION IN THE LAGONEGRO BASIN (BASILICATA, ITALY)

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

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

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

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

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

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

- the presence of *M. polygnathiformis* (Budurov and Stefanov) and *Gl. tethydis* Huckriede from the sample PG1 to PG10;
- the coexistence of *M. polygnathiformis* (Budurov and Stefanov) and *M. nodosus* (Hayashi) from PG11 to PG12B;
- the first occurrence of *M. pseudodiebeli* (Kozur) in the sample PG13A. This species is associated to *M. nodosus* (Hayashi) up to the sample PG15;

- the first occurrence of *M. communisti* (Hayashi) in the sample PG13B and its last occurrence in the sample PG15B, where it is associated to *M. pseudodiebeli* (Kozur). The specimens of *M. communisti* appears to be morphologically close to *M. communisti* morphotype A *sensu* Krystyn.
- the presence of *E. spatulata* (Hayashi) and *E. triangularis* (Budurov) in the sample PG15D;
- the first occurrence of *E. bidentata* Mosher in the sample PI5;
- the first occurrence of *E. postera* (Kozur and Mostler) in the sample PG16;
- the first occurrence of *M. posthernsteini* Kozur and Mock in the sample PG19.

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

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

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Halobiid bivalves and the Carnian-Norian Boundary in North America

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

ASSESSMENT OF IMPLICATIONS OF RECENT MARINE MAGNETOSTRATIGRAPHIC CORRELATIONS FOR NON-MARINE IDENTIFICATION OF THE CARNIAN-NORIAN AND NORIAN-RHAETIAN BOUNDARIES

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

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

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

The implication of a short Rhaetian is that biotic change should be concentrated in multiple episodes before but close to the Triassic-Jurassic boundary, while a long Rhaetian spreads the biotic change out, perhaps to background levels, leaving the significant turnover at the Triassic-Jurassic boundary. In either case, however, there is

little indication of significant faunal or floral turnover at the North American equivalent of the Norian-Rhaetian boundary. The hypothesis of a long Rhaetian stage (Channell et al, 2003; Muttoni et al., 2004) based on identification of the Norian-Rhaetian boundary in the Newark basin, versus the short Rhaetian of Krystyn et al. (2002) should be easily tested by paleomagnetic sampling of actual Rhaetian marine sections; a long Rhaetian should have a relatively large number of polarity zones, while the short Norian hypothesis requires very few.

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A new conodont zonation for the Carnian-Norian boundary at Black Bear Ridge, northeast British Columbia.

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

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

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

Magnetostratigraphic Correlation and the Late Triassic Timescale

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

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

UPPER TRIASSIC OF THE WESTERN CAUCASUS: FORAMINIFERS, SUBDIVISION, CORRELATION

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