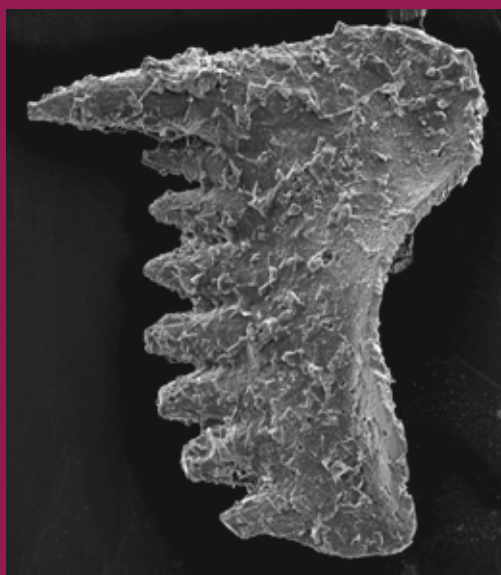


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Contents

	<i>Pages</i>
Executive Notes	
From the Chair	3
From the Secretary	3
From the Editor	4
Reports	
S. G. Lucas & P. J. Hancox: Tetrapod-based correlation of the non-marine Upper Triassic of Southern Africa	5
M. J. Orchard, J. P. Zonneveld, M. J. Johns, C. A. McRoberts, M. R. Sandy, E. T., Tozer & G. G. Carrelli: Fossil succession and sequence stratigraphy of the Upper Triassic of Black Bear Ridge, northeast British Columbia, a GSSP prospect for the Carnian-Norian boundary.	10
T. Jinnan, Z. Jianjun & Z. Laishi: Report on the Lower Triassic of Chaohu, Anhui Province, China.	23
Y. D. Zakharov, A. V. Ignatiev, N. G. Boriskina, T. A. Velivetskaya, O. P. Smyshlyaeva, K. Tanabe, Y. Shigeta, H. Maeda, A. M. Popov, V. V. Golozubov, T. B. Afanasyeva & K. Moriya: Palaeozoic and Mesozoic Carbon-isotopic macrorhythms and macrocycles of solar activity.	28
New Triassic Literature	
W.M.Kürschner, H. Visscher, H. Kerp, G. Warrington, S.G. Lucas: Triassic Bibliography	36
G. Warrington British Triassic Literature: Supplement 25	48
Meetings	49
Guidlines for the submission of manuscripts	53

The primary aim of ALBERTIANA is to promote the interdisciplinary collaboration and understanding among members of the I.U.G.S. Subcommittee 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 announcements, literature reviews, progress reports, preliminary notes etc. - i. e. those contributions in which information is presented relevant to current interdisciplinary Triassic research.

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Cover: Hindeodus parvus (Kozur and Pjatakova 1976). Specimen number GSC 101761, from the basal Triassic Otoceras woodwardi beds of Lalung, Spiti.

Executive Notes

From the Chair

On the occasion of this, my first report to the STS membership, I would like to take the opportunity to thank our past-Chairman, Maurizio Gaetani, our retiring vice-chair, Hans Rieber, and the past-editor of *Albertiana*, Hans Kerp, for their service to the Subcommission. As the new Chair and Editor take up their positions, we should see some changes in both the composition of the STS, and the dissemination of information via the web. As far as the membership is concerned, as you should all be aware, I have spent the winter soliciting members for their current research interests and seeking renewal of the voting slate and a broader geographic and specialist representation amongst the corresponding membership. I hope this will lead to both greater participation and opportunities for voting member turnaround. This exercise is largely complete and I plan to publish the new STS membership and their research interests in the next *Albertiana*. At this stage, I would like to thank those titular members who volunteered to step down and allow this first phase of renewal to proceed smoothly.

The business of boundary definition is moving along. The basal Triassic GSSP drawn at the appearance of the conodont *Hindeodus parvus* at Meishan in China is now ratified by the IUGS. Yin Hongfu led the working group that finally agreed on this definition and he is to be congratulated for providing us with our first formal stadial definition. Yuri Zacharov is active in leading deliberations on the Induan-Olenekian boundary, which now has three prospects, the Abrek Bay and the Tri Kamnya Cape - Orel sections in Russia, and a soon to be described section in South China; Himalayan sections may also provide a further candidate. The working groups on boundaries of the Middle Triassic, which Maurizio Gaetani continues to lead, are more advanced. The Olenekian-Anisian and Anisian-Ladinian boundaries, with candidates in Romania, Italy and Hungary, have been the focus of intense study in recent years and we must soon come to a final decision on them. The Ladinian-Carnian boundary has a formal candidate in Italy, but new data is anticipated from the Himalaya and North America. I have recently begun work on gathering data for Carnian-Norian boundary candidates, with prospects identified in both Europe and North America. The Norian-Rhaetian boundary has as yet no formal working group. I urge all members to contribute data and opinion about all of these boundaries, ideally through the medium of *Albertiana*,

so that we may soon accomplish some standardization of our scientific language.

Mike Orchard

From the Secretary

Know Your Neighbours

STS members working around the upper and lower boundaries of the Triassic should note the following changes in the IUGS subcommissions for the Jurassic and the Permian.

Triassic-Jurassic Boundary Working Group

The STS Secretary was also the Secretary of the Triassic-Jurassic Boundary Working Group (TJBWG) of the IUGS International Subcommission on Jurassic Stratigraphy (ISJS), the body charged with the selection of a candidate GSSP for the base of the Hettangian Stage and, inter alia, the top of the Triassic System. He was recently asked to become Convenor of the TJBWG and a Voting Member of the ISJS; the new Secretary of the TJBWG is:

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The ISJS publishes a newsletter; for further information contact the Secretary of the ISJS:

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Subcommission on Permian Stratigraphy

The IUGS Subcommission on Permian Stratigraphy (SPS) now has a new Secretary:

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The SPS publishes a newsletter (Permophiles); for further information contact the Secretary of the SPS.

G. Warrington

From the Editor

This is for me the first time serving you, STS members, as the editor of ALBERTIANA and I would like to take the opportunity to thank you and particularly the former editor, Hans Kerp, for your confidence passing this task into my hands. It is a great pleasure for me to present you the new issue of ALBERTIANA in a new layout. Please note that I have written NEW guidelines for the submission of manuscripts at the end of this volume. These are the times of electronic publishing and the internet. It opens not only the possibility of faster distribution of information but also gives way to for more sophisticated data presentations with coloured figures / photographic pictures and computer animations. Thus, Albertiana has not only received a new outfit but is from now on also available as PDF file on our www-server (www.bio.uu.nl/~palaeo). Manuscripts should be submitted as email attachments. Alternatively, you may also transfer your contributions that exceed the email attachment size limit to our ftp server. Our address is <ftp://131.211.28.160>, userID "alb" and the password "alb". Finally, electronic distribution may help us also to reduce the high production and mailing costs. Therefore I would like to ask you to let me know whether or not you prefer to receive ALBERTIANA in future only electronically.

Gückauf!

Wolfram M. Kürschner

Reports

Tetrapod-Based Correlation of the Nonmarine Upper Triassic of Southern Africa

S. G. Lucas & P. J. Hancox

Tetrapod fossils suggest the Molteno Formation in southern Africa is no older than late Carnian, whereas the overlying lower Elliot Formation is most likely Norian in age. However, these are not strong correlations, and additional data are needed to confirm correlation of the southern African Upper Triassic strata.

Introduction

The classic nonmarine Triassic section in the Karoo basin of southern Africa yields tetrapod fossils of the *Lystrosaurus* and *Cynognathus* assemblage zones of the Lower-Middle Triassic. These assemblage zones are the standard by which other tetrapod-bearing units of the Lower Triassic are correlated (Ochev & Shishkin, 1989; Hancox & Rubidge, 1997; Lucas, 1998). More problematic for correlation are the younger Triassic nonmarine strata in southern Africa assigned to the Molteno and Elliot formations (of the now defunct "Stormberg Group"). Here, we review tetrapod-based age assignments of the Molteno and Elliot formations.

Molteno Formation

The lowest formation of the Stormberg Group is the Molteno Formation, which rests unconformably on the Permo-Triassic Beaufort Group (Fig. 1). The youngest strata of the Beaufort Group beneath this unconformity belong to the Burgersdorp Formation, which yields a tetrapod assemblage near its top that includes the Perovkan (early Anisian) index taxon *Shansiodon* (Hancox & Rubidge, 1997; Hancox, 1998, 2000). The Molteno Formation in the Karoo basin attains a maximum thickness of around 600-650 m in the Cape Province, and gradually thins northward to less than 30 m across Lesotho into Natal and the Free State; it is mostly fluvial/alluvial plain deposits with minor coal beds (Turner, 1984; Hancox, 1998).

Whereas fossil plants, insects and conchostracans are locally abundant in the Molteno Formation (Cairncross et al., 1995), vertebrate body fossils are scarce, and represented only by specimens of semionotid fishes (Jubb, 1973). Based on the composition of palynomorph and megafossil plant as-

semblages ("*Dicroidium flora*"), Anderson and Anderson (1993; Anderson et al., 1998) regarded the Molteno to be of Carnian (undivided) age. Hancox (2000) also concluded that at least the lower half of the Molteno Formation is Carnian.

The only tetrapod fossils from the Molteno Formation are footprints. Raath et al. (1990) and Raath (1996) documented small theropod dinosaur tracks (ichnogenus *Grallator*) from the upper part of the formation. The oldest records of dinosaur fossils are Otischalkian (late Carnian: Lucas, 1998), so the Molteno dinosaur tracks suggest late Carnian as a maximum age for the upper part of the formation. Of course, a younger, Norian age cannot be excluded based on the footprint evidence.

Elliot Formation

The Molteno Formation is disconformably overlain by mudrock-dominated facies of the lower Elliot Formation (Fig. 1). Earlier claims of a lateral equivalence of the upper Molteno and Lower Elliot are not supported by field evidence (Hancox, 1998). Indeed, the change in fossil representation and the major facies change at the top of the Molteno Formation argue against its lateral equivalence to the Lower Elliot.

The Elliot Formation approaches a maximum thickness of around 500 m in the southern area of the Karoo basin, and thins to less than 200 m north of Lesotho, following the generalized isopach trend of the underlying Molteno Formation (Visser, 1984; Hancox, 1998, 2000). The lower Elliot contains a tetrapod fossil assemblage (Fig. 1) dominated by prosauropod dinosaurs (common *Euskelosaurus*, rare *Melorosaurus* and *Blikinasaurus*). The assemblage also includes a dinosaur incertae sedis (*Aliwalia*), rare temnospondyls (a large chigutisaurid), a traversodontid (*Scalenodontoides*) and the possible rauisuchian *Basutodon* (Haughton, 1924; Heerden, 1979; Hopson, 1984; Kitching & Raath, 1984; Crompton & Ellenberger, 1957; Galton, 1985a, b; Galton & Heerden, 1985, 1998; Gow & Hancox, 1993; Heerden & Galton, 1997). The lower Elliot also contains a tetrapod ichnofauna (Ellenberger, 1970) that, according to Olsen & Galton's (1984) revision, includes *Brachychirotherium* ("thecondont"), *Tetrasauropus* (prosauropod dinosaur), *Grallator* (theropod dinosaur) and a form of uncertain affinity, *Pentasauropus*. Note that although *Pentasauropus* is only toe imprints, and Ellenberger originally considered it prosauropod, Olsen & Galton (1984) identified it as a dicynodont footprint, a conclusion generally followed by later workers (e.g., Anderson et al., 1998).

The lower Elliot assemblage ("*Euskelosaurus* range

beds dated as Carnian." Gauffre (1993:148) further argued for "a lower Carnian age for the Ischigualasto, Santa Maria and Lower Elliot Formation with their traversodonts-rauisuchians-rhynchosaurs assemblage." There are clearly three problems here: (1) traversodontids are known through the Rhaetian (Hahn et al., 1988; Lucas & Hunt, 1994; Godefroit & Battail, 1997); (2) the Ischigualasto and upper Santa Maria assemblages are late Carnian (Lucas, 1998); and (3) no taxa are shared between Ischigualasto-Santa Maria and the lower Elliot, so their correlation lacks any basis.

Warren & Damiani (1999) assigned a Carnian age to the lower Elliot Formation, following some of the earlier workers. Galton & Heerden (1998) simply accepted the correlation of Gauffre (1993) that the lower Elliot Formation is Carnian, possibly early Carnian. They concluded, therefore, that it includes the oldest record of articulated prosauropods and the first evidence of the diversification of the group.

The *Euskelosaurus* range zone of the lower Elliot must be Triassic as it includes fossils of rauisuchians and traversodontids, taxa not known from post-Triassic beds. The fauna is dominated by prosauropod dinosaurs and thus resembles two other Late Triassic prosauropod-dominated faunas of Norian age—that of the German Knollenmergel and that of the Los Colorados Formation in Argentina. Furthermore, the tetrapod footprint ichnofauna of the lower Elliot Formation is very similar to the footprint ichnofauna of the Rock Point sequence of the Chinle Group, strata of Norian-Rhaetian? age (Lockley & Hunt, 1995).

Furthermore, note that if the Lower Elliot is assigned a Carnian age, then there must be a substantial unconformity representing a hiatus of at least 20 million years between it and overlying Lower Jurassic strata of the Middle Elliot. However, field evidence does not indicate such an unconformity.

We thus assign the lower Elliot Formation a Norian age because: (1) the only other prosauropod-dominated Late Triassic faunas are Norian; (2) *Euskelosaurus* may be an ecological vicar of *Plateosaurus*, as Cooper argued; (3) its footprint ichnofauna is closest to Norian ichnofaunas; and (4) Lower Jurassic strata directly overlie the lower Elliot. However, none of these arguments is incontrovertible.

The middle and upper Elliot contains a more diverse tetrapod assemblage that Kitching & Raath (1984) defined as the "*Massospondylus* range zone." The combined assemblage is dominated by the tritylodontid *Tritlyodon*, which occurs with rare brachyopid amphibian remains, a proganochelyid turtle (Gaffney & Kitching, 1994), sphenosuchian

archosaurs

(*Sphenosuchus* and "pedeticosaurids"), a variety of dinosaurs (the prosauropod *Massospondylus*, a coelurosaur referred to cf. *Syntarsus*, and several ornithischians), other cynodonts including *Pachygenelus* and *Tritheledon*, and the mammals *Megazostrodon* and *Erythrotherium* (Kitching & Raath, 1984). The *Tritlyodon* acme zone is interpreted as a reworked paleosol (Smith & Kitching, 1996, 1997), and is widely, and we believe correctly, assigned an Early Jurassic age. The age of the *Massospondylus* range zone between the *Euskelosaurus* range zone and the *Tritlyodon* acme zone is unclear and we conservatively assign it an Early Jurassic age (Fig. 1).

The overlying Clarens Formation contains a limited fauna that includes taxa of mostly ornithischian dinosaurs and cynodonts common to the underlying upper Elliot assemblage and also is of Early Jurassic age. Olsen & Galton (1984) described the upper Stormberg footprint fauna to include *Batrachopus* (crocodylomorph), theropod tracks referable to *Grallator* (*Anchisauripus*) and *Grallator* (*Eubrontes*), *Anomoepus* sp. (Ornithischia), *Ameghinichnus* sp. (tritylodontid?), and the enigmatic *Episcopopus ventrosus* Ellenberger.

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Fossil succession and sequence stratigraphy of the Upper Triassic of Black Bear Ridge, northeast British Columbia, a GSSP prospect for the Carnian-Norian boundary.

M.J. Orchard, J.P. Zonneveld, M.J. Johns, C.A. McRoberts, M.R. Sandy, E.T. Tozer & G. G. Carrelli

Black Bear Ridge on Williston Lake is one of several important North American reference sections for intercalibrating the ranges of Upper Triassic ammonoids, conodonts, bivalves, ichthyoliths, and brachiopods. The section, largely comprising the Ludington and Pardonet formations, consists of four sequences (BB-I through IV) spanning the uppermost Carnian through Hettangian of the Lower Jurassic. These sequences record deposition on the distal slope and adjacent abyssal plain, west (seaward) of the Pangaeian continental shelf. Fossil fauna and sequence stratigraphy serve to identify significant biological and sedimentary events in the history of the Late Triassic. Each of the four sequences consists of a comparably coarse-grained lowstand succession which grades up through a thick transgressive succession marked by peak abundances of the conodont *Norigondolella* and ichthyolith *Birgeria*. Highstand systems tracts within the study interval are thin, consisting of condensed intervals with few fossiliferous limestone beds. The Carnian-Norian boundary interval lies within sequence BB-1 and the transitional beds between the Ludington and Pardonet Formations, wherein a lineage of several *Metapolygnathus* conodont species provide two potential datums for boundary definition: the base of the Communisti and Primitius zones. Within the same interval, several ammonoids and bivalves occur, and there are several changes in the ichthyolith fauna.

Introduction

This article summarizes the biostratigraphy of one of several important Triassic outcrops on the shores of Williston Lake in northeast British Columbia. This region has produced much of the data on which North American Upper Triassic biochronology is based (e.g. see Tozer, 1967, 1994; Orchard, 1983, 1991b; Orchard and Tozer, 1997). Considerable progress has been possible since the Peace River was dammed in 1967 and its valley was flooded to form Williston Lake. New Triassic outcrops along the

perimeter of the lake were first noted by Tozer in 1979, and in subsequent years (chiefly 1980-1983) Tozer and Orchard examined most of these and made large collections of ammonoids and conodonts. This work continued sporadically through the 1990s and was supplemented by stratigraphic studies by Gibson (e.g. Gibson and Edwards, 1992; 1995) and Zonneveld (e.g. Zonneveld and Gingras, 2000; Zonneveld et al., 1997a, b), and paleontological work by M.J. Johns (ichthyoliths, Johns et al., 1997), C. McRoberts (bivalves), and M. Sandy (brachiopods). G. Muttoni also undertook a magnetostratigraphic study but found the Triassic polarity overprinted (Muttoni et al., in press).

The Black Bear Ridge section lies on the north shore of Williston Lake (Fig. 1), 4 km northeast of the mouth of Nabesche River (NTS Map 94 B/3; zone 10, UTM 497670E, 6215500N). The section begins within the Upper Carnian Ludington Formation, extends through the largely Norian Pardonet Formation, and ends in the Lower Jurassic Fernie Formation. The entire Pardonet Formation is exposed with the exception of a small covered interval. The steeply dipping beds are locally disturbed but there is no major structural complexity.

Of the several chronostratigraphic boundaries recognized in this section, the Carnian-Norian boundary interval offers the most continuous and fossiliferous succession, particularly for conodonts. As such, it is presented as a potential GSSP candidate section (see also Orchard et al., 2000). In the following text, responsibility of individual authors is indicated in parentheses.

Stratigraphy (JPZ/GGC/MJO)

The Black Bear Ridge section has been described in a number of field guides (e.g. Gibson and Edwards, 1992; 1995; Zonneveld et al., 1997; Zonneveld and Gingras, 2000), not all of which have been published; the following stratigraphic summary draws freely on these guides.

The Ludington Formation at Black Bear Ridge consists of approximately 40 meters of interlaminated siltstone, dolostone and minor limestone. These strata are generally laminated to ribbon-bedded, although convolute bedding and slumping also occur. A large olistolith and numerous smaller intraclasts occur at the base of the outcrop. The Ludington is characterized by a comparably clean outcrop gamma profile. Calcite, chert and quartz-lined vugs, many of which are filled with pyrobitumen are also common. The Ludington Formation was deposited on the western Pangea slope, far offshore of the continental coastline (Gibson and Edwards, 1995; Zonneveld and Gingras, 2000). Individual beds and

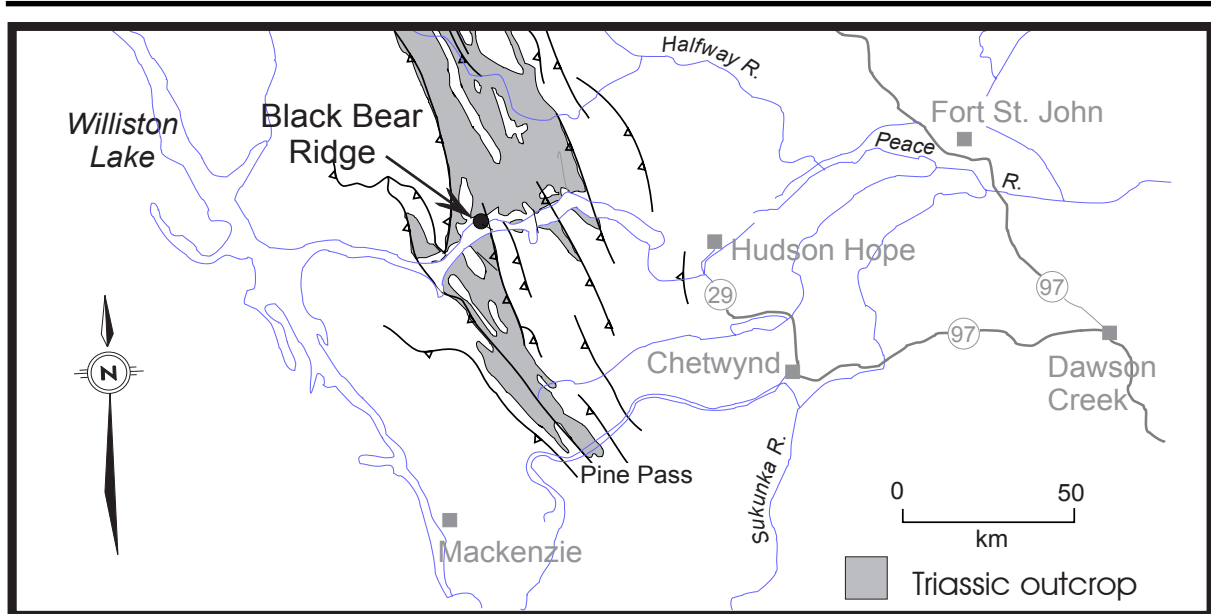


Figure 1: Location of the Blackbear Ridge section on Williston Lake in northeast British Columbia.

bed-sets represent deposition by various submarine mass transport mechanisms including slumping, debris flows and turbidity currents. These deposits represent thanatocoenoses in which individual taxa from shallower settings are brought together in a more distal setting by sedimentary processes. The Ludington Formation represents the deep water equivalent of the primarily shallow water Baldonnel Formation and the primarily marginal marine Charlie Lake Formation.

At Black Bear Ridge, the Ludington Formation is overlain by the Pardonet Formation. Gibson and Edwards (1995) drew the base of the Pardonet Formation between his units 3 and 4 (Fig. 2), where dominantly dolostone beds grade into bioclastic, brachiopod grainstone/packstone layers containing rare ammonoids, halobiids, and the calcite spheres or "pseudo-oolites" that characterize the Pardonet Formation elsewhere on Williston Lake. This study recognizes a transitional zone, approximately 28 meters thick, where clean, silty dolostone is intercalated with dark grey, carbonaceous limestone (Gibson units 4 and 5, Fig. 2). Prior to revision of Upper Triassic lithostratigraphy, these strata had been incorporated into the Baldonnel Formation, subjacent to the base of the Pardonet Formation (Gibson and Edwards, 1992). Outcrop gamma measurements support the transitional nature of this interval between the Ludington and Pardonet Formations (Fig. 2). Deposition within this transitional interval is also dominated by submarine mass transport mechanisms, primarily turbidity currents. Numerous sharp-based bioclastic grainstone/packstone beds in this interval likely represent individual calcareous turbidites. Like those discussed above, bioclastic accumulations in this interval are

thanatocoenoses rather than biocoenoses transported basinward from a variety of settings on the shelf and proximal slope. The monotypic brachiopod packstone beds that characterize this interval may represent a series of events sourced from brachiopod banks on the shelf, similar to those described from the Middle Triassic (Ladinian) Liard Formation (Zonneveld et al., 1997; Zonneveld, in press).

The Pardonet Formation consists of carbonaceous silty limestone, calcareous and dolomitic siltstone and shale, and densely packed bioclastic grainstone beds composed primarily of whole and unabraded bivalve shells. Limestone concretions are common throughout the Pardonet Formation and often contain ammonoids and scattered ichthyosaur bones. The Pardonet Formation is rich in organic carbonaceous matter and has a strong fetid sulphurous odour. Radioactive uranium bound within this organic material has resulted in the jagged, relatively high, gamma ray profile (Figs. 2, 3).

Limestone beds and concretions rich in ammonoids and belemnoids (including *Aulacoceras*) associated with abundant ichthyosaur bones and horizons rich in pseudo-oolites occur approximately 10-20 m above the 'Pardonet gash', a 30 cm thick shale bed characterized by high gamma radiation that occurs near the top of the transitional zone (Fig. 2). These fossil beds are recrystallized and macrofossil extraction is difficult. Overlying beds are silty and sparsely fossiliferous. Richly fossiliferous limestone beds do not occur again until just below (east of) a covered beach interval at 162 metres (Fig. 3).

West of the beach, stratigraphically higher strata contain many rich fossil horizons yielding excellent

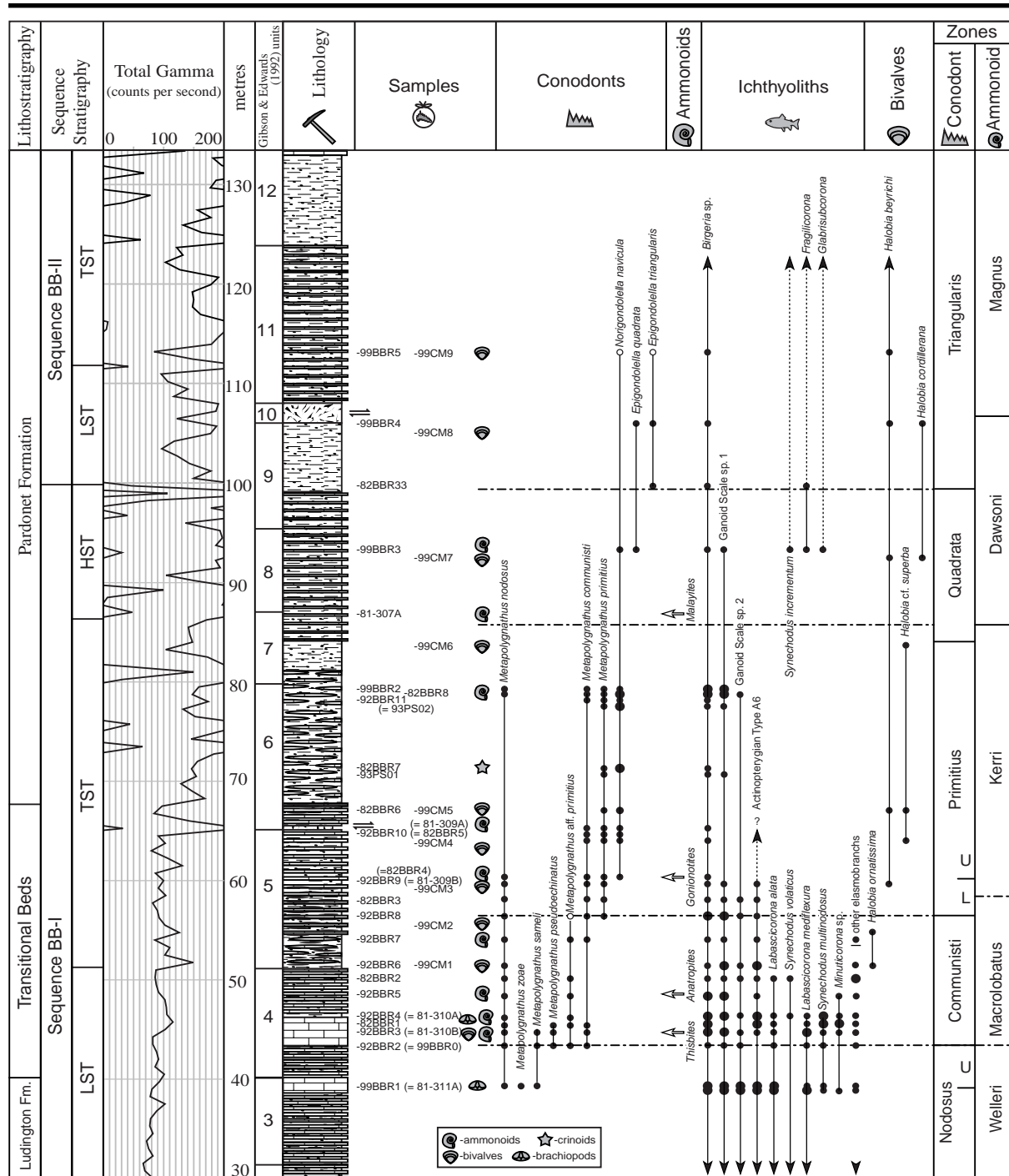


Figure 2: Schematic section of the Upper Carnian-Lower Norian part of the Black Bear Ridge section showing occurrence and distribution of conodonts, ammonoids, ichthyoliths, bivalves, and brachiopods within the Ludington and lower Pardonet formations. The larger dots show the position of abundant specimens of the named taxon. Also shown are units differentiated by Gibson and Edwards (1992). On the left are shown lithostratigraphic and sequence stratigraphic units within the study interval as well as general lithology and outcrop gamma patterns measured with a Scintrex BGS-4 hand-held gamma ray scintillometer. Numbered samples which were taken for conodonts and/or ammonoids, and bivalves (CM) are shown to the right of the lithology column. Ichthyolith fauna was recovered from the former. See text for lithological descriptions.

ammonoid faunas and a succession of wavy, crenulated, bivalve grainstone beds (Fig. 3). Although much of the upper Pardonet is fossiliferous, the best preservation occurs in rare limestone concretions. The distinctive *Monotis* beds comprise much of the

upper 30 m of the Triassic section. They are extremely rich in organic residue, contain a monotypic assemblage of *Monotis subcircularis* and are variably dolomitic, calcareous, silty and shaly.

The Pardonet Formation at Black Bear Ridge was

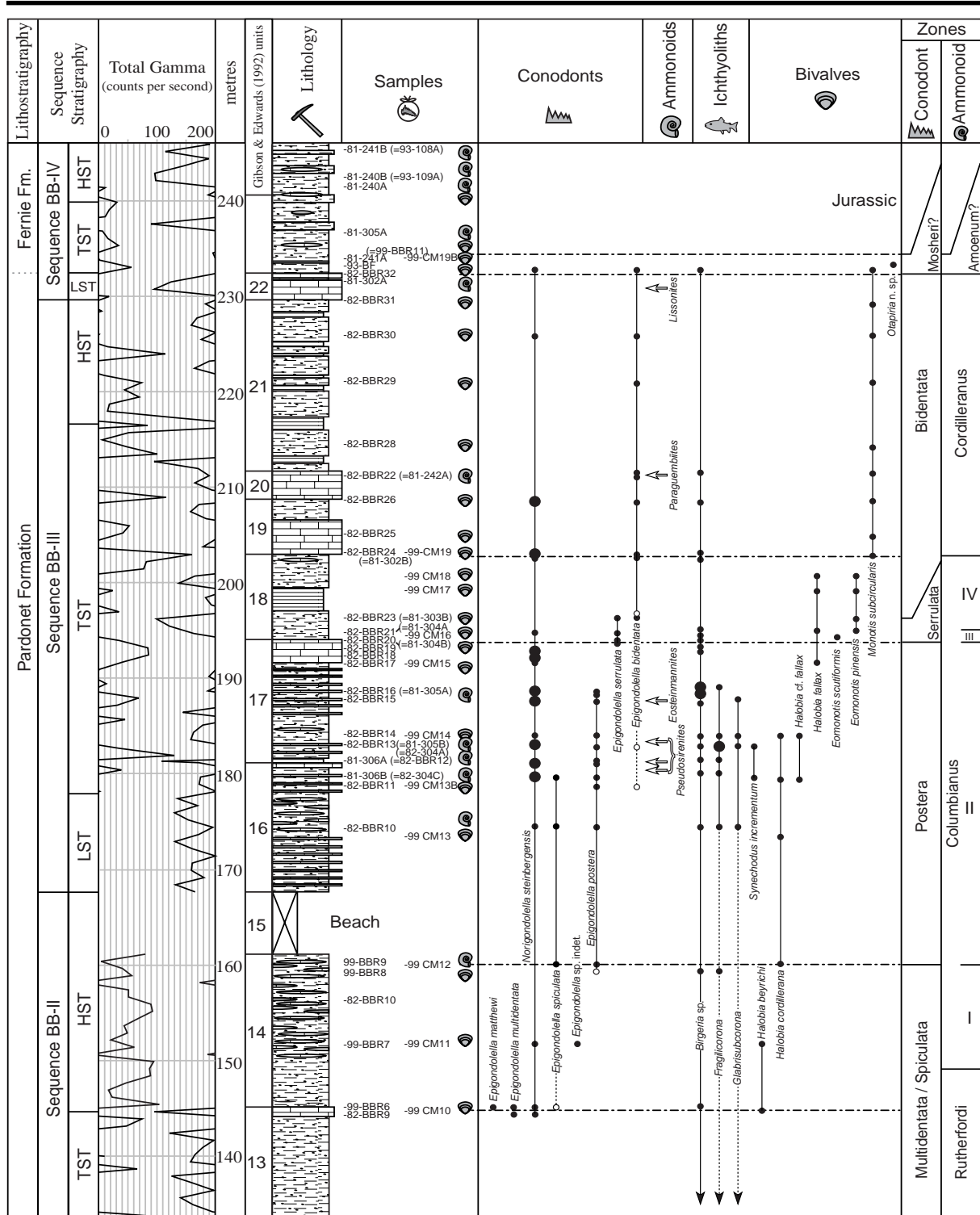


Figure 3: Schematic section of the Middle-Upper Norian and younger part of the Black Bear Ridge section showing occurrence and distribution of conodonts, ammonoids, ichthyoliths, and bivalves within the upper Pardonet and lowest Fernie formations. Other features as in Figure 2.

deposited in a deep water setting, likely on the distal slope or abyssal plain, well offshore of the west Pangaea coastline. Its deposition followed a major transgression and represents the deepest water deposition in the Upper Triassic of western Canada. Lithological and faunal attributes are consistent with

a deep water, restricted anoxic basin environment well below storm wave-base.

Few, if any, of the bioclastic beds in the Pardonet represent in situ communities. Bioclastic material in most of these beds consists of a mix of whole

and fragmentary material which is oriented primarily parallel to bedding. In rare cases, the bioclasts (ammonoids and bivalves alike) exhibit crude imbrication. Many of these beds are sharp based and are ungraded to normally graded. These beds are interpreted as calcareous turbidites deposited on the distal slope and abyssal plain below the Pangaeon continental shelf (Zonneveld and Gingras, 2000). The absence of coarse (sand-sized or larger) clastic material reflects deposition during a period of sediment starvation on the shelf and slope. The origin of the dense *Monotis* beds is interpreted to result from similar processes. Although the *Monotis* shells are primarily whole and unabraded, they occur primarily in a convex-up orientation (>80% of valves), implicating current processes in the development of these deposits.

Triassic strata in the Western Canada Sedimentary Basin (WCSB) have been subdivided into three "facies assemblages" reflecting large scale cycles in regional sea level; I) Early Triassic (Griesbachian through Spathian), II) Middle Triassic (Anisian through early Carnian) and III) Late Triassic (Carnian through Rhaetian) (Gibson and Barclay, 1989). The study interval comprises the upper portion of the last of these large scale cycles. It comprises an overall aggradational succession of four third-order sequences (BB-I, BB-II, BB-III, and BB-IV) based on lithologic criteria, outcrop gamma characteristics and correlation with other outcrop sections (Figs. 2 and 3). Fluctuations in sea-level responsible for these sequences and their bounding surfaces were likely driven by both eustatic and regional tectonic influences. Each of the four sequences identified here has been separated into lowstand, transgressive and highstand systems tracts (Figs. 2 and 3). Evidence of subaerial exposure was not noted at any of the sequence boundaries. These surfaces are interpreted to represent the basal, conformable equivalents to subaerial unconformities landward (east) of the study area.

In general, lowstand systems tracts in the study interval consist of aggradational successions of calcareous turbidites and (in the case of sequence BB-I) by debris flows and slumping. These intervals generally include the coarsest sediment in the study interval and are characterized by relatively clean (low) outcrop gamma patterns (Figs. 2 and 3).

Transgressive systems tracts within the study interval are characterized by outcrop gamma profiles that are increasingly spiky upwards (Figs. 2 and 3). These intervals represent periods of relative sediment starvation in the basin. Although bioclastic turbidites do occur, these intervals are dominated primarily by suspension deposition and may be considered to be condensed intervals. Increasing wa-

ter depth in these intervals is supported by spikes in the quantity of *Norigondolella* and *Birgeria* elements (Figs. 2 and 3). Highstand systems tracts in the study interval occur as relative sea-level reached a maximum and sedimentation in the basin gradually began to outpace the increase in accommodation space. These intervals are generally much thinner than subjacent transgressive systems tracts. The contact between highstand and overlying lowstand systems tracts are picked where the proportion and thickness of coarser bioclastic beds shows a sharp increase.

Embry (1997) identified four globally correlatable sequences and sequence boundaries in the study interval: 1) near Carnian-Norian boundary; 2) mid-Norian boundary; 3) near Norian-Rhaetian boundary; and 4) near Triassic-Jurassic (Rhaetian-Hettangian) boundary. The base of sequence BB-I occurs beneath the study interval, within the upper Carnian and may be equivalent to the global near Carnian-Norian sequence boundary. Two mid-Norian sequence boundaries (BB-I\BB-II and BB-II\BB-III) are interpreted to occur within the Black Bear Ridge section. Additional work is needed to ascertain which, if either, is correlative to the globally recognized sequence boundary.

The upper surface of the top *Monotis* bed contains small, discontinuous patches of phosphatic granules. This surface has previously been interpreted as an erosional unconformity and interpreted as both the Fernie-Pardonet lithostratigraphic contact and the Triassic-Jurassic contact (Gibson and Edwards, 1992). However, evidence of an erosional unconformity at this boundary is not evident and the presence of conodonts and possible Rhaetian bivalves in dolomitic siltstone beds immediately above this surface demonstrates a Triassic age for some of these strata. The Triassic-Jurassic contact occurs somewhere within the dolomitic siltstone interval between 233 and 236 meters (Fig. 3), the level of the lowest reported Hettangian ammonoids (see Tozer, 1982). The surface at the top of the abundant *Monotis* beds is here interpreted as a transgressive surface, below wave base and may represent sediment starvation in a deep water setting. The boundary between sequence BB-III and sequence BB-IV apparently occurs near the Rhaetian-Norian boundary and may be coeval with the global boundary discussed in Embry (1997). A sequence boundary equivalent to the Triassic-Jurassic boundary has not been observed within the study area.

Gibson and Edwards (1992; 1995) measured a total of about 212 m for the Black Bear Ridge section, with the Pardonet Formation attaining a thickness of about 182 m and the Ludington about 30 m. Cumulative thicknesses in Figures 2 and 3 were com-

piled over several visits, most recently May, 2000. The zero datum used here has been chosen a few meters below a large olistolith within the Ludington Formation, 40 meters below the base of the Ludington-Pardonet transitional facies. The total outcrop thickness as presented here is 245 meters (Ludington, 40 meters; transitional zone, 28 meters; Pardonet, 180 meters). Discrepancies between this and earlier studies are the result of shifting beach outcrops between successive visits, inclusion here of lower Jurassic strata into the Pardonet Formation, and the transitional nature of the Ludington-Pardonet lithostratigraphic contact. Reliable datums include the main brachiopod bed near the base of the section (~39 meters), the radioactive 'gash' within the lower section (~66 meters, Fig. 2), and the base and top of the *Monotis* beds in the upper part of the section (~203 and ~232 respectively, Fig 3).

Conodonts (MJO)

Conodont faunas have been collected from throughout the Black Bear Ridge section and provide a rather complete framework for Late Carnian through Late Norian time. The lowest conodont faunas come from the turbiditic shell beds of the 'transitional facies'. The lowest fauna (Fig. 2, 92BBR-1) contains predominantly unornamented to weakly nodose metapolygnathids assigned to the *Metapolygnathus* ex gr. *nodosus* Hayashi. More ornate forms correspond to *Metapolygnathus samueli* Orchard and rarely *M. zoeae* Orchard. This association identifies the Upper *Nodosus* Zone of Orchard (1991a). Several samples taken across 1 m of shell beds containing brachiopods and rare halobiids and ammonoids reveal a major diversification of the conodont fauna characterized as the base of the *Communisti* Zone (Fig. 2, 92BBR-2). *Metapolygnathus communisti* Hayashi appears concurrently with a variety of *M. pseudoechinatus* Kozur morphotypes, regarded as a proxy for the *Communisti* Zone in western Canada. Both *Metapolygnathus* ex gr. *nodosus* and *M. samueli* occur at this level but amongst the former considerable variety leads to the recognition of several morphotypes, one of which is here called *M. aff. primitius* (Mosher). Unlike the index of the succeeding zone, this distinctly nodose form lacks the consistent node differentiation and low posterior platform of *M. primitius* as shown by Orchard (1991a, Pl. 3, F) but the trend toward that species is clear.

Above the brachiopod beds (Fig. 2, 92BBR-5, 6, 7), the sharp-noded species disappear, and most collections are dominated by *Metapolygnathus* ex gr. *nodosus* through to near the top of the siliceous facies (lower Unit 5 sensu Gibson). At this level (92BBR-8), a major faunal shift is evident and *M.*

primitius becomes the dominant metapolygnathid. A little higher (92BBR-9), within the typical concretionary facies of the Pardonet Formation, *Norigondolella navicula* (Mosher) appears. This datum marks the base of the "Upper" *Primitius* Zone in the Williston Lake exposures (Orchard, 1983), but the taxon is rare at first and occurs sporadically through the *Primitius* Zone, as it does elsewhere (Carter and Orchard, 2000; Orchard et al., 2000). Peak abundance of *Norigondolella navicula* occurs only in higher collections from the *Aulacoceras*-bearing pseudo-oolite beds collections near the top of the *Primitius* Zone (Fig. 2). Overlying strata is characterized by siltier and less fossiliferous beds but single conodont collections nevertheless document the succeeding Lower Norian *Quadrata* and *Triangularis* zones (99BBR-3, 4).

Richly fossiliferous limestone beds re-appear in the Middle Norian (Fig. 3). The *Multidentata* Zone is succeeded by the *Spiculata*, *Postera*, and *Serrulata* zones in succession (Orchard, 1991b). The first two imply levels corresponding to the *Rutherfordi* and *Columbianus* I ammonoid zones although neither macrofauna is certainly identified at Black Bear Ridge. The *Postera* Zone, which occurs through 10+ m of section with ammonoids of *Columbianus* Subzone II, is characterized by abundant specimens of *Norigondolella steinbergensis* (Mosher), the second such 'flood' of the genus in the Black Bear Ridge section. Conodonts of the *Serrulata* Zone are associated with the overlying species of *Eomonotis* bivalves.

Upper Norian *Monotis* coquina and associated strata extend through about 30 m of section at Black Bear Ridge (Fig. 3). The *Bidentata* Zone fauna occurs both with *Monotis* bivalves and more abundantly in limestone concretions with the ammonoid *Paraguembillites*. Variation in the conodont faunas are noted: abundant *Norigondolella steinbergensis* occurs in the lower part of the *Monotis* coquina, but indices of *Epigondolella* dominate the limier ammonoid beds. The stratigraphically highest conodonts occur in a small limestone concretion sitting directly above the youngest bedding surface of *Monotis*. These are examples of *Epigondolella* ex gr. *bidentata* Mosher, including a few large elements resembling the younger *E. mosheri* Kozur and Mostler (Orchard, 1994). This species is known overlying *Monotis* strata at a single locality elsewhere on Williston Lake (Ne Parle Pas Point), that is in the "*Rhacophyllites* beds" assigned to the Rhaetian *Amoenum* Zone. The data is sparse but provides an indication of Rhaetian strata.

Ammonoids (ETT)

Well preserved and locally abundant ammonoids occur in the Middle and Upper Norian, and in the overlying Lower Jurassic strata at the Black Bear Ridge section. Ammonoids also occur in Upper Carnian and Lower Norian but they are less common and difficult to separate from the matrix. Many of these ammonoid faunas are reported by Tozer (1994, p. 344-5, indicated below as *; see also Tozer, 1982). The notable features of the ammonoid succession are the several levels of the Columbianus Subzone II fauna, and the superimposition of two *Eomonotis* faunas and two subzones of the Upper Norian Cordilleranus Zone. The Lower Jurassic (Hettangian) succession is also unique (currently under study by R. Hall, U. of Calgary). Available data are summarized in ascending stratigraphic order below with both field numbers (see Fig. 1) and GSC locality numbers indicated. These data enable the other faunal elements to be calibrated with the standard Triassic ammonoid biochronology.

99-BBR0 = GSC loc. C-304377. Ammonoid indet.

81-310A = GSC loc. 98555. Ammonoids indet.

82-BBR1 = GSC loc. C-101002. *Thisbites* sp. indet.

92-BBR5 = GSC loc. C-201931. *Anatropites* sp. indet.

81-309B = GSC loc. 98554. *Gonionotites* sp. indet.

81-307A = GSC loc. 98553. cf. *Malayites dawsoni* McLearn. Approximates 82-305B = 98872.

81-306B = *GSC loc. 98552. *Pseudosirenites pardoneti* (McLearn), *Mesohimavatites columbianus* (McLearn), *Distichites canadensis* McLearn, *Leiodistichites ursidens* Tozer, *Helicites decorus* McLearn. Repeated as 82-304C = 98770.

81-306A = *GSC loc. 98551. *Pseudosirenites pardoneti* (McLearn), *Himavatites multiauritus* McLearn, *Distichites canadensis* McLearn, *Helicites decorus* McLearn, *Episculites teres* (McLearn).

81-305B = *GSC loc. 98550. *Pseudosirenites pardoneti* (McLearn), *P. pressus* (McLearn), *Distichites canadensis* McLearn, *Leiodistichites ursidens* Tozer, *Helicites decorus* McLearn. Repeated as 82-304A = 98868.

81-305A = *GSC loc. 98549. *Eosteinmannites orientalis* Tozer, *Himavatites appinatus* Tozer, *Helicites decorus* McLearn, *Parajuvavites canadensis* Tozer. Repeated as 82-303A = 98867.

81-304B = GSC loc. 98548. *Eomonotis scutiformis* (Teller)

81-304A = GSC loc. 98547. *Eomonotis pinensis* (Westermann)

81-303B = GSC loc. 98546. *Eomonotis pinensis*

(Westermann)

81-242A = *GSC loc. 98534. *Paraguembilites ludingtoni* Tozer, *Monotis* sp. Repeated as 82-301A = 98865.

81-302A = *GSC loc. 98545. *Lissonites* sp. indet., *Monotis* sp.

81-305A = GSC loc. 98871. *Primapsiloceras?* sp.

81-240A = GSC loc. 98531. *Psiloceras calliphyllum* (Neumayr), *phylloceratids* (Tozer, 1982).

81-240B = GSC loc. 98532; 93-109A = GSC loc. C-209258. *Curviceras* sp.

81-241B = GSC loc. 98533; 93-108A = GSC loc. C-209257. *Caloceras* sp.

82-316F = GSC loc. 98894. *Schlotheimia* sp.

82-316G = GSC loc. 98895. *Pseudaetomoceras* sp.

In addition to these levels, Tozer collected faunas of both the *Juvavites magnus* Subzone 2 and Columbianus 3 from talus on the west slope of Black Bear Ridge prior to dam construction and flooding. These are respectively:

64-137D = *GSC loc. 64636. *Dimorphoceras caurinum* (McLearn), *D. ursinum* Tozer, *Juvavites concretus* McLearn.

64-138C = *GSC loc. 64638. *Paragymnites symmetricus* (Mojsisovics), *Steinmannites* sp. indet.

McLearn (1960) also collected several rich examples of the Columbianus Subzone 2 fauna (*GSC locs. 9741, 9744, 9745; see Tozer, 1994, p. 295-6).

Bivalves (CAM)

The continuous sequence of the Pardonet Formation and its transitional facies at Black Bear Ridge provides documentation of a *Halobia* and *Monotis* succession unparalleled throughout the North American Cordillera. Biostratigraphic resolution is best in the lower and uppermost parts of the Pardonet Formation in which diagnostic halobiid and monotid species occur. In particular the succession of *Halobia ornatissima* Smith overlain by *H. beyrichi* (Mojsisovics) indicates the traditional Carnian/Norian stage boundary which, based on *Halobia* species, lies between beds 99CM-2 and -3 (Fig. 2). *Halobia beyrichi* (*H. alaskana* Smith is considered a junior synonym) is known to occur throughout the Cordilleran terranes from Alaska to Nevada. It is well rep-

resented from Vancouver Island and the Queen Charlotte Islands of British Columbia (Tozer, 1967; Carter et al., 1989; and undescribed GSC collections), southeast Alaska (Muffler, 1967), as well as from the Willowa Terrane Oregon (McRoberts, 1993), and the Shoshone Mountains of Nevada where it occurs with the ammonoid *Stikinoceras kerri* (Silberling, 1959; and Silberling and Tozer, 1968, Kristan-Tollmann and Tollmann, 1983). In the Tethys realm and the western Pacific regions the place of *H. beyrichi* is replaced by *H. styriaca* (Mojsisovics), a key zonal fossil of the earliest Norian which is conspicuously absent from North America (e.g. Gruber, 1976).

In the higher parts of the Pardonet Formation, *H. cordillerana* Smith together with *H. beyrichi* indicates the probable occurrence of the Dawsoni and Magnus zones. *Halobia cordillerana* is known from throughout the Cordillera with significant occurrences in Nevada (*H. hochstetteri* Mojsisovics listed by Kristan-Tollmann and Tollmann (1983) from the Luning Formation is here treated as a synonym for *H. cordillerana*), California, possibly northeast Oregon, and southern, eastern, and arctic Alaska (see McRoberts, 1997). In British Columbia, this species was known as *Halobia pacalis* McLearn, which is now considered a junior synonym.

The bivalve succession in the Middle Norian Columbianus Zone and the Upper Norian Cordilleranus Zone is demonstrated in the succession of *Eomonotis* and *Monotis* species. *Eomonotis pinensis* (Westermann) is the more common Middle Norian species (Fig. 3, 99CM-17, -18), but earlier collections made by E.T. Tozer (see above) also included a lower horizon with *E. scutiformis* (Teller) (Fig. 3, 81-304B); both species apparently occur within the upper range of *Halobia fallax* Mojsisovics. *Eomonotis* is well known from numerous middle Norian localities elsewhere in northeastern British Columbia (e.g. Westermann, 1962) as well as in several allochthonous terranes such as the Nixon Fork and Alexander terranes of central and southern Alaska (see Silberling et al., 1997). In all of these localities it occurs in the upper part of the Middle Norian Columbianus Zone where is often associated with the ammonoid *Himavatites* (see for example Tozer, 1979; Silberling et al., 1997).

At Black Bear Ridge, the *Eomonotis pinensis* beds are overlain by beds dominated by Upper Norian *Monotis subcircularis* Gabb, perhaps one of the most abundant of monotids in the North American Cordillera and eastern Asia (see for example Tozer, 1982; Silberling et al., 1997). The first appearance of *Monotis subcircularis* is taken as the base of the Cordilleranus Zone. Overlying the uppermost *Monotis subcircularis* bed occur a probably new and

undescribed species of *Otapiria*. While several species of *Otapiria* are well known from the Norian and Rhaetian of the circum-Pacific (e.g. New Zealand, Japan, and Russia) and Tethys (e.g. Austria) they become increasingly common in Lower Jurassic strata. The specimens recovered from Black Bear Ridge are Rhaetian or Hettangian.

The transitional beds from the Pardonet Formation to the Jurassic Fernie Formation contain abundant specimens belonging to at least two pectinacean genera, *Entolium* and *Agerchlamys*. Similar pectinacean specimens occur from approximately the same stratigraphic horizon elsewhere in northeastern British Columbia (e.g. Ne Parle Pas Point, Pine Pass; Tozer, 1982), where some appear to be Triassic. A complete taxonomic assessment of these "Pecten Beds" awaits further study.

Ichthyoliths (MJJ)

The study of ichthyolith distributions in the Upper Triassic strata of northeastern British Columbia (Johns et al., 1997) suggest that ichthyoliths are longer ranging in deeper water facies (e.g. outer shelf to slope Pardonet Fm.) but far more variable and abundant in the shallower and thicker Baldonnel Formation and its equivalents (Johns et al., 1999, 2000a,b, 2001). The section at Black Bear Ridge provides an excellent opportunity to compare what appear to be more distal ichthyolith assemblages in the sub-Pardonet transitional beds (Fig. 2) to more proximal assemblages to the north and east.

Ichthyoliths recovered from the transitional beds between the Ludington and Pardonet formations (Nodosus and Communisti conodont zones) at Black Bear Ridge are abundant and diverse. The lowest level, corresponding to the Upper Nodosus conodont Zone (Fig. 2, 81-311A & 99BBR-1), contains abundant actinopterygian (bony fish) teeth and ganoid scales in addition to abundant *Labascicorona mediflexura* Johns and a variety of other elasmobranch (shark) scales and teeth (Johns et al., 1997). The next ichthyolith-rich and distinct level occurs in the Communisti Zone (Fig. 2, 81-310B, 82BBR-1, 92BBR-2, 3 & 4). It is marked by a peak abundance of the elasmobranch tooth *Synechodus multinodosus* Johns, *Minuticorona* scales, actinopterygian teeth and scales, and other ichthyoliths; this interval represents the type locality for the *S. multinodosus* concurrent-range ichthyolith Zone (Johns et al., 1997). Just above this level (Fig. 2; 92BBR-5) there is a change in the distribution of ichthyoliths. *Birgeria* sp., Type A6, and ganoid scale sp. 1 are abundant and there are only a few small elasmobranch scales. These beds show a shallower water *S. multinodosus* assem-

blage followed by a deeper water *Birgeria*-abundant assemblage.

Sample 82BBR-2 contains an odd diversity and abundance of ichthyoliths including: 1) elasmobranch scales commonly observed from shallow water and older rocks in the region that do not occur in the *Nodosus* and *Communisti* zones (see Johns et al., 1997, p. 112 and compare to p. 100-107); 2) other actinopterygian and elasmobranch ichthyoliths that are commonly found in the *Communisti* Zone (Fig. 2); and 3) an absence of diagnostic taxa of the *S. multinodosus* ichthyolith Zone (including *S. multinodosus*, *Minuticorona*, and *Labascicorona alata*). Just above this level (Fig. 2; 92BBR-6), no elasmobranch teeth or scales were recovered and actinopterygian scales and teeth were common to abundant in the sample. The mixing of shallower water ichthyoliths presumably arose from downslope transport in turbidites during the system lowstand and deeper water ichthyoliths (92BBR-6) returned during the transgressive system tract. Above, in sample 92BBR-7, a new ichthyolith assemblage occurs: it includes the last examples of the elasmobranchs present in older units, and is correlative to the uppermost Baldonnel Formation at other locations.

Ichthyoliths in the Pardonet Formation throughout northeastern British Columbia predominantly contain *Birgeria*. However, in at least three levels at Black Bear Ridge, the *Synechodus incrementum* assemblage (from shallower water than the *Birgeria* assemblage) occurs, that is within the *Quadrata*, *Multidentata/Spiculata* and *Postera conodont* zones. In sample 92BBR-8 (Fig. 2), *Birgeria* and ganoid scale sp. 1 are very abundant. For about 30 additional metres of strata, fish diversity remains low (Fig. 2). Near the top of the Upper Primitius Zone (Fig. 2, 82BBR-8) there is another peak abundance of *Birgeria* sp. and ganoid scale sp. 1 in addition to a rare occurrence of ganoid scale sp. 2 (Fig. 2). Higher strata in the Pardonet Formation (Fig. 2, 99BBR-3, 82BBR-33) contain the first new elasmobranchs typical of the Norian (Johns et al., 1997), including *Synechodus incrementum* Johns, and form species of *Fragilicorona*, and *Glabrisubcorona*. The *S. incrementum* assemblage repeats in 99-BBR-8, and in the set of samples 82BBR-10, 82-BBR-12, 81-306A, -306B, -305B, and 82-BBR-14 and 15 (Fig. 3) in the *Postera conodont* zone. The remaining Upper Norian strata at Black Bear Ridge mainly contain *Birgeria* ichthyoliths. Some new ichthyoliths were found in the ?Rhaetian (Fig. 3; 93-BF).

Brachiopods (MRS)

Low diversity brachiopod faunas are known from a number of localities on Williston Lake, and the Upper Carnian fauna at Black Bear Ridge has counterparts at the nearby Brown Hill and Pardonet Hill. The brachiopods are generally very well preserved in carbonates, often "popping out" of the sediment; only the high level of induration of some of the carbonate layers prevents their easy removal from matrix for study. The Black Bear Ridge brachiopod fauna is concentrated in several layers within a 60 cm bed and is composed of monotypic rhynchonellids referred to *Piarorhynchia winnema* (Smith).

Although the brachiopods have yet to be subjected to detailed taxonomic investigation, the species has been interpreted as quite varied morphologically. Other authors have considered that varieties or subspecies may be present. Ager and Westermann (1963) recorded two species, *P. winnema* and *P. hamiltonensis*, from the Carnian of Caribou Ridge in the Mount Laurier area of northeastern British Columbia; these are thought to be probable synonyms. Their material was composed of smaller specimens compared with that of Smith (1927), who first recorded the species from the Hosselkus Limestone of Brock Mountain in Shasta County, California. The material from the rhynchonellid horizons at Williston Lake show both small and larger forms, and some of these resemble other species that Smith identified; it seems likely that these are also synonyms of *P. winnema*. There have been no other records of the taxa in North America to date.

Although first described from the Jurassic, *Piarorhynchia* is known to range into the Triassic. The genus has been identified from the latest Triassic of southern Europe, and Dagys (1974) recorded the range as Carnian - Rhaetian. Ager and Westermann (1963) regarded the British Columbian occurrences of *Piarorhynchia winnema* as Lower Carnian although this was not substantiated. The occurrences at Black Bear Ridge and elsewhere on Williston Lake are high in the Carnian.

Intercalibration and Summary

An integrated bio- and sequence-stratigraphic summary of the Black Bear Ridge section is summarized below in point form emphasizing the essential features of the succession.

1. The base of the section occurs within the upper Ludington Formation. A relatively low diversity association of Upper *Nodosus* Zone conodonts occurs at the top of the Ludington Formation (Fig. 2). Ichthyoliths are both diverse and abundant and in-

clude the elasmobranch *Synechodus multinodosus* and a peak abundance of ganoid scale sp. 2.

2. The upper Ludington Formation and the base of the Ludington-Pardonet transitional interval is interpreted as a lowstand succession characterized by event beds deposited by a variety of submarine mass transport mechanisms including turbidity currents, slumps and debris flows. Monotypic, brachiopod-bearing, bioclastic limestone beds within this succession likely represent faunas transported basinward by turbidity currents.

3. The study interval represents deposition on the slope and abyssal plain west of the Pangaeian continental shelf. It has been subdivided into four sequences (BB-I, BB-II, BB-III and BB-IV, Figs. 2 and 3), bound by the basinward conformable equivalents to subaerial unconformities. Although, with the exception of bioclastic material, the entire succession is fine-grained, sequence boundaries can be identified by an increase in the proportion of sharp-based bioclastic beds (calcareous turbidites). These surfaces are readily identified on outcrop gamma profiles by an abrupt decrease in gamma radiation. Transgressive systems tract are characterized by a gradually upward increasing gamma profile and a decrease in the quantity of bioclastic turbidites. Highstand systems tracts are characterized by fine-grained deposits and high gamma radiation.

4. At 43 m, Communisti Zone conodonts appear with rare Macrolobatus Zone ammonoids in bioclastic grainstone beds of *Piarorhynchia winnema* brachiopods. This level marks the peak abundance of *Synechodus multinodosus* and *Minuticorona* ichthyoliths. *Halobia ornatissima* ranges within the upper part of the Communisti Zone, where several changes in ichthyolith fauna are noted.

5. At ~56 m, Primitius Zone conodonts appear above the commonly cherty beds and at the base of the concretionary beds of the Pardonet Formation. Associated ichthyoliths are abundant, low diversity actinopterygian teeth and ganoid scales, with most of the older elasmobranch teeth and scales having disappeared. This interval occurs within the early transgressive systems tract of sequence BB-I. A little higher *Halobia beyrichi* appears.

6. From ~70 m - ~80 m, there is a peak abundance of *Norigondolella navicula* within the Primitius Zone. This interval includes rich ammonoid and belemnoid

beds that also contain "pseudo-oolites". Extremely abundant actinopterygian ichthyoliths occur at 38 m. Dawsoni Zone ammonoids and *Halobia* cf. *superba* are identified within these strata, which are thought to represent an interval of sediment starvation in the basin during maximum transgression.

7. From ~115 m through ~144 m, monotonous, generally unfossiliferous strata bear uncommon levels of Lower Norian Quadrata and Triangularis Zone conodonts, and the bivalve *Halobia cordillerana*. New elasmobranchs - *Synechodus incrementum*, *Fragilicorona*, and *Glabrisubcorona* - occur within the Quadrata Zone. Fossiliferous strata become more common in Middle Norian Multidentata and Spiculata zones, which include the last *Halobia beyrichi*. This interval occurs within the late lowstand and early transgressive system tracts of sequence BB-II

8. At ~160 m - ~194 m, diverse ammonoids of Columbianus Subzone 2, Postera Zone conodonts, the bivalves *Halobia cordillerana* and *H. cf. fallax*, and abundant ichthyoliths of the *Synechodus incrementum* Zone occur in limestone nodules. From ~178 m through the end of the Postera Zone, a peak abundance of *Norigondolella steinbergensis* is interpreted to represent another interval of sediment starvation in the basin during maximum transgression of sequence BB-III.

9. Between ~194 m and ~202 m, a succession of *Eomonotis scutiformis* followed by *E. pinensis* occurs within the range of *Halobia fallax*. Serrulata Zone conodonts are associated with the lower part of this succession.

10. Above ~203 m, Upper Norian *Monotis* grainstone/packstone beds and Bidentata Zone conodonts occur together throughout a succession that includes two ammonoid faunas characterized by *Paraguembillites ludingtoni* and *Lissonites* sp. These represent the Cordilleranus subzones 1 and 2. *Norigondolella* is very common in the lower 5 m of the *Monotis* beds, reflecting deposition during continued transgression.

11. Above ~232 m, a very thin Rhaetian succession is tentatively identified on the basis of *Otapiria* sp. and possible Mosheri Zone conodonts that abruptly overlie *Monotis* grainstone/packstone beds. The upper surface of the top *Monotis* bed is interpreted

as a transgressive surface based on the abrupt change in lithology and the presence of a discontinuous phosphate granule lag. Other bivalves of the overlying "Pecten Beds" include *Entolium* and *Agerchlamys* and may be of latest Triassic or earliest Jurassic age. New ichthyoliths occur at this level.

12. At least six levels of Lower Jurassic ammonites were collected from within the basal Fernie Formation during preliminary investigations. Subsequent work has located 30 separate horizons of ammonites over 22 m of Fernie Formation, and indications are that at least parts of the Lower, Middle, and Upper Hettangian are represented (R.Hall, pers. comm.).

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Report on the Lower Triassic of Chaohu, Anhui Province, China

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With the final decision of the Global Stratotype Section and Point (GSSP) of the Permian and Triassic boundary (PTB), the Triassic has its first GSSP and the base defined at last. The next step in the Triassic study is to extend and correlate this GSSP into every parts of the Triassic as well as to establish the other chronostratigraphic GSSPs of the Triassic.

The GSSP of the PTB is located in a protected quarry at Meishan, Changxing County, Zhejiang Province, China, where the uppermost Permian Changhsingian stage was proposed, and the Lower Triassic at Meishan Section can be well traced on the hillside

from the boundary up to the top of the hill. The index fossils and some relative forms of six Lower Triassic conodont Zones were found at the section: *Hindeodus parvus* Zone, *Isarcicella isarcia* Zone, *Clarkina carinata* Zone, *Neospathodus kummeli* Zone, *N. cristagalli* Zone and *N. waageni* Zone (Tong and Yang, 1998). This is an excellent section containing the most lower Lower Triassic conodont Zones in South China. The *Neospathodus waageni* is believed to belong to the Olenekian (Sweet et al., 1971). The continuous sequence from the PTB up to the *N. waageni* Zone is quite positive and valuable for the serialized studies, such as magnetostratigraphy, chemostratigraphy, cyclostratigraphy and so on, to define the next chronostratigraphic boundary, that is the Induan and Olenekian boundary in the Triassic. Unfortunately, at Meishan section as well as in its neighboring area the uppermost of the Lower Triassic was eroded off. Moreover, the Lower Triassic in Meishan area is made mostly of carbonate rocks, in which ammonoids and bivalves are rare except for the lowest part, about ten meters, which is predominated by argillaceous rocks, probably condensed (Tong and Yin, 1998), and contains rich specimens of the *Ophiceras-Claraia* Assemblage.

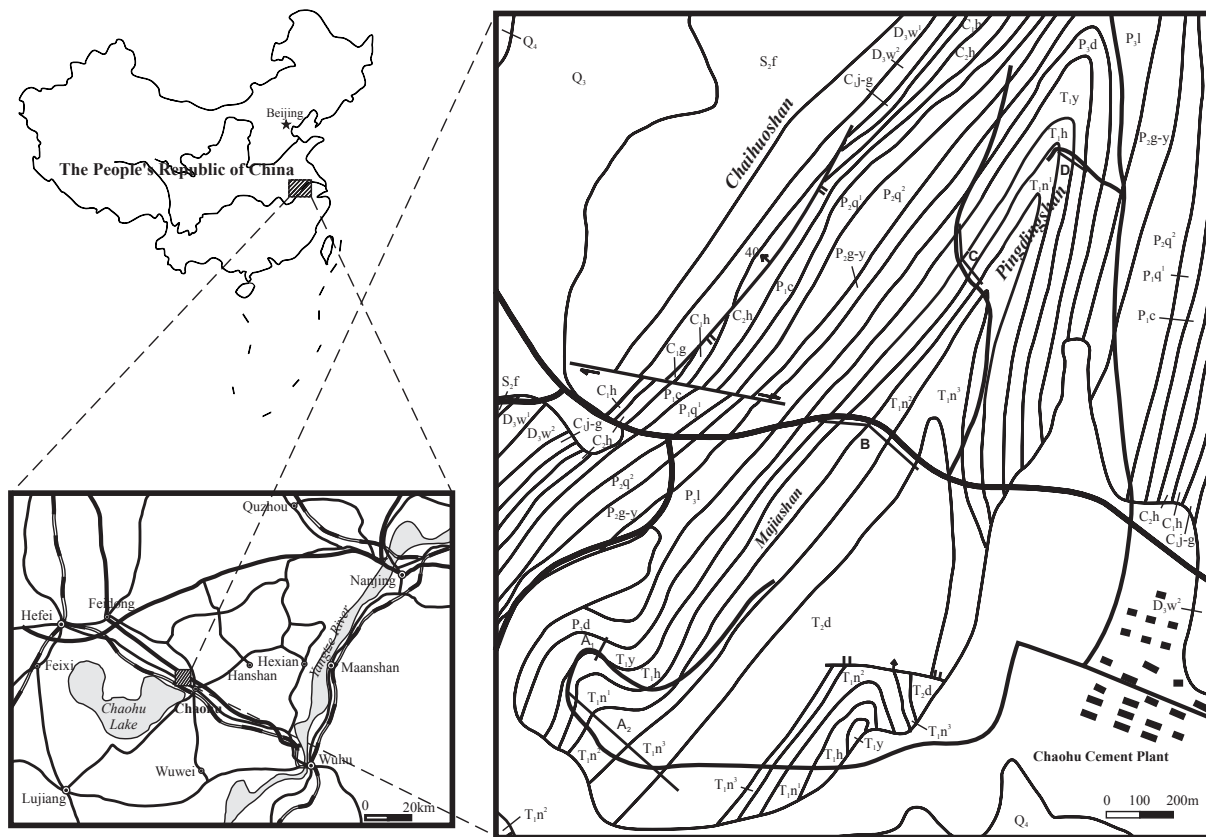


Figure 1: Regional geological map of Chaohu area, Anhui Province and the localities of the Lower Triassic sections. A1+A2 Majiashan Section, B N-Majiashan Section, C W-Pingdingshan Section D N-Pingdingshan Section

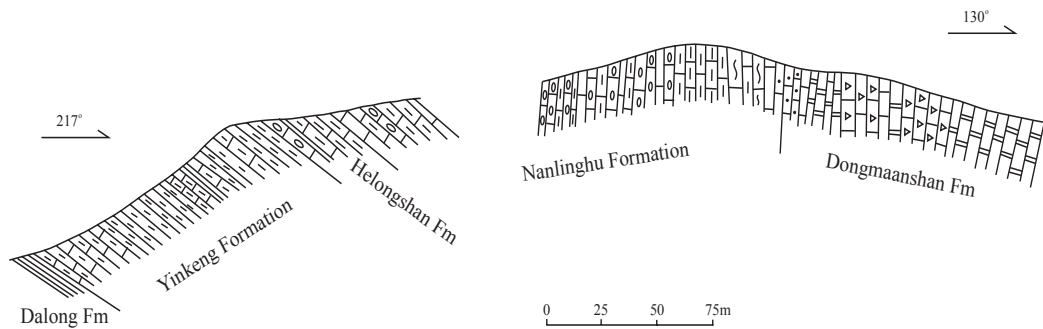


Figure 2: The Lower Triassic profile of the Majiashan Section, Chaohu, Anhui Province.

The first extension of Meishan section is on the Lower Yangtze block, where the section is located. Evidence indicates that the Lower Yangtze region (platform) was a separate block though it had a very similar sedimentary history to the Upper Yangtze platform during the Permian and Triassic (Yin et al., 1999). The Early Triassic sedimentary basin on the Lower Yangtze block was a carbonate ramp inclined northward. While the south part, where Meishan is situated, was occupied by the shallowing carbonate sediments, the north was still in relatively deep water in the most time of the early Triassic and formed fossil-rich argillaceous rocks.

The most outstanding Lower Triassic on the Lower Yangtze block is in Chaohu area, Anhui Province, where the Lower Triassic sequence is complete and rich of fossils from the PTB to the base of the Middle Triassic. In paleogeography Chaohu was in the deep part of the Lower Yangtze platform and its Lower Triassic is relatively thinner and contains more mudrocks than other areas of the Lower Yangtze region. It is at the northern edge of the present Lower Yangtze block, suturing the North China block.

The best-studied Lower Triassic sequence in Chaohu is the Majiashan Section in the north to the Chaohu Lake, about five kilometers from the center of Chaohu City. Chaohu is a mid-size city of Anhui Province and it has very good traffic, about one hour on the freeway or railway to Hefei City, the capital of Anhui Province (Fig.1). The Majiashan Section was first reported by the Anhui Geological Surveying Team (AGST) in their report of the 1:200000 Regional Geological Survey in 1978. The upper part of the Lower Triassic and the lower part of the Middle Triassic are mainly composed of carbonate rocks and they are superb materials of the cement plants so that they are quarried and exposed well. But the lower part of the Lower Triassic and the Upper Permian consist mainly of argillaceous rocks and thus usually covered heavily. During the AGST's geological survey a big prospecting trench was excavated to

display all the argillaceous strata from the upper Upper Permian up to the Lower Triassic carbonate rocks. The trench had entirely exposed all the covered Lower Triassic. It was so big that it had existed for over decade and the most of the following studies were performed on its exposure. The upper part of the section is on the side of the road to the quarries of the cement plants.

The Lower Triassic of the Majiashan Section is about 270m thick (Fig.2). In lithostratigraphy it is subdivided into three formations from the lower to upper: Yinkeng Formation, Helongshan Formation and Nanlinghu Formation. The Yinkeng Fm and Helongshan Fm are predominated by mudrocks but intercalated frequently by marl and limestones to form various mudrock-marl/limestone couplets or cycles. The Nanlinghu Fm is mostly made of limestones but argillaceous components are common to form marl-limestone cycles though the argillaceous rocks are thin and inapparent in many cycles. The underlying upper Upper Permian is Dalong Formation composed of siliceous rocks and mudrocks while the overlying lower Middle Triassic, Dongmaanshan Formation, is mostly evaporites predominated by dolomites and evaporite-solution breccias. The lithological boundaries between the Lower Triassic formations and the Permian and the Middle Triassic formations are clear but not exactly coincident with the chronostratigraphic boundaries (Yin and Tong, 1995).

The fossils are very rich and diverse throughout the Lower Triassic at the Majiashan Section. The bivalves were firstly described by Li (1979) and two new genera, *Periclaraia* and *Guichiella*, were named based on the rich specimens from the section and its neighboring areas (Li and Ding, 1981a). But only three bivalve assemblages are proposed, two are in the lower, which are the basic biostratigraphic units as well in South China, and one in the upper, *P. circularis*, which is typical in the upper Lower Triassic of the region.

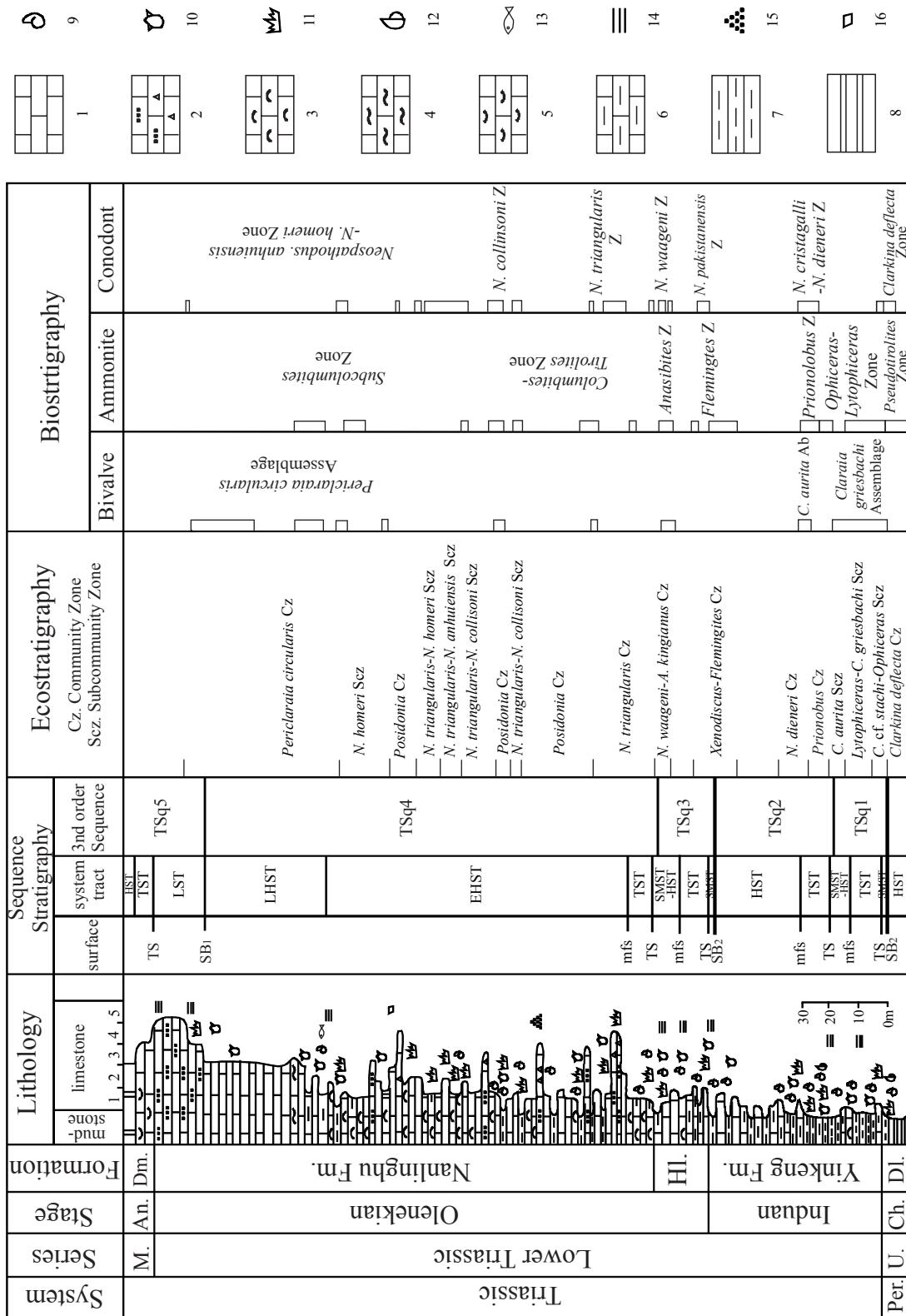


Figure 3: The comprehensive Lower Triassic sequence of the Majiashan Section, Chaohu, Anhui Province. 1. micrite, 2. calcarenite-calclrudite, 3. shelly limestone, 4. myrmekite limestone, 5. nodular limestone, 6. marl, 7. mudstone, 8. siliceous rock, 9. ammonite, 10. bivalve, 11. conodont, 12. brachiopod, 13. vertebrate, 14. horizontal beddings, 15. grading beddings, 16. gypsum pseudomorph; An. Anisian, Ch. Changhsiangian, DI. Dalong Formation, Dm. Dongmaanshan Formation, EHST early highstand system tract, Hl. Helongshan Formation, HST highstand system tract, LHST late highstand system tract, LST lowstand system tract, M. Middle, mfs maxim flooding surface, Per. Permian, SMST shelf margin system tract, TS transgression surface, TST transgressive system tract, U. Upper.

Ammonoids are common and biostratigraphically significant fossils in the Lower Triassic of the Majiashan Section. Guo and Xu (1980) reported the ammonoids of the section and subdivided the Lower Triassic into six zones: *Lytophiceras-Ophiceras* Zone, *Prionolobus* Zone, *Flemingites* Zone, *Anasibirites* Zone, *Tirolites-Columbites* Zone and *Subcolumbites* Zone. These ammonoid Zones constitute the basic Lower Triassic ammonoid succession of the region but only the Majiashan Section has the whole sequence. Ding (1983) studied the Lower Triassic conodonts of the section and described six conodont zones: *Carkina carinata* Zone, *Neospathodus dieneri* Zone, *N. cristagalli* Zone, *N. waageni* Zone, *N. collinsoni* Zone and *N. anhuiensis-N. homeri* Zone. The further studies found a specimen of *N. pakistanensis* Zone and established *N. triangularis* Zone (Figure 3) (Yin et al., 1995). The conodonts are relatively rich in the middle and upper parts of the Lower Triassic as the lower part is composed largely of mudrocks and the top of dolomitic components. Ammonoids and conodonts are the basis of the biostratigraphical study in the Lower Triassic. The good Lower Triassic ammonoid and conodont sequences at the Majiashan Section make it outstanding in South China and it almost becomes the standard sequence in the region. The correlation of the lithostratigraphic, biostratigraphic and chronostratigraphic sequences is relatively clear.

In addition, some vertebrate fossils were collected from the Nanlinghu Formation of the Majiashan Section, including reptiles *Anhuisaurus chaoxianensis* Chen and *Chaohusaurus* sp., and *Perleidiformes*. Based on the accumulated wealthy fossil records, the ecostratigraphy had been properly applied to the Lower Triassic study of the section (Yin et al., 1995) and the Lower Triassic was divided into five community sequences: *Claraia* Community Sequence (Cs), *Neospathodus dieneri* Cs, *Flemingites* Cs, *Neospathodus triangularis* Cs and *Periclarara circularis* Cs, and 15 community/subcommunity zones (Figure 3). These community and subcommunity zones were traced over the Lower Yangtze region (Yin et al., 1995), thus the stratigraphic resolution is greatly improved.

The ecostratigraphic achievements have been well applied to the study of the Permian and Triassic sequence stratigraphy in South China (Yin et al., 1997; Tong and Yin, 1998). The cyclic sedimentation of ramp carbonate rocks is also very helpful in the study of the sequence stratigraphy in the Lower Triassic of the Majiashan Section (Tong, 1997). Four third order sequences are subdivided in the Lower Triassic though the sequence boundaries are not exactly coincident to the chronostratigraphic boundaries (Yin and Tong, 1995). All the Lower Triassic

sequences are type II sequence with sequence surface 2 (SB₂), including the sequence across the Permian and Triassic boundary (Tong and Yin, 1998; Tong et al., 1999). But the sequence across the Lower and Middle Triassic boundary is type I with SB₁ owing to the Middle Triassic regression caused by the Indosinian tectonic movement. As the Chaohu area was located in the relatively deeper part of the carbonate ramp during the Early Triassic, the sequence surfaces are not remarkable while the transgression surfaces and maximum flooding surfaces are clearly indicated by the variations of the fossil assemblages and lithological cycles (Tong, 1997; Tong and Yin, 1998).

Meanwhile, the sedimentology of the Lower Triassic at the section had been studied as well (Li and Wu, 1988). It was concluded that the Yinkeng Formation and Helongshan Formation were formed in the deeper shelf basin poor of carbonates while the Nanlinghu Formation deposited in a deep and relatively restricted carbonate basin with some intercalated beds of gravitative calcirudites in the lower part of the Formation. The basin became shallow, restricted and salty in the later of the Early Triassic and then the Anisian sediments were predominated by evaporates.

As a whole, Chaohu has the good Lower Triassic lithostratigraphical and biostratigraphical sequences, which are characteristic in South China and the Lower Triassic of the Majiashan Section is one of the best-studied sequences in stratigraphy in China. However, nowadays the Majiashan Section has a big problem. As the lower part of the Lower Triassic in the area is composed mostly of mudrocks the section was discovered by a man-made trench. All the studies were produced within this trench in the early years. But now the trench is filled in and the vegetation is blooming so that the strata are heavily covered. Moreover, the upper part of the section has been more or less quarried by the cement plants. Therefore it is hard to carry out any further successive researches at the original section in field.

These years we have found some better Lower Triassic exposures near the Majiashan Section, which are uncovered by road construction (Figure 1). Section D in Figure 1 is situated on the northern slope of the Pingdingshan Hill, which has a good exposure from the upper Dalong Formation till the Helongshan Formation. The Permian and Triassic boundary is well observed and a high-resolution cyclostratigraphy has been achieved here in the lower Yinkeng Formation on the basis of the bed-by-bed lithological and 2cm-interval elementary chemostratigraphic studies (Peng et al., 1999). At section C the road goes through the Upper Permian Longtan Formation and Dalong Formation till the

Lower Triassic Yinkeng Formation, Helongshan Formation and the lower part of Nanlinghu Formation at the western foot of the Pingdingshan Hill. The section is quite continuous and all the boundaries between the formations are very distinctive but about two meters in the lower Yinkeng Formation is covered by a small road to the quarry up on the hill. Section B is on the side of the highway from Chaohu to Hefei and the Helongshan Formation and Nanlinghu Formation are well exposed here. But the detailed study at these newly discovered sections has not been reported yet. It is planned that a field excursion after the International Symposium on the Global Stratotype of the Permian-Triassic Boundary and the Paleozoic-Mesozoic Events (in Changxing on 10-13 August, 2001) will visit these sections in Chaohu. We will report the progression in the study of these sections in the coming volumes of *Albertiana*.

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**Palaeozoic and Mesozoic
Carbon-Isotopic Macrorhythms
and Macrocycles of Solar
Activity**

**(Annual Report 2001 of PTBWG,
IOBWG and Russian NWG IGCP
Project 434 Report)**

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It has been realized that the high $\delta^{13}\text{C}$ values in organogenic carbonates from selected Upper Palaeozoic and Mesozoic horizons are the testimony of an abundance of organic carbon in ocean of appropriate time and that the sharp drop of the $\delta^{13}\text{C}$ values at Permian-Triassic and Cretaceous-Tertiary boundary transitions coincides with reduction of organic carbon accumulation (Magaritz et al., 1981, 1983, 1986, 1988, 1991; Magaritz & Turner, 1982; Anderson & Arthur, 1983; Holser, 1984; Holser & Magaritz, 1985; Holser et al., 1986, 1991; Zachos & Arthur, 1986; Baud et al., 1989, 1995; Zachos et al., 1989; Magaritz & Holser, 1991; Alcalá-Herrera et al., 1992; Yang, 1992; Anderson et al., 1994; Jenkyns et al., 1994; Naidin & Kiyashko, 1994; Hirano & Takagi, 1995; Jenkyns et al., 1995; Hirano & Fukuju, 1997; Foster et al., 1998; Atudorei, 1999; Baud et al., 1999; Jenkins, 2000; Ando et al., 2000; Zakharov et al., 2000a; Zakharov et al., 2001a, in press among others). According to the opinions by previous authors, the degree of enrichment by a heavy isotope ^{13}C appears to reflect intensity of exception of a light isotope ^{12}C during photosynthesis, i.e. intensity of organic production.

As suggested by Alcalá-Herrera et al. (1992), some variations in $^{13}\text{C}/^{12}\text{C}$ ratios recorded in deep-water marine organogenic carbonates might be controlled by such environmental factors as the carbon budget, upwelling and primary productivity. It is difficult to separate the effect of each of these factors in deep-water conditions; but when worldwide carbon isotope shifts are observed in shallow-water carbonates, they are generally attributed to changes in primary biological productivity, first of all in phytoplankton one. Therefore, $\delta^{13}\text{C}$ value can be used for a

measure of biological productivity of ancient shallow seas. Agreeing with such rough, approximate estimation of the data on $\delta^{13}\text{C}$, Weimarn et al. (1998), however, scored that not any weighting of carbonate carbon can be treated so, as the carbon-isotopic anomalies in number of cases grow out of composite effect of many factors.

The peculiarities in distribution of some producers (phytoplankton), one of main utilizators of a solar energy on the surface of the present day ocean, are now well investigated (Bogorov, 1974). Their main biomass is contained in an upper 100-meter water mass that is connected with a feature of photosynthesis, but their location in it depends first of all on a degree of hydrological intermixing of waters under influence of considerable thermal gradients and winds and their distribution. The phytoplankton productivity is great in areas characterized by an intensive vertical circulation (boreal realms and the zone of equatorial uprising of waters between 10-12° of Northern latitudes and 7-8° of Southern latitudes). The uprising of deep waters reduces enrichment of surface layer by nutritious substances that promotes increase of phytoplankton production and intensity of its photosynthesis. The small amount of plankton in Recent Arctic and Antarctic seems to be originated in the short vegetal period of a phytoplankton of high latitudes.

In time of absence of polar ice on the Earth (it is expected at least for the significant part of Late Palaeozoic and Mesozoic) hydrological conditions, probably, considerably differed from Recent ones first of all in an "unusual" poleward transport of large equatorial warm water masses and weaker vertical circulation of waters in some climatic zones. During that time, another sort of regularities in distribution of phytoplankton in the surface layer of the ocean, apparently, took place, therefore the actual method for isotopic investigation of Phanerozoic organogenic carbonates can be applied only with considerable stipulation.

Recently, Pokrovsky, Letnikov and Samylin (1999) proposed a model which is compatible with observations on the Recent ocean and with the data on Quaternary glacial period: the high $\delta^{13}\text{C}$ values in carbonates of the Lower Proterozoic, Upper Rhyphen, Vendian and Permian seem to be connected with conditions of largest glacial epochs. We must briefly remark that their reference to Bauds et al. (1989) who examined the isotopic compositions of Upper Permian carbonates is not appropriate, but there is another publication (Rao, 1988) showing that Lower Permian Berriedale Limestone of Tasmania, formed, as they believed, during Main Gondwanian glacial epoch, is also characterized by anomalously high $\delta^{13}\text{C}$ values (up to +5.4‰).

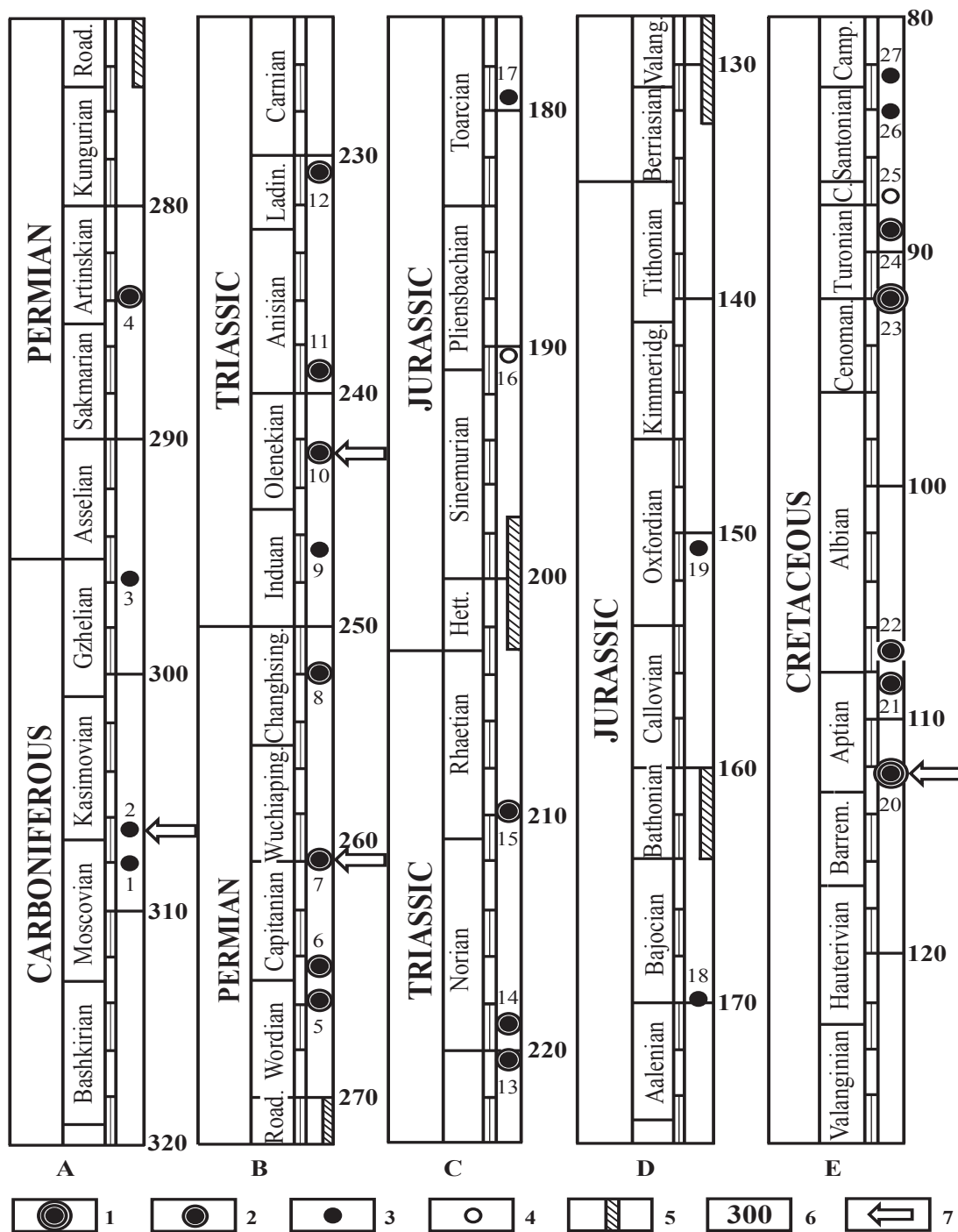


Figure 1: Late Palaeozoic and Mesozoic $\delta^{13}C$ anomalies. 1 – anomalies discovered in many localities and their number, 2 – anomalies discovered in some (2-7) localities and their number, 3 – anomaly discovered in a single locality and its number, 4 – anomaly in question and its number, 5 – brightest Phanerozoic event ($d^{13}C$ more than 6‰, 6 – uninspected interval, 7 – age in Ma. Road. – Roadian, Wuchiaping. – Wuchiapingian, Changhsing. – Changhsingian, Ladin. – Ladinian, Hett. – Hettangian, Kimmeridg. – Kimmeridgian, Valang. – Valanginian, Barrem. – Barremian, Cenoman. – Cenomanian, C. – Coniacian, Camp. – Campanian. Information on 1-27 see in the text.

However, the present study, based on data from selected horizons of post-Sakmarian carbonates, characterized by high $\delta^{13}C$ values suggests that they were formed in more or less warm climate during

eustatic transgressions. This interpretation is supported by following facts: (1) the primary concentration of a heavy oxygen-isotope in them is low, being comparable to temperatures of 19.6-27.9°C ; which came from calcite of well-preserved brachiopod shells

No	Type	Duration MA
1	Microcycle of solar activity (levels 1-3)	11 ⁶ -1 ³
2	Macrocycle of solar activity	1.5-12.0, less often up to 15-18
3	Megacycle of solar activity	About 300

Table 1. Typification of cycles of solar activity, established in the present paper.

from the Capitanian-Wuchiapingian transition beds in Transcaucasia (Zakharov et al., 1997), upper Lower Changhsingian of Transcaucasia (Zakharov et al., 1997) and North Caucasus (Zakharov et al., 2000a), and aragonitic portion of *Inoceramus* shells from the upper Santonian of Hokkaido (Zakharov et al., 1999), (2) calcitic material from the positive $\delta^{13}\text{C}$ anomalies is mostly characterized by high content of magnesium (Zakharov et al., 1997, 2000a); (3) sediment rocks showing positive anomalies record tracks of particular biological events, being represented by high taxonomic diversity of their fossils, which is common for assemblages of tropical and subtropical facies (Zakharov et al., 2001a, in press).

The stably warm climatic conditions at the time of eustatic transgressions promoted a high bioproductivity of the seas, and intensive photosynthesis, repeatedly arose during Phanerozoic. As was shown by Gao (1993), the Lower Devonian limestone of Central Oklahoma with approximately +2.6‰ $\delta^{13}\text{C}$ values was formed at temperature of about 25°C. The analysis of many positive carbon-isotopic anomalies made it possible to assume that during Late Palaeozoic and Mesozoic there were at least about 27 events, fixed by them, most part of which proved to be global.

(1) Moscovian. The anomaly (5.6‰) was discovered in Spain (Scotese et al., 1979) (Fig.1).

(2) Kasimovian. The anomaly (6.2‰) locates in Spain (Scotese et al., 1979). There are some problems in correlating the anomaly with the anomaly (5.6‰) known in the Winchell Formation (Missourian) in Texas (Grossman et al., 1991).

(3) Gzhelian (middle-late Virgilian) anomaly is known from the Colony Creek shale (5.6‰), shales of the Finis (4.3‰), Necessity (4.5‰) and Wayland (5.5‰) members of the Graham Formation (Virgilian) of Texas (Grossman et al., 1991),.

(4) Early Permian (Artinskian?). An anomaly was found in Kabayama Limestone of the Sakamotozawa Formation in Kitakami, Japan (4.7‰; Zakharov et al., 2000c). Anomaly (up to 5.4‰) discovered in Lower Permian Berriedale Limestone of Tasmania (Rao, 1988) seems to be the same age.

(5) Wordian. Anomalies of the Wordian level were observed on the basis of limestones of the two sec-

tions in Oman: in the Member A of the Maquam Formation (5.4‰) in the Wadi Maquam section and in the Unit 2 of the Wordian in the Wadi Wasit section (5.1‰) (Atudorei, 1999). It seems to be present also in the same level (Unit 2 of the Wargal Formation) of Salt Range (4.8‰) (Atudorei, 1999).

(6) Early Capitanian. Abnormally high $\delta^{13}\text{C}$ values were recognized in limestones of the Kattisawa member of the Kanokura Formation (4.5‰) (Zakharov et al., 2000c) and member 4a of the Wargal Formation in Salt Range (5.3‰) (Baud et al., 1995; Atudorei, 1999).

(7) Latest Capitanian - Earliest Wuchiapingian. Anomalies of the Capitanian-Wuchiapingian boundary transition were found in organogenic carbonates of many localities: Bell Canyon (upper part) (more than 3‰) and Castile (lower part) (6.5‰) Formations in Texas (Magaritz et al., 1983), Iwaizaki member of the Kanokura Formation in Kitakami (4.1‰) (Zakharov et al., 2000c), upper Chandalez Formation (3.8‰) and Nakhodka reef limestone (4.1‰) in South Primorye (Zakharov et al., 1996), upper Khachik Formation in Transcaucasia (4.0 ‰) (Zakharov et al., 1997), lower unit of the Bellerophon Formation in the Alps (3.5‰) (Holser & Magaritz, 1985), Zechstein Formation of western Europe (Magaritz & Turner, 1982) and, apparently, the upper part of the Wargal Formation in Salt Range (5.4‰) (Baud et al., 1995; Atudorei, 1999) and the middle part of the Kapp Starostin Formation in West Spitsbergen (7.3‰) (Gruszczynski et al. 1983; Wignall et al., 1998).

(8) Early Late Changhsingian. Anomalies of the Upper Changhsingian level were discovered from organogenic carbonates of the three localities: Nikitin Limestone of North Caucasus (4.7‰) (Zakharov et al., 2000a), upper Akhura Formation in Transcaucasia (2.8‰) and lower Upper Changhsingian in South China (5.1‰) (Chen et al., 1984).

(9) Middle Induan - ?Early Olenekian. The 3.2-4.0‰ shifts of approximately Middle Induan-Lower Olenekian level were recorded in limestone exotics of Oman (Atudorei, 1999).

(10) Middle Olenekian. Anomalies of the *Tirolites* beds were discovered in limestones of the four Russian localities: Schmidt Formation of Primorye re-

gion (4.9‰) (Zakharov et al., 2000b), Yatyrgvart Formation of Belaya River (3.6‰), Sakhray River (4.2‰), and Malaya Laba River (6.9‰) basins in North Caucasus (Zakharov et al., 2000a). According N.-V. Atudorei's (1999) data, the two additional positive excursions apparently of the same level in the Himalaya occur: in limestones of the middle part of the Mianwali Formation in Salt Range (4.7‰) and the middle part of the Tamba Kurkur Formation in Spiti (2.6‰).

(11) Early Anisian. Lower Anisian anomalies were discovered from limestones of the four localities: lower Malotkhachskaya Formation of Kapustin Ravine in North Caucasus (3.5‰) (Zakharov et al., 2000a), base of Nity Limestone of the Kurkur Formation in Kashmir (2.6‰) (Atudorei, 1999), member A2 of Mottled Limestone in North Dobrogea (more than 4‰) (Atudorei, 1999) and lower part of the Aegean of Albania (4.3‰) (Atudorei, 1999).

(12) Latest Ladinian – Lowermost Carnian. Anomalies of this level were discovered in Coryphyllia moiseevi beds of a large olistolite in the Lower Cretaceous olistostrome of Sikhote-Alin (2.6‰) (Zakharov et al., 2000b) and lower part of Enisala Limestone of North Dobrogea (3.2‰) (Atudorei, 1999).

(13) Late Carnian. Upper Carnian anomalies have been discovered in limestones at the two localities: Opponiz Formation in the Alps (3.5‰) (Zakharov et al., 2000b) and Congaz Formation in Dobrogea (3.9‰) (Atudorei, 1999).

(14) Early Norian. Lower Norian anomalies are known only in Russian territory: in *Margarosmia melnikovae* beds of a large olistolith in the Lower Cretaceous olistostrome of Sikhote-Alin (3.1‰) (Zakharov et al., 2000b) and limestones of the Shapkinskaya Formation of the Kuna River in North Caucasus (2.6‰).

(15) Early Rhaetian. Abnormally high $\delta^{13}\text{C}$ values of the Norian-Rhaetian transition beds of the Shapkinskaya Formation in North Caucasus were discovered in limestones at the three localities: Bzhebs (2.8‰) and Sakhray (2.5‰) Rivers, and Tkhach-Bakh River watershed (2.5‰) (Zakharov et al., 2000a). The high $\delta^{13}\text{C}$ value (2.79‰) was identified also in the carbonates of the lower unit of the Koessen Formation in the Alps (Morante & Hallam, 1996).

(16) Early Pliensbachian. High $\delta^{13}\text{C}$ values (up to 2.6‰) were discovered recently at the Sinemurian-Pliensbachian boundary horizon (Redcar Mudstone Formation, bed 73) (Hesselbo et al., 2000).

(17) Toarcian. High positive $\delta^{13}\text{C}$ values (up to 4.4‰) occur in the Toarcian limestones of Siberia (Ignatiev

et al., 1982).

(18) Aalenian-Bajocian. Abnormally high $\delta^{13}\text{C}$ values (about 4.0‰) were discovered in belemnite rostra from Passet member of KongsØya Formation of Kong Karls Land, Svalbard (Ditchfield, 1997).

(19). Oxfordian. The shift of $\delta^{13}\text{C}$ (3.0‰) was recognized in Oxfordian carbonates of England (Anderson et al., 1994).

(20) Early Aptian. Lower Aptian anomalies were discovered in organogenic carbonates from various regions of the world, including the Alps (4.5‰) (Erbacher, 1994) and the Koryak Upland (6.8‰) (Zakharov et al., 2001b, in press).

(21) Late Aptian. Upper Aptian anomalies were also distinguished in carbonates of western Europe (4.0‰) (Erbacher, 1994).

(22) Early Albian. Lower Albian anomaly (3.0‰) is known from carbonates of western Europe (Erbacher, 1994). Within large interval, from upper Albian to upper Cenomanian no $\delta^{13}\text{C}$ anomalies have been discovered (Price et al., 1998).

(23) Cenomanian-Turonian. Abnormally high $\delta^{13}\text{C}$ values (up to 4.7‰) were discovered from the Cenomanian-Turonian transition beds in carbonates of many regions of the world, including the Alps, South England and Tibet (Boersma & Schackleton, 1981; Douglas & Savin, 1973, 1975; Zachos & Arthur, 1986; Erbacher, 1994; Naidin & Kiyashko, 1994; Weimarn et al., 1998; Wan & Wang, 2000).

(24) Late Turonian. Upper Turonian $\delta^{13}\text{C}$ anomalies were discovered in the upper Penzhinskaya Formation of the Mamet River, Koryak Upland (up to 3.9‰) (Zakharov et al., 2001b, in press); Lewes Marl (3.46‰), Southstreet Marl (5.51‰), Zoophycus bed (3.61‰) and Snowdrop Flint 1 (3.15‰) of Navigation Pit, England; Bridgewick Marl 3 (3.64‰), Lewes Marl (4.18‰) and Navigation Marl 1 (3.34‰) of Shoreham, England; Bridgewick 2 (3.72‰) of Dover, England; Bridgewick 2 (3.04‰) of St. Margaret's Bay, England; Hitchwood Hardground ((3.29‰) of Kensworth, England; Glynde Marl 4 (3.08‰) of New Pit, England (Voigt, 2000); Micrafter Marl (3.82‰) of Soehlide quarry, Germany; and upper Turonian (3.77‰) of Salzgitter-Salder quarry, Germany (Voigt, 2000).

(25) Coniacian. Abnormally high $\delta^{13}\text{C}$ value (up 5.0‰) was recently discovered by us only in aragonite of the single Coniacian inoceramid shell from the lower Haborogawa Formation, Inoceramus uwajimensis Zone in the Yutakazawa River, Hokkaido and therefore the existence of the Coniacian anomaly needs in verification (Zakharov et al., in prep.).

(26) Late Santonian. Comparatively high $\delta^{13}\text{C}$ val-

ues (up 2.5‰) were recognized in some ammonoid shells from the middle Upper Yezo Group of Hokkaido (Zakharov et al., 1999).

(27) Early Campanian. Abnormally high $\delta^{13}\text{C}$ values (3.0-3.7‰) were obtained from lower Campanian planktonic foraminifers of Falkland Plateau, South Atlantic (Huber et al., 1995).

We can consider the four brightest Phanerozoic events, which were probably reflected by the greatest phytoplankton heyday and, accordingly, by an intensive photosynthesis: Kasimovian ($\delta^{13}\text{C} = 6.2\%$) (Scotese et al., 1979), Capitanian-Wuchiapingian (6.5-7.3‰) (Gruszczynski et al., 1983; Magaritz et al., 1983), middle Olenekian (6.9‰) (Zakharov et al., 2000a) and Early Aptian (6.8‰) (Zakharov et al., 2001b, in press).

Thus, the data on isotopic composition of organogenic carbonates testify that the carbon-isotopic anomalies in many periods of the Phanerozoic appreciably are reflection of climatic fluctuation. Their positive maxima during the end of Paleozoic and Mesozoic fell, probably, on warm epochs caused by several factors, main of which seem to be: (1) rise of solar activity (Shcherbinovskij, 1964; Chistyakov, 1997), (2) macropulsations of an energy core of the sun (Chistyakov, 1997) and (3) number of astronomical variations (Milankovich, 1939; Lengershausen, 1964; Naidin, 1989; Bolshakov & Bolshakov, 1999).

About eight solar cycles (Chistyakov, 1997, 1999) distinguishing on their duration are known now.

All eleven-year, secular and thousand-year cycles, confirmed by data on oxygen-isotopic rhythms of Quaternary carbonates (Naidin, 1989), sediment recurrence of evaporites of the Permian Zechstein Formation (Richter-Bernburg, 1968), and tape-clay and some other sediments of the Upper Cenozoic (Lengershausen, 1964; Zubakov, 1984; Chistyakov, 1997), we offer to name as solar microcycles of the different levels.

300 Ma-year cycles (Chistyakov, 1997), based on periodicity of largest glacial epochs, can be called, in our opinion, as solar megacycles (Table 1).

Carbon-isotopic macrorhythms of Late Palaeozoic and Mesozoic demonstrated here (Fig. 1) may testify to the existence of also cycles of solar activity of an intermediate type (solar macrocycles) by duration from 1.5 up to 12 Ma, less often up to 15-18 Ma.

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British Triassic Palaeontology: Supplement 25

G. Warrington

Since the completion of the writer's previous supplement (No.24; ALBERTIANA, 24: 51) on British Triassic palaeontology, the following works relating to aspects of that subject have been published or have come to his notice:

- Benton, M. J., Juul, L., Storrs, G. W. & Galton, P. M. 2000. Anatomy and systematics of the prosauropod dinosaur *Thecodontosaurus antiquus* from the Upper Triassic of southwest England. *Journal of Vertebrate Paleontology*, 20 (1): 77-108.
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- Bucephalo Palliani, R. & Riding, J. B. 2000. Subdivision of the dinoflagellate cyst Family *Suessiaceae* and discussion of its evolution. *Journal of Micropalaeontology* 19 (2): 133-137.
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- Glennie, K. W. 2000. Invited Review: Contribution of the Scottish offshore to the advancement of geology. *Scottish Journal of Geology*, 36: 17-32.
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- Powell, J. H., Glover, B. W. & Waters, C. N. 2000. Geology of the Birmingham area. Memoir of the British Geological Survey, 1:50000 geological sheet 168 (England & Wales). London: The Stationery Office, viii+132pp.
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- Spencer, P. S. 2000. The braincase structure of *Leptopleuron lacertinum* Owen (Parareptilia: Procolophonidae). *Journal of Vertebrate Paleontology*, 20 (1): 21-30.
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- Turner, N. S. 2000. A catalogue of the type, figured and cited fossils in the Nottingham Natural History Museum, Wollaton Hall, Nottingham, U.K. *The Geological Curator*, 7 (3): 111-121.
- Whatley, R. & Boomer, I. 2000. Systematic review and evolution of the early Cytheruridae (Ostracoda). *Journal of Micropalaeontology* 19 (2): 139-151.

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

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Meetings

The International Symposium on The Global Stratotype of the Permian-Triassic Boundary and the Paleozoic-Mesozoic Events

10-13 August 2001

to be held in

**Changxing, Zhejiang Province, The
People's Republic of China**

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

SPONSORS

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

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OBJECTIVES:

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

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

DATE, VENUE AND LANGUAGE:

Pre-symposium Field Excursion: 8-9 August 2001

Symposium: 10-13 August 2001

During-symposium Field Excursion: 11 August 2001

Post-symposium Field Excursion 1: 14-15 August 2001

Post-symposium Field Excursion 2: 14-18 August 2001

Place: Changxing, Zhejiang Province

Language: English will be the official language for all presentations

IMPORTANT DATES:

1 February 2001: Deadline for submission of response to first circular

1 May 2001: Deadline for submission of abstracts for the proceedings

1 July 2001: Deadline for submission of pre-registration

13 August 2001: Deadline for submission of papers for the special symposium volume

THEMES:

The symposium will be structured into four main themes:

The global stratotype of the Permian-Triassic boundary and its geological setting;

Stratigraphy of the Permian and Triassic boundary and its global correlation over various facies;

Tectonics, paleogeography, paleoclimatology and paleoecology during the Paleozoic and Mesozoic transition;

Biotic crisis, mass extinction and recovery, and connected events across the Permian and Triassic boundary.

FIELD EXCURSIONS:

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

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

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

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

Post-Symposium Field Excursion 1: Chaohu, Anhui

Province (14-15 August 2001)

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

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

This excursion supposes to provide you for a unique chance to trace the Permian-Triassic boundary from marine to continental via paralic facies. Many excellent marine Permian-Triassic boundary sequences have been studied in the central and southern Guizhou while the continental sections are in the western Guizhou and northeastern Yunnan. The paralic Permian-Triassic boundary sections are located in the central-western Guizhou Province. During the excursion you will visit a series Permian and Triassic boundary sections from marine to continental via paralic facies in the central-western Guizhou Province so that you might figure out a correlation between the marine and continental boundaries.

PUBLICATIONS:

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

REGISTRATION:

Registration should be made to the registration form attached on the second circular, which will be sent to all who respond to the first circular. Registration fee for the symposium (including the Proceedings, morning and afternoon teas, and the during-symposium field excursion and during-symposium

sightseeing in Changxing County) will be \$200 US Dollars. Pre-Symposium field excursion fee (including field guidebook, transportation and meals) will be \$100 US Dollars. The post-symposium field excursion 1 to Chaohu costs \$150 US Dollars (including field guidebook, transportation, and accommodation). The post-symposium field excursion 2 to Guizhou will be \$450 US Dollar (including field guidebook, accommodation, transportation during the field excursion in Guizhou, and a single flight from Nanjing to Guiyang). Refer to the second circular for the details.

HOTELACCOMMODATION:

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

TRANSPORTATION:

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

Pre-Registration Form for:

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

Forename:

Initial(s):

Surname:

Sex (M/F):

Title:

Institution:

Full Address:

Country:

Telephone:

Fax:

Email:

I plan to attend the Symposium (Please tick)

very probably

probably

unlikely

I plan to contribute with an

oral paper

poster

Tentative title:

I plan to attend the pre-Symposium field excursion

very probably

probably

unlikely

I plan to attend the post-Symposium field excursion 1 to Chaohu

very probably

probably

unlikely

I plan to attend the post-Symposium field excursion 2 to Guizhou

very probably

probably

unlikely

Comments/Suggestions:

Date:

Signature:

NEW GUIDELINES FOR THE SUBMISSION OF MANUSCRIPTS TO ALBERTIANA

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Text files can be submitted formatted as *.wpd, *.doc or *.rtf files and illustrations as pixel based graphics (e.g: *.bmp, *.tif, *.gif or *.jpeg) or vector based graphics (e.g: *.ai, *.cdr) that can be directly imported into Adobe PageMaker. Please provide good, clean, flat, printed copies (NOT xerox copies) of any illustrations, which MUST be designed to fit on an A4 page (centered, with at least 2.54 cm wide margins left and right, and 4 cm margins at the top and bottom).

Special attention should be paid to grammar and syntax - linguistic corrections will be minimal. In case of doubt, send your manuscript to a colleague for proof reading. References should be in the format used in the 'New Triassic Literature' section in issue 25 of Albertiana. Please write all Journal titles in full length. The use of names of biostratigraphic units should be in accordance with the International Stratigraphic Guide:

The formal name of a biostratigraphic unit should be formed from the names of one, or preferably no more than two, appropriate fossils combined with the appropriate term for the kind of unit in question."

The writing and printing of fossil names for stratigraphic units should be guided by the rules laid down in the International Code of Zoological Nomenclature and in the International Code of Botanical Nomenclature. The initial letter of generic names should be capitalized; the initial letter of the specific epithets should be in lowercase; taxonomic names of genera and species should be in italics. The initial letter of the unit-term (Biozone, Zone, Assemblage Zone) should be capitalized; for example, Exus albus Assemblage Zone."

The name of the fossil or fossils chosen to designate a biozone should include the genus name plus the specific epithet and also the subspecies name, if there is one. Thus Exus albus Assemblage Zone is correct. After the first mention, the genus name may be abbreviated to its initial letter if there is no danger of confusion with some other genus beginning with the same letter; for example, Exus albus may be shortened to E. albus. On the other hand, the use of the specific epithet alone, in lowercase or capitalized, in italics or not (albus Assemblage zone, Albus Assemblage zone, albus Assemblage zone, or Albus Assemblage zone), is inadvisable because it can lead to confusion in the case of frequently used species names. However, once the complete name has been cited, and if the use of the specific epithet alone does not cause ambiguous communication, it may be used, in italics and lowercase, in the designation of a biozone; for example, uniformis Zone."

From: Salvador, A. (ed.), 1994. International Stratigraphic Guide. Second Edition. International Commission on Stratigraphic Classification of IUGS International Commission on Stratigraphy. IUGS/GSA, Boulder, Co, p. 66.

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