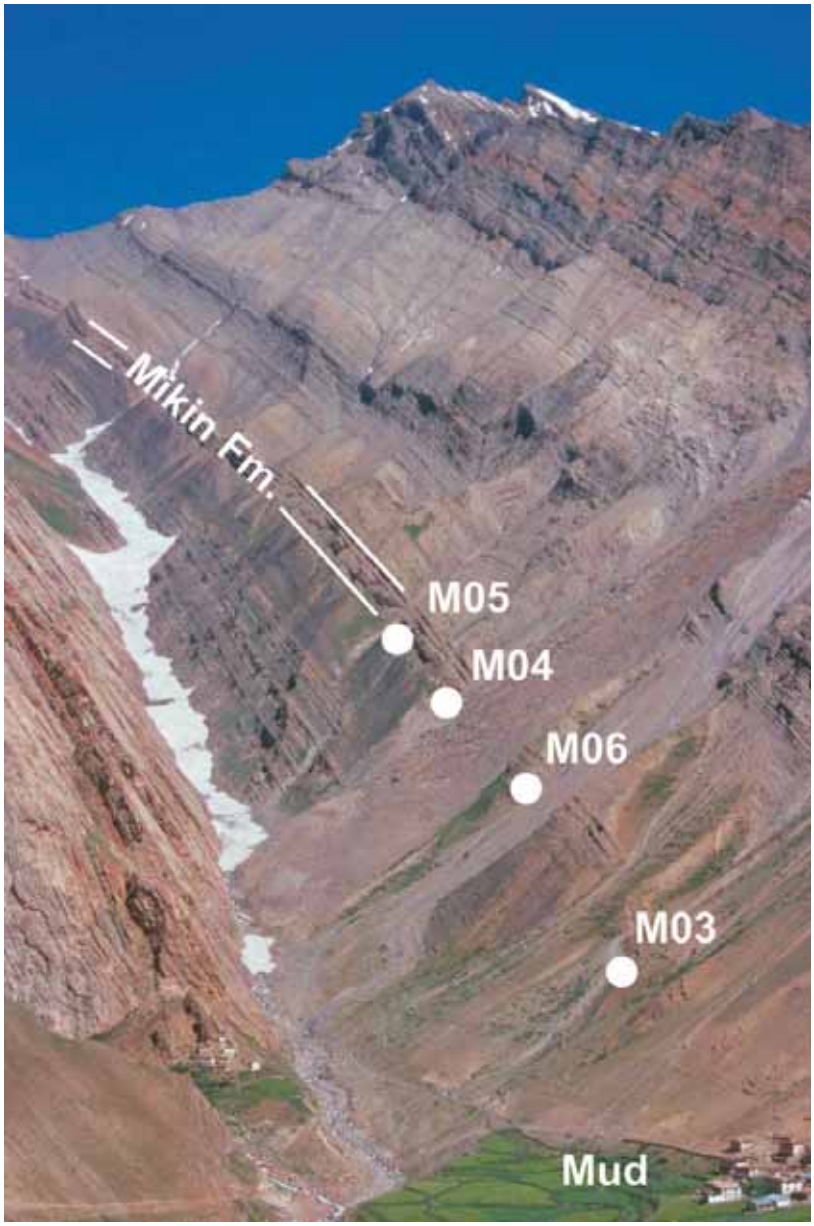
ALBERTIANA



35

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Contents

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

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Cover: Views of Mud and the western Pin valley flank with location of IOB sections M03 till M06. See also paper by Krystyn et al. on pages 5-29, this issue.

Executive Notes

From the Chair

As this issue of Albertiana goes to press, preparations for the Global Triassic meeting (WEB) in Albuquerque, New Mexico are in full swing. Spencer Lucas has been very busy producing one bulletin as a field guide, and a second as a proceedings volume: both will be available for the conference, May 23-25. The volumes will have an emphasis on intra-Triassic boundaries, some of which will be visited during the field trip and all of which will be discussed during the meeting. This will be an important gathering for reviewing the state of GSSP deliberations, and making some decisions. It is fitting that the proceedings volume will be dedicated to Tim Tozer and Norm Silberling, whose work in western North America set the standard for biochronological studies. See you New Mexico.

Mike Orchard
17 March 2007

Correlation of the Chaohu (South China) and Muth (Himalayas) sections from ammonoid and carbon-isotope data

Open letter to Prof. Leopold Krystyn

I am satisfied that there is a quite correspondence between Chaohu and Spiti in terms of conodont succession (new Orchard's data). It increases possibility to use the important Chaohu magnetostratigraphic data (Tong et al., 2003, 2004a; Tong and Zhao, 2005; Chinese Triassic Working Group, 2006; Hounslow, 2006) or global correlation.

Concerning carbon-isotopic correlation, I have an original version, which is in a good agreement with new conodont data. The positive value of $\delta^{13}C$ discovered in the middle part of the Bed 25 in the Western Pingdinshan Section (Chinese Triassic Working Group, 2006, p. 8, Fig. 11) seems to be corresponded to the positive value in the base of the Bed 13 in the Muth section.

Concerning Chaohu ammonoids, the semi-evolute ammonoid shown on pl.2, fig. 14 (Tong et al., 2004) I have idenified with *Euflemingites* cf. *tsotengensis* Chao (Tong et al. 2004, p. 200, Pl. 2, Figs. 13-15). *Euflemingites* cf. *tsotengensis* shells with regular spiral ridges were found only in the North Pindingshan section located about 500 m from the West Pingdingshan. The lack of spiral sculpture in flemingitids at the West Pingdingshan section seems to be connected with their poor preservation (they are represented by deformed internal casts). I continue to consider the ammonoid internal cast X302-2023 (Tong et al., 2004, p. 200, pl. 2, fig. 11) to be *Flemingites* sp. In the suture of *F. flemingianus* Koninck, type-species of the *Flemingites*, one can see that the second lateral saddle is smaller than the first one (Waagen, 1895, pl. 12). We have the similar suture for our sample X302-2023 (Tong et al., 2004b). I agree that representatives of flemingitid *Rohillites* may be present in the Chaohu section, but it is difficult to confirm because of significant deformation of the main part of the Chaohu ammonoids.

I entirely agree with Mike's correlation, according which the lower part of the *Flemingites-Euflemingites* Zone in Chaohu (Tong et al., 2003, 2004a; Tong and Zakharov, 2004; Tong and Chao, 2005) corresponds the *Rohillites rochilla* Zone in Spiti (Krystyn et al., 2005). In the Tri Kamnya Cape section in South Primorye, *Rohillites* sp., firstly described by me as *Flemingites* sp. (Zakharov, 1968, p. 87, Pl. 16, Fig. 2), was discovered in the member, where *Flemingites radiatus* Waagen and *Euflemingites prynadai* (Kiparisova) are known.

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Yuri Zakharov

(Leader of Induan-Olenekian Task Force)

Scientific Reports

A candidate GSSP for the base of the Olenekian Stage: Mud at Pin Valley; district Lahul & Spiti, Himachal Pradesh (Western Himalaya), India.

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Abstract The M04 section near Mud (Spiti, India: N 31°57'55.5 / E 78°01'28.5) is proposed as candidate GSSP for the base of the Olenekian stage. The boundary interval is within the second or Limestone and Shale Member of the Mikin Formation, slightly above the base of the *Flemingites* Beds, which constitute the middle part of this member. Following the recommendation of the Subcommission on the Triassic Stratigraphy, the boundary is drawn 60cm above the base of *Flemingites* Beds corresponding to the FAD of the conodont *Ns. waageni* s.l. in sub-bed 13A. The worldwide found *Ns. waageni* group allows an intercontinental Tethyan-Panthalassan and a trans-provincial correlation of the boundary between low and high palaeolatitudes. Additional boundary events are (i) the FAD of the ammonoid *Rohillites rohilla* appearing also in 13A closely associated with other typical Olenekian genera (*Kashmirites, Beoflemingites, Pseudaspidites, Pseudohedenstroemia*), and (ii) a characteristic inflexion point respectively positive peak in the δ^{13}C-curve of sub-beds 13A/B described earlier from many Induan-Olenekian boundary (IOB) sequences. The event is also characterized by an explosive radiation in conodonts with nearly concurrent appearance of several genera (*Eurygnathodus, Discretella*) and species. A second conodont event, 90 cm above the proposed boundary point in bed 15, correlates to the FAD of *N. spitiensis* and to that of the ammonoid *Euflemingites* whose pandemic occurrence provides another worldwide recognizable datum.

The section is excellently exposed and since it is located in a National Park, its long-time preservation is assured. Fossils are abundant and well preserved at the boundary. Despite half the rate of sedimentation as compared to that of the other candidate GSSP in Westpingdingshan, Chaohu (China) – the Mud sequence shows no signs of breaks or condensation and maintains a uniform lithofacies across the boundary level. Apart a regional remagnetisation, preventing a meaningful magnetostratigraphy, the Mud section full-fills all other requirements necessary for a global stratigraphic section and point selection.

Introduction

The marine Palaeozoic and the Mesozoic sequences in the Indian Plate are mainly preserved in the inner part of the Higher Himalaya and in literature have been referred to as the Tethyan sequences which often rest with a tectonically decoupled contact over the crystalline rock. These successions are well exposed in the Western (Kashmir, Zanskar- Spiti and Uttrakhand) and the Central (Nepal) Himalaya (Fig. 1). Due to rich fossil contents the Tethyan sequences of Kashmir, Spiti and Kumaon (Uttrakhand) have been investigated since 19th century (e.g. Stoliczka, 1864). Amongst all the Palaeozoic and Mesozoic sequences, the Triassic is most complete and extensively developed. It rests over the Permian Gungri Formation with minor break where a part of Dorashmian is missing. During the Triassic time, this Himalayan zone had formed a part of the tropical Gondwana margin, hence often described as Peri-Gondwana Tethyan succession (Matsuda, 1985). The original mid-low latitude provided a large and mixed pelagic faunal diversity and a high carbonate precipitation rate favoured an exceptional fossil preservation potential. Of all the areas mentioned above, the Triassic succession (Lilang Supergroup, redesigned by Bhargava et al., 2004), particularly the Lower Triassic (Mikin Formation) of the Spiti Valley is one of the best in the world with a well-known, classically monographed ammonoid fauna by Diener (1897) and Krafft & Diener (1909).

The Spiti Valley forms part of the district of Lahul & Spiti (Fig. 2) located in the northern part of the Himachal Pradesh, which occupies a central position in the Western Himalaya. Mud Village is situated in the Pin Valley, which is an important tributary of the Spiti River. This area is open to persons of all nationality and is becoming an important tourist place due to the Pin Valley being developed as a National Park for high altitude wild life. Spiti can be approached from (i) Shimla via National Highway 22, following the Sutlej River up to Khab and then the road is along the Spiti River up to Attargoo and (ii) from Manali (on NH 21) via Rohtang and Kunzam Passes, first following the Chandra river and then the Spiti river up to Attargoo, beyond which the road is along the Pin River (Fig. 2). The total journey from Delhi to Mud with prior arrangements can be accomplished in

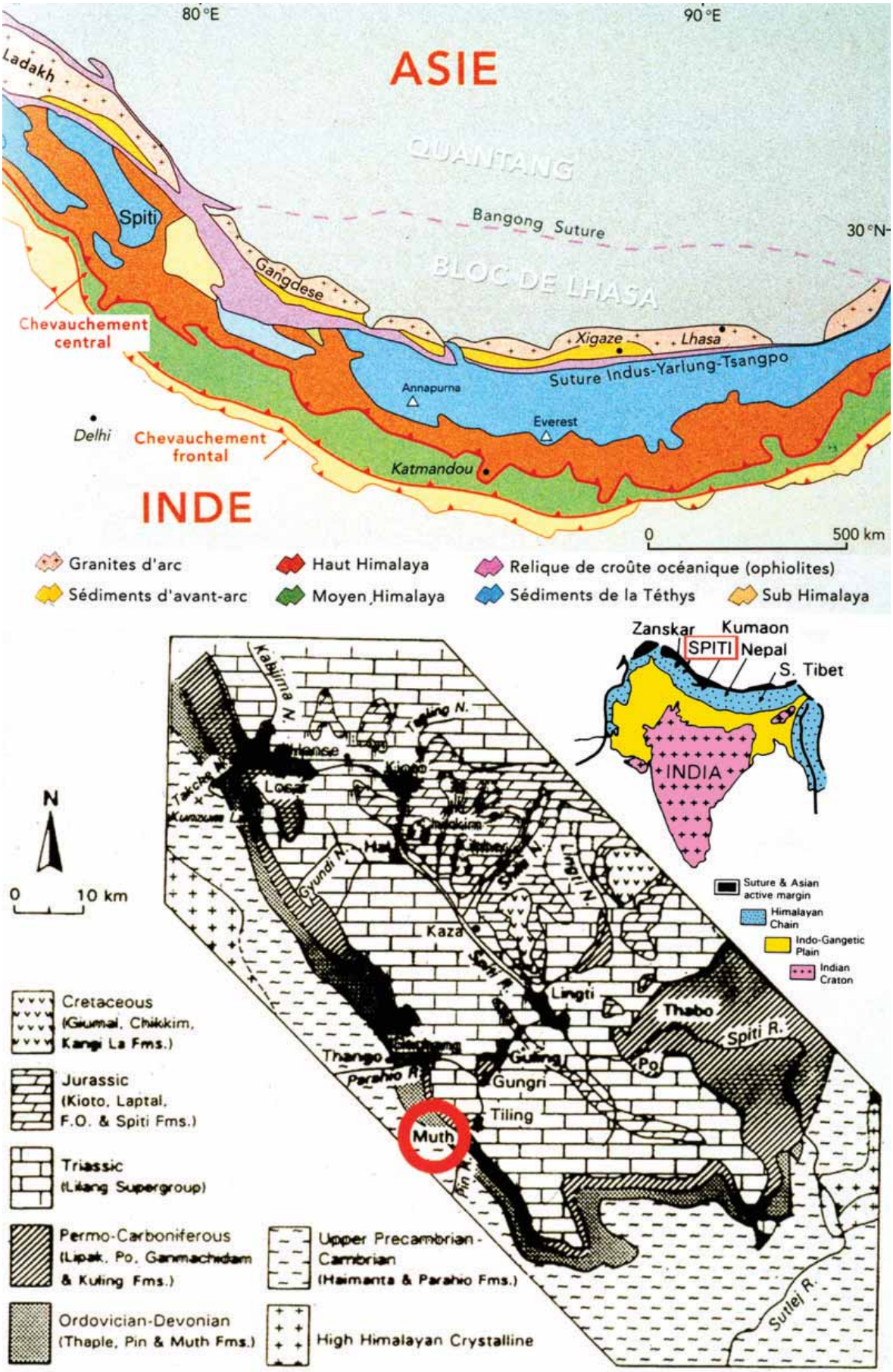

Fig. 1. Tectonic outline of the Himalayas and geological map of Spiti (after Garzanti et al., 1995) with location of Mud (Muth).

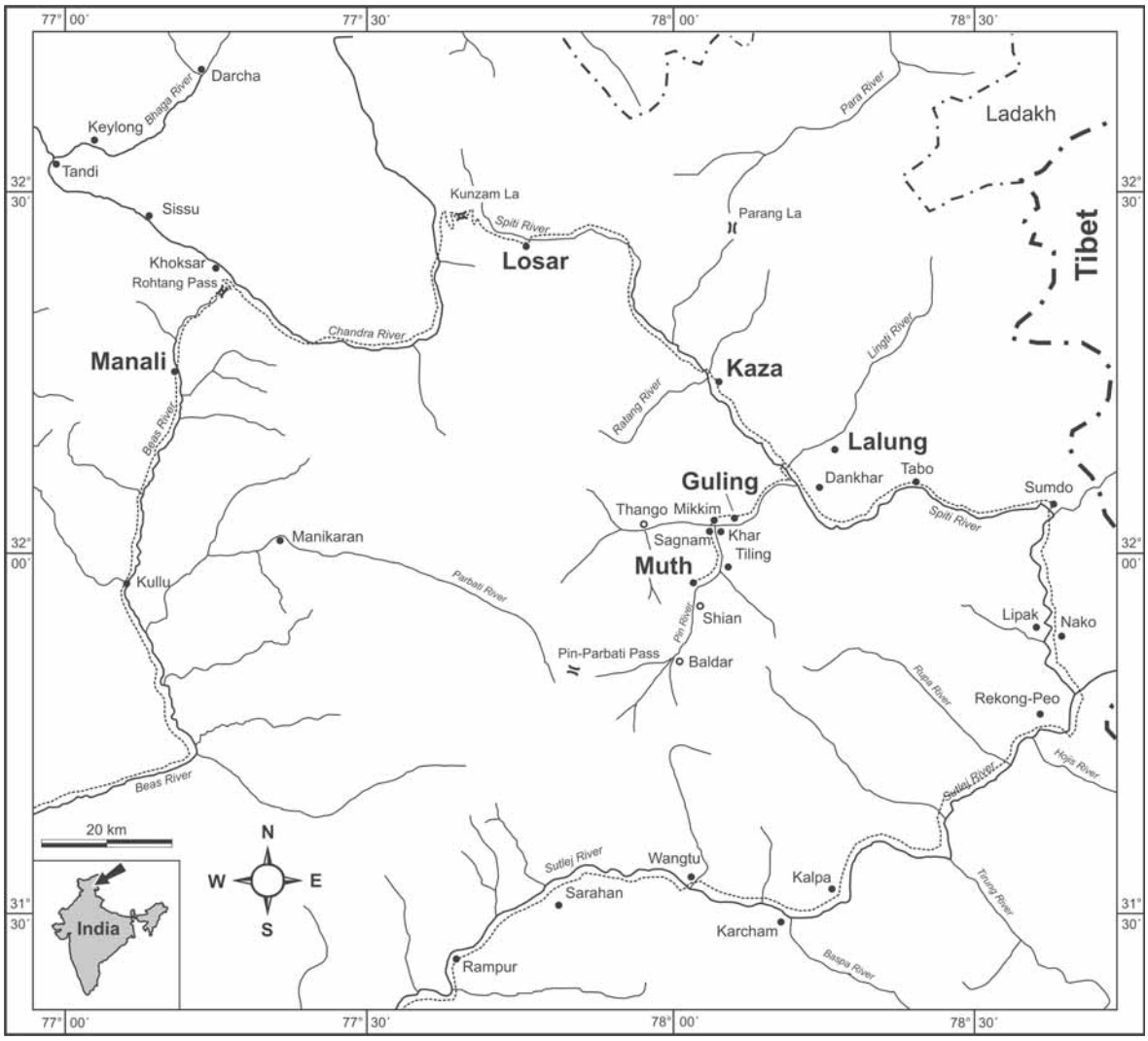

Fig. 2. Topographic map of Spiti and Lahul with location of Mud and other main Lower Triassic sites (after Draganits et al., 2004).

three days. Alternatively, during fair weather, one could take a flight from Delhi to Kullu and reach Mud the same day or at best the next day. Guling is also situated in the Pin Valley and is about 18km from the Attargoo bridge. Lalung in the Lingti Valley is about 15 km from Attargoo along a branch road to the North.

June to September is ideal period for a visit, which can also be carried out during the month of October, provided there is no early snowfall. The snowfall normally commences in the month of November and the area remains snow bound till April. Board and lodging facilities are available at Mud and Guling, the more adventurous can pitch tents, which either can be carried or hired from several travel agencies located at Manali and Shimla. At Lalung board and lodging facilities can be availed of at the local gompha (monastery).

Geographic and geologic setting

The Mud (old spelling Muth) section in the Spiti Valley provides excellent exposures of nearly the complete Triassic within the northern, flat to moderately steep towards northeast dipping limb of an anticline (Fig. 3). Lower Triassic rocks are represented by the Mikin Formation, which is divisible in three members from bottom to top i) the Lower Limestone Mb., ii) the Limestone and Shale Mb. and the iii) the Niti Limestone Mb. (Fig. 4; 6). Of relevance to the IOB is the second member with its three subdivisions: *Gyronites* Beds (3,5m) of Dienerian, *Flemingites* Beds (2m) of topmost Dienerian to basal Smithian and *Parahedenstroemia* Beds (app. 10m) of Smithian age (Fig. 4).

The most remarkable faunal change, both in ammonoids and conodonts, is found in the basal *Flemingites* Beds, which are rich in extractable ammonoids and enclose abundant conodont fauna, and their integrated biostratigraphy provides an excellent control on IOB. The beds form continuous exposures on the northern valley slope at Mud and afford ample scope of measurement and sampling of the entire sequence at several places, viz. M03 (close to Mud Village) and between M04 and M06 at 3900m and 4100m (Fig. 5). All the sections are reachable through normal walking (without climbing), the most distant place is M05 (Fig. 6) at an altitude of 4100m and a one and half hour walk from Mud (3750m). Section M04 (Fig. 7) is located below at an altitude of about

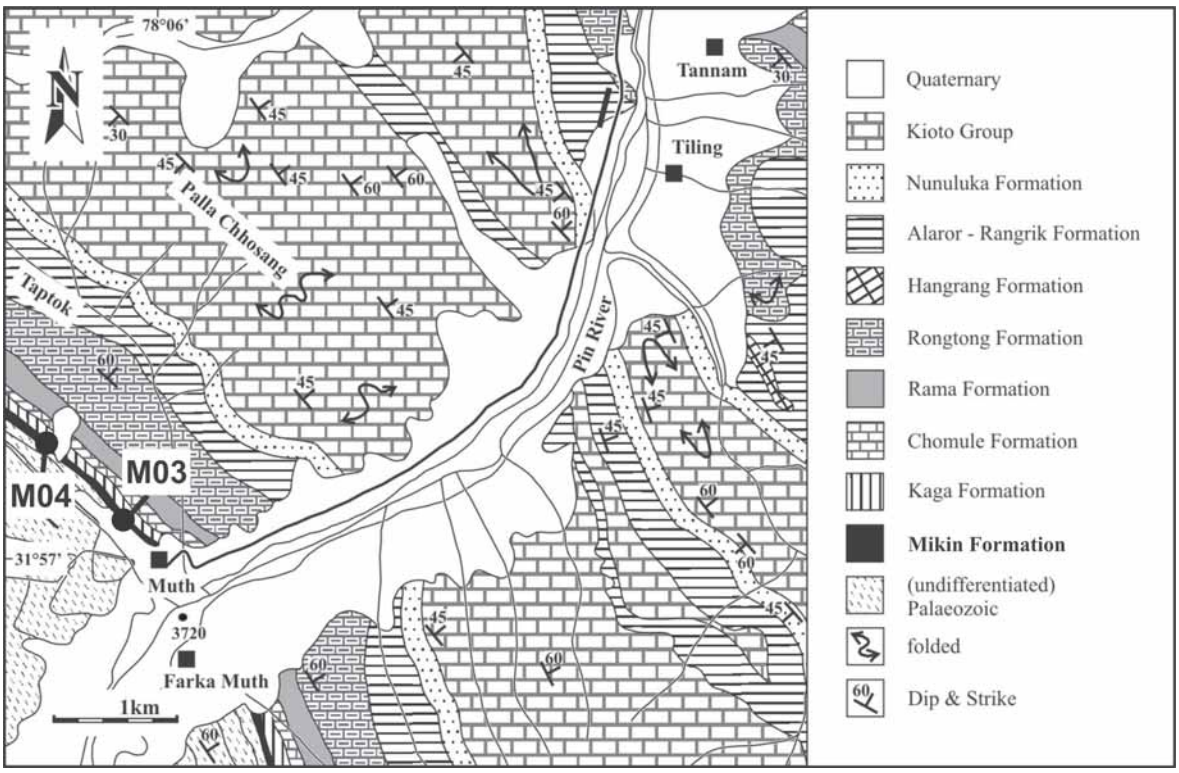

Fig. 3. Geology of Mud with position of sections M03 and M04 (proposed candidate GSSP) in the Mikin Formation.

4000m, to the west of an old rock fall (Fig. 3) and is reachable from Mud within an hour. East of the rock fall follows the locality M06 and, just 100m above Mud village lies the section M03 (Fig. 3; 7). Though the last locality is within a walking distance of less than 30 minutes, and thus the easiest to access, it is poor in ammonoid record within the critical boundary interval (Table 1). As the section M04 (coordinates N 31°57'55.5 / E 78°01'28.5) contains the richest macrofauna and a complete succession of all zonal markers resp. boundary-relevant ammonoid species, it is explicitly selected as the candidate GSSP (Fig. 8). Of the 400 specifically determinable ammonoids, 60% have been collected in M04, 25% in M06, 10% in M05 and only 5% in M03.

The outcrops between M04 and M05 are extensively weathered and offer ideal setup for collection of macrofossils from each bed. The added advantage in this section is that each bed can be traced for several kilometers with high level of confidence due to comparable lithology (Fig. 9) and excellent fossil control. This allows a range chart presentation within one composite section (Fig. 10) complemented, of course, by individual ammonoid (Table 1) and conodont faunal details (Orchard and Krystyn, this volume). A comprehensive geological description of the Mud site is to be found in Krystyn et al., (2004) and additional outcrop photos can be made available on request.

The other good Lower Triassic sections are at Guling in the Pin Valley itself and another at Lalung in the Lingti Valley, a northern tributary of the Spiti River (Fig. 2). At the later locality the Mikin Formation is exposed on a dip slope that affords excellent condition for sampling. Garzanti et al., (1995) restudied Triassic rocks of Spiti, and Bhargava and Bassi (1998) have published a more recent geological monograph on Spiti.

Faunal content

According to the basinal depositional setting ammonoids and conodonts are dominating and only associated with some rare or indeterminate pteriod bivalves. Ammonoids are very common in bed 10, almost missing in bed 11 and not so rare in the boundary-near bed 12. The latter bed is, however, too compact and difficult to break thereby reducing the fossil extractability. A rich and very well preserved fauna occurs in beds 13 and 14 with large-sized and undeformed specimens. The fauna of these two beds forms a major part of the monographs of Diener (1907) and Krafft and Diener (1909). The preservation of the fauna is not so good in beds 15 and 16 but it is smaller-sized or fragmented and sometimes distorted, and the ammonoids are less well extractable. The newly collected material is listed in Table 1 and figured in plates 1-4.

Conodonts are prolific, well preserved and diverse from bed 13 upwards. Specimens from below (bed 13) though still common, are more fragmented and often diagenetically overgrown. The faunal composition is of basinal type as demonstrated by the *Neospathodus* dominance and comparably underrepresented ramiforms. Age relevant taxa are described and documented in Orchard and Krystyn (this volume).

Biostratigraphy

The Lower Triassic fossils of Mud have been studied for

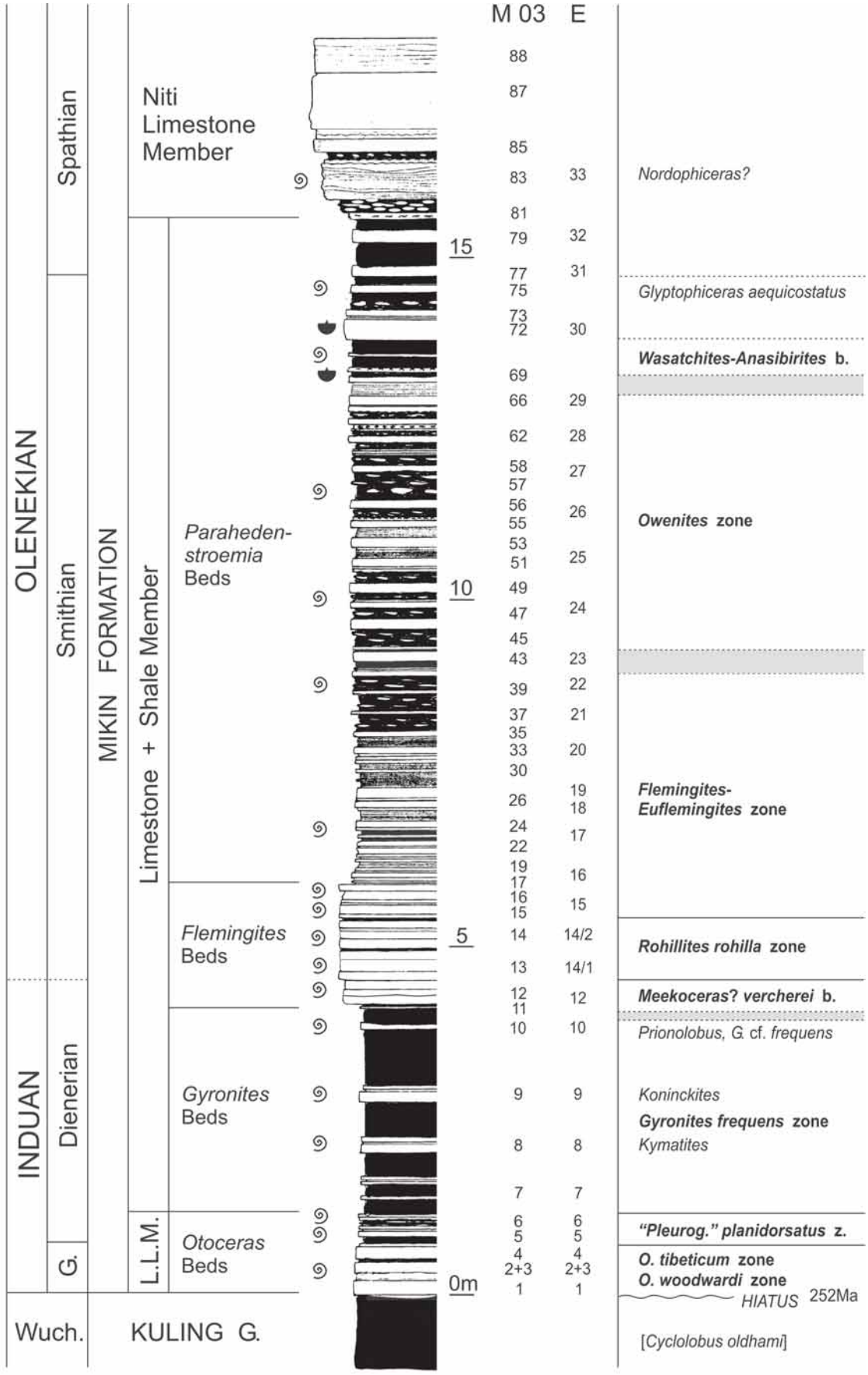

Fig. 4. Lower Triassic (Induan, Olenekian) stratigraphic column and ammonoid zones for Mud.

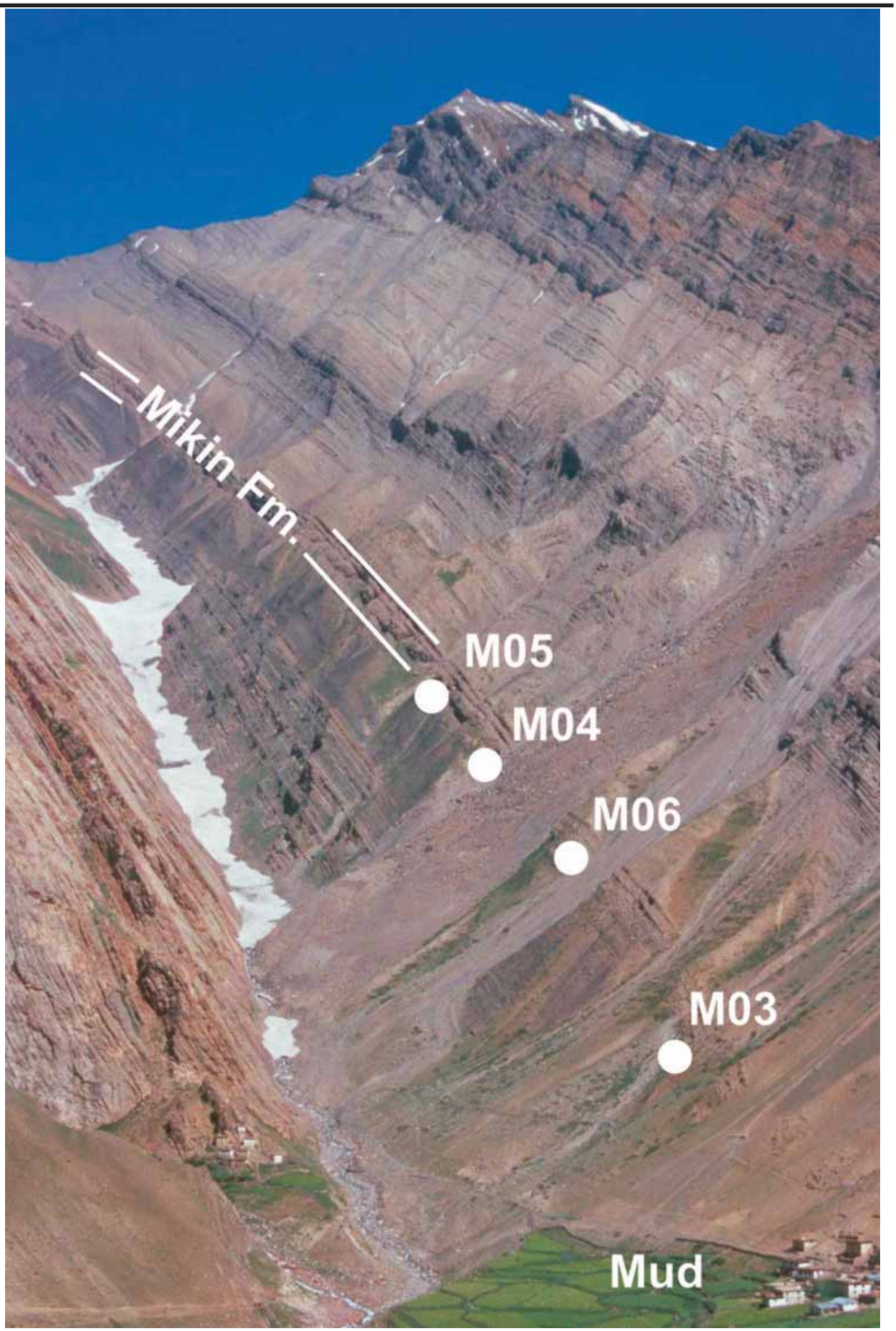

Fig. 5. Views of Mud and the western Pin valley flank with location of IOB sections M03 till M06.

Fig. 6. Overview of section M05 with subdivisions of the Mikin Formation.

more than a century, but key investigations are rare and centered on the ammonoid monographs of Diener (1897) and Krafft & Diener (1909), the shelly fauna study of Bittner (1899) and a recent conodont investigation by Bhatt et al. (2004). Krystyn and Orchard (1996) and Krystyn et al. (2005, 2006) presented detailed summaries including new biostratigraphic data.

Ammonoids

The *Flemingites* Beds (Fig. 10) constitute a monofacial succession (of) in the lower part, approximately 1dm-, and in the upper third c. 5 cm-bedded, dark grey limestones. Fifteen layers, numbered as 12A to 12C, 13A to C, 14A to C, 15A to C and 16A to C record a sequence of three ammonoid zones. From the base to the top these are (thicknesses according to M04):

1) *Meekophiceras*? *vercherei* beds (0,6 m – beds 11 to 12C);
2) *Rohillites rohilla* Zone (0,9 m – beds 13A to 14C);
3) *Flemingites – Euflemingites* Zone (0,4m – bed 15A to 16C + 3,6m of *Parahedenstroemia* Beds).

Meekophiceras? *vercherei* Beds

They contain a relatively poor fauna and have not been sampled extensively. Besides the index, *Proptychites* and *Koninckites* also, both of typical Induan affinity, are present. *Meekophiceras*? *vercherei* (Waagen) was originally assigned to *Koninckites* with which it differs by tabulate cross-section and strong terminal umbilical egression. *Meekophiceras* Tozer, 1994 is more similar but shows a less eggressive and externally rounded adult whorl.

Rohillites rohilla Zone

Named for the first time by Krafft around 1900 and later discussed in more detail by Krafft and Diener (1909), this zone includes beds 13 and 14. It is defined at the base (13A) by the FA of the genus *Rohillites* and the presence of Induan holdovers (*Prionolobus, Proptychites*). *Rohillites* has a general gyronitid morphology with faint strigate ornamentation and a tendency to increasing costulation through time. The oldest representative *Rohillites* n. sp. 1 is seen with evolute, very week strigate and narrowly tabulate whorls found in 13A, whereas *Rohillites rohilla* occurring from 13A to 13C is less evolute, variably smoothly to coarsely ribbed, externally again it has narrow tabulate whorls. It is replaced in 14A by *Rohillites* n. sp. 2 with closer spaced but still broad ribs, a fat tabulate venter and a distinct umbilical shoulder that is missing in the stratigraphically older species. The new species seems to have a close and most probably time-correlative counterpart in *Rohillites* sp.

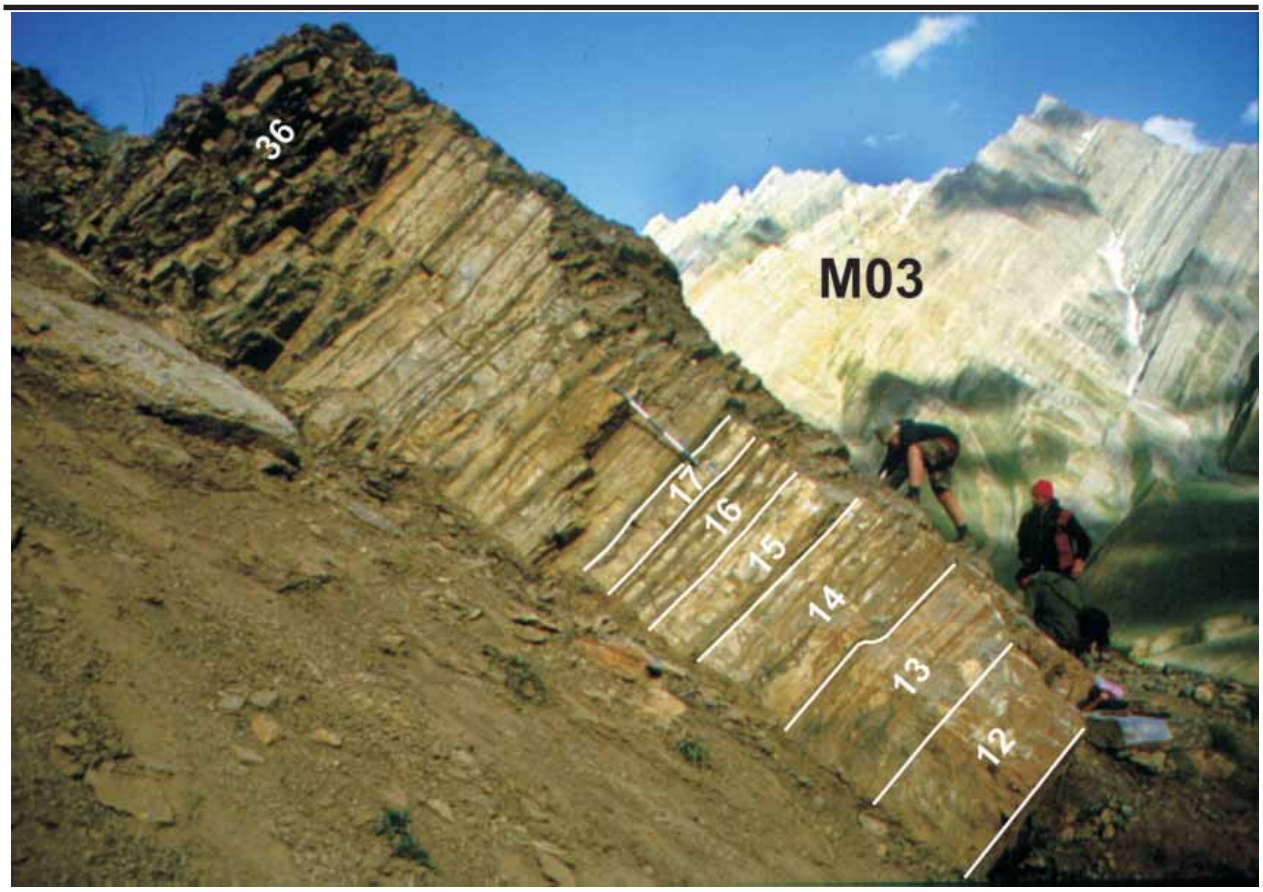

Fig. 7. Photo of section M03 showing bed sequence 12 to 40 (*M.*? *vercherei* beds to *Flemingites-Euflemingites* zone).

indet. in the upper "*Kashmirites kapila* beds" of northwestern Guangxi, China (Brayard & Bucher, in press).

Successive appearances of other flemingitids allow a discrete subdivision of the *rohilla* Zone by the FA of *Beoflemingites griesbachi* (Krafft) in 13B and *Beoflemingites mandhata* (Diener) in 14B. The genus *Beoflemingites* has been established by Waterhouse (1996) for *Flemingites trilobatus* Waagen, 1895 and is distinguished from *Flemingites* s. str. by a stronger incised suture line and, in the Himalayan species by slender balloon-like saddles. Other common *rohilla* Zone species are *Kashmirites kapila* (Diener) and *K. nivalis* (Diener) first reported in 13B, and ranging slightly above the top of the zone (15C). Of further importance could be the FA of the hedenstroemiid *Pseudohedenstroemia himalayica* (Spath) in 13B and that of *Pseudaspidites muthianus* (Krafft) in 13A.

The *rohilla* Zone contains a rather rich fauna dominated by flemingitids (40-60%) and *Kashmirites* (30-40%). Compared to the underlying *Meekophiceras*? *vercherei* beds the fauna is highly diverse and marked by an explosive radiation in the ammonoids. Of the represented 10 genera at least five are definitely new, only two are true holdovers and three are indefinite (*Parakymatites, "Koninckites", "Meekoceras" pulchrum*). Ammonoids of bed 13 show by far the best preservation within the *Flemingites* beds by protecting the shell and the original body form.

Flemingites – Euflemingites Zone

Including only beds 15 and 16, the *Flemingites* Beds contain a very minor part (10%) of this zone; its major part is confined to the lower *Parahedenstroemia* beds (Fig. 4; 11). The FAD of the genera *Flemingites* and *Euflemingites*, a first order bioevent of obvious worldwide correlatability, marks bed 15. *Flemingites* disappears soon above bed 16 for unknown reasons; of 11 specimens from beds 15 and 16 some are close to *F. compressus* Waagen, 1895 with respect to style of ribbing and the whorl proportions (i.e. height and degree of involution). Specimens of *Euflemingites* are still more rare (two each in bed 15 resp. 16), fragmentary and distorted but the preserved strigate rib-less ornamentation allows at least a generic identification. Of importance is a specimen of *Euflemingites guyerdeti* documented in Diener (1897, pl. 1, Fig. 7) from Mud, housed in the collections of the Geological Survey of India (GSI 5293) in Kolkata (old spelling Calcutta). Waterhouse (1996) has created a new genus (*Colchenoceras*) for this species, which seems untenable. *Euflemingites guyerdeti* has been recorded by Diener (1897, p. 99) as belonging to a "dark semicristalline limestone containing *Nannites herberti* and *N. hindustanus* from the *Otoceras* beds". The two "*Nannites*" are now referable to the genus *Juvenites,* which has a massive occurrence in a thin dark gray tempestitic packstone layer numbered as bed 23 of the Mud sequence, thus *E. guyerdeti* is relocated to this level about one meter above the base of this zone (Fig. 11).

Additional genera appearing in bed 15 are *Anaxenaspis,*

Fig. 8. Photo of the candidate GSSP (section M04) with beds numbers.

Waagenoproptychites and *Parahedenstroemia* with the species *P. acuta* (Krafft). Holdovers in bed 15 from the underlying zone are *Beoflemingites mandhata*, *Pseudohedenstroemia himalayica* (Spath) and *Pseudaspidites muthianus* (Krafft). *Kashmirites* ranges up from the *rohilla* Zone and is common in beds 15 and 16 with newly appearing zones forms (Kashmirites sp. 1 and Kashmirites cd. borealis Tozer). Bed 16 shows the FA of *Juvenites* and *Dieneroceras*? followed by the entry of additional genera (*Prejuvenites, Paranannites, Paranorites, Nilgiria*) slightly higher, within one meter of thickness (Fig. 11).

The base of the *Flemingites – Euflemingites* Zone recalls a second strong turnover in the ammonoid fauna with six newly appearing and four holdover genera, followed closely by another four new genera., many of them worldwide known in lower to middle palaeolatitude southeastern Tethys, China, US, Canada). Most of the collected material (75%) comes from the section M04 and is dominated by the genus *Kashmirites* (>50%) with orthoceratids being further common. Stratigraphically relevant taxa are rare comparably rare but collections could be easily enlarged with additional sampling.

Conodonts

Details on the conodont succession of Mud can be found in Orchard and Krystyn (this volume). Results of the study are here summarized as follows:

1) Three intervals have been discriminated corresponding to the above-described ammonoid zones (Fig. 10):

Zone 1 (Beds 11–12 = *M.*? *vercherei* B.) shows a typical Induan fauna dominated by *Ns. dieneri*, *Ns. cristagalli*, *Ns. pakistanensis*, and *Bo. nepalensis*, with uncommon *Ns. chii* and *Ns. concavus* restricted to the interval.

Zone 2 (Beds 13–14 = *Rohillites rohilla* Zone) contains *Ns. posterolongatus*, *Ns*. ex gr. *waageni* (FAD in 13A) and *D. dicreta*, and by this a traditional Olenekian fauna initially associated with species of the underlying bed.

Zone 3 (Beds 15–16 = basal *Flemingites–Euflemingites* Zone) is marked by the entry of *Ns. spitiensis*, which occurs in association with *Ns*. *waageni* and *D. dicreta*.

2) The conodont sequence is directly correlatable with West Pingdingshan (Chaohu, South China), the other proposed candidate GSSP for the IOB. Compared with Chaohu, Zone 1 of Mud can be broadly correlated with the upper part of the *dieneri* Zone. Zone 2, based on the FAD of *Ns. waageni* s.l. can be recognized in both areas: in West Pingdingshan, it falls in the top-part of Bed 24 compared with a position close to the base of the *Rohillites* Zone in Mud. A further difference about these levels is the order of appearance of *Ns. waageni* morphotypes 2 and 3. In West Pingdingshan, the appearance of *Ns. w. eowaageni* (~morphotype 3) is slightly earlier (in bed 24 top) than *Ns. w. waageni* (~morphotype 2, bed 25 base), whereas the two forms appear either concurrently or in reverse order at Mud. The base of Zone 3, identified by the FAD of *Ns. spitiensis*, begins in bed 15 in Mud and

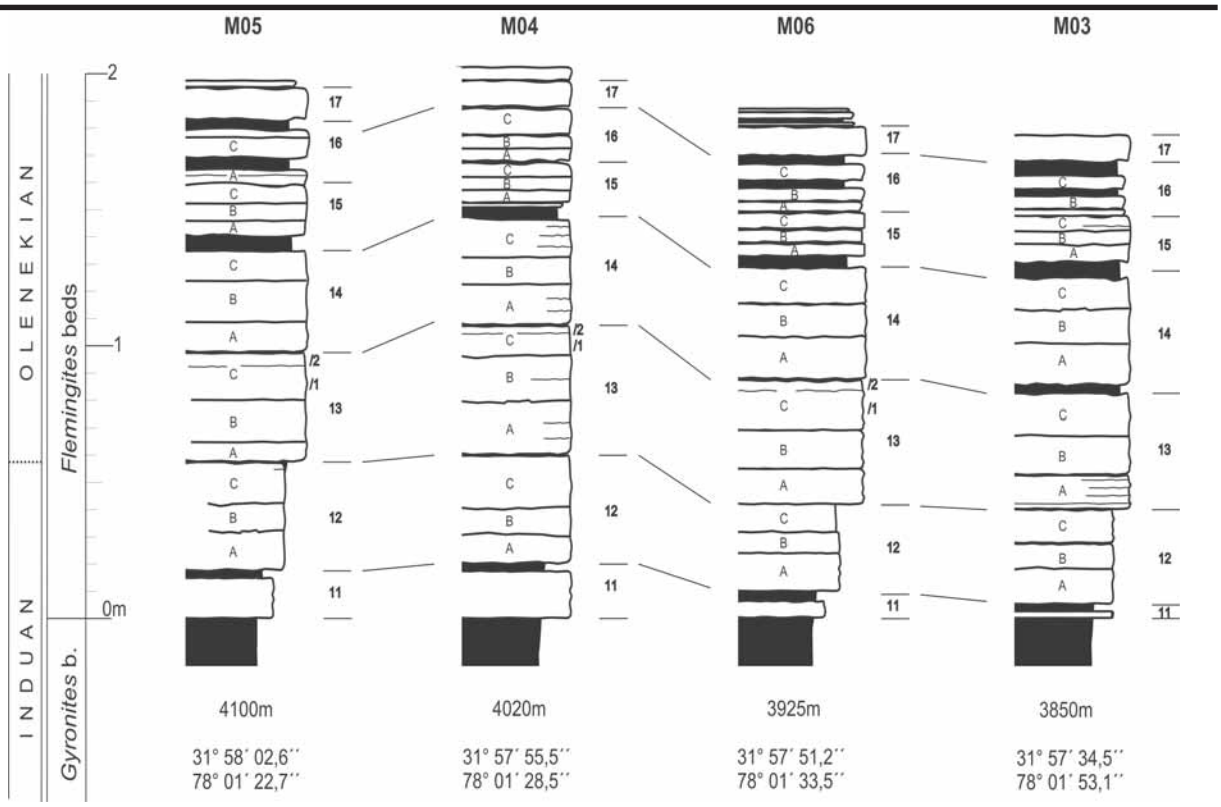

Fig. 9. Lithostratigraphic correlation and location of the sections M03 to M06 (M04 = candidate GSSP).

in bed 26 in the West Pingdingshan section. In both cases it corresponds to the *Flemingites – Euflemingites* Zone.

3) The highly diverse conodont fauna contains elements (*Ns. pakistanensis, Bo. nepalensis*) of specific importance for long-distance correlations within the Tethys as well as with the Panthalassa and Boreal realm, which are either rare or missing in Chaohu.

Depositional Setting

The Induan-Olenekian boundary beds of Mud (and Spiti respectively) show a gradual change in the sedimentary environment from black laminated pyrite-rich an- or disoxic shales (below bed 10) to dark gray, brownish weathering lime mudstones (beds 10 – 12) with rare thin ammonoid shell concentrations followed up-section by gray well oxygenated and bioturbated bioclastic wackestones rich in fragments or complete specimens of large ammonoids (beds 13-16). The consistent pure mud-dominated sediment indicates deposition in calm water below active wave base. Current-indicative layers occur only in bed 12C within two 1-2 cm thin and discontinuous shelly packstones, and as a single ripple-bedded packstone layer in 14B. Shelly-rich, thin pack- to grainstone intercalations get common and thicker within the overlying *Parahedenstroemia* beds (bed 22 and above). Sharp erosive base, dense grain-supported accumulation of predominantly fragmented small ammonoid shells (mean diameter below 5 cm) or lumachelles of parallel-aligned thin-shelled bivalves are interpreted as tempestitic layers. Their higher frequency can be explained either by a sea level drop or an increase of storm activity and of bottom water currents. A distinction between the two alternatives would be important but seems presently not possible. At least a primary basin depth close to storm weather base (i.e. 50-70 m) is most logical. The pelagic fossils such as ammonoids, specific bivalves and conodonts are found both in fine-grained carbonates (mudstone, wackestone,) as well in tempestites (filamentous pack- to grainstone).

The Himalayan Lower Triassic thus formed part of a large deeper-neritic basin and the Spiti sediments were deposited on wide stable shelf to provide extensive continuity to the beds. This not only affords ideal setup for delineation and improvement of the IOB but also for a long-distance correlation of the discriminated ammonoid zones along the southeastern Gondwana margin.

Carbon isotope stratigraphy and magnetostratigraphy

Richoz et al.(this volume) have published a detailed account of δ^{13}C-curve of Mud. Because of a relatively high thermal overprint (CAI~5) during the Himalayan orogeny, rocks in Spiti might have suffered a certain degree of diagenetic alteration that could have influenced the isotopic signature. Thin section, carbonate content and C- versus O-isotopes cross-plot studies have, however, shown that the limestones have not been affected enough by diagenesis for any significant alteration of the C-isotope signature (Richoz et al., this volume). To get a reliable isotope profile more than 60 samples have been measured within a 3m interval around the IOB with repeated runs for the 20 sampled beds.

The δ^{13}C-curve (Fig. 13) fluctuates in the top-*Gyronites*

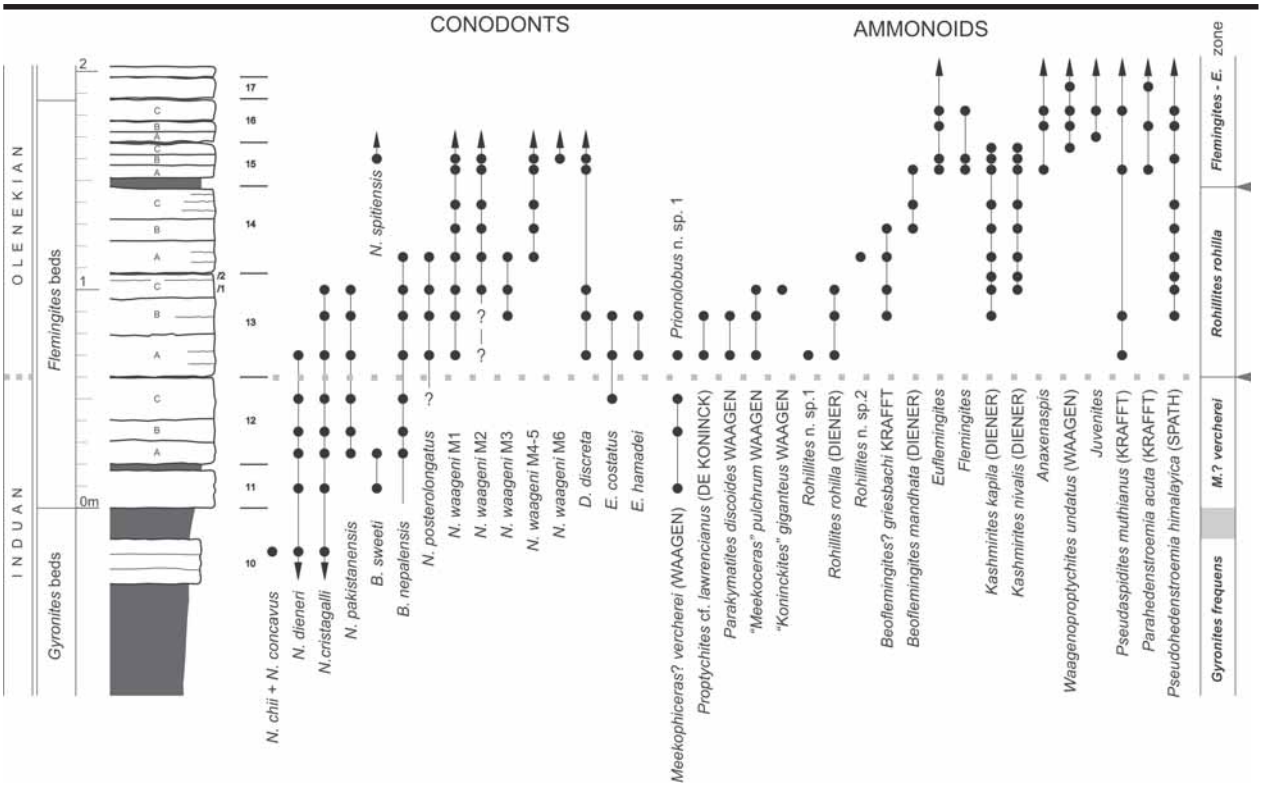

Fig. 10. Vertical range and zonation of conodonts and ammonoids in the IOB beds in Muth. Arrows mark the two boundary options of which the lower (bed 13A) is preferred.

Beds (11-12) around -1‰, followed by a sharp positive excursion of 1‰ leading to a prominent peak close to 0‰ in 13A and 13B. Bed 13C records a quick return to more negative values of below -1‰. Within bed 14 occur only minor variations till a second negative shift in 15A leads to a minimum around –2.5‰. The signal recovers slightly to –1.7‰ during bed 16 to return again to - 2‰ in bed 17.

To summarize, the Mud curve is characterized by a well-marked singular inflexion point in connection with a relatively small positive excursion (of 1‰) in the basal *rohilla* Zone (from 13A to 13B). This positive excursion seems to reflect a distinct, widespread and short-termed event known from many Tethyan sections around the Induan-Olenekian boundary with usually much larger amplitude of 4-6‰. Correlation of this excellent marker event to West Pingdingshan is problematic since a strongly deviating curve with an unusual flat and long-lasting C-isotope plateau between the *dieneri* and the *spitiensis* conodont Zones replaces the short peak developed elsewhere (Richoz et al., this volume).

Due to common thermal overprint during the Himalayan orogeny it can be assumed that the original palaeomagnetic signature in the Mikin Formation has been erased and has received a Tertiary remagnetisation.

Correlation

Induan-Olenekian boundary options

The Mud data are crucial to delineate two potential boundary levels indicated by arrows in Fig. 10:

1) *Base of Bed 13*: the FAD of R*ohillites rohilla* in bed 13A marks the entry of flemingitids or typical Olenekian (Smithian) ammonoids. The nearly contemporaneous appearance of kashmiritids and of *P. himalayica* strengthens the event as the latter may indicate close synchronicity (?) with the appearance of *Hedenstroemia* in the Boreal. According to Orchard and Krystyn (this volume) the same event corresponds to the strongest change in the conodonts with the FAD of *Ns. waageni* and other typical Smithian fauna, allowing long distance correlations to both basinal (by *Ns. waageni, Discretella*) and platform environments (by *Eurygnathodus*). The presence of *Bo.* (=*Ch.*) *nepalensis* further facilitates cross-correlation with the Boreal. Following the data of Richoz et al. (this volume) a characteristic turning point in the C-isotopes in bed 13 is another advantage of and point for this boundary. The strongest argument for option 1 stems from the decision of the STS to prefer the FAD of *Ns. waageni* s.l. as defining bio-event and this recommendation is followed here too.

2) *Base of Beds 15*: the FOs of *Flemingites* and *Euflemingites* in bed 15A correspond to a second ammonoid radiation phase with intercontinental correlation potential from the Tethys to Panthalassa (North America) and to the Boreal. Conodonts and C-isotopes are, however, less indicative for boundary option 2.

Regional correlation

The co-occurrence of well preserved diverse and biostratigraphically diagnostic ammonoid and conodont

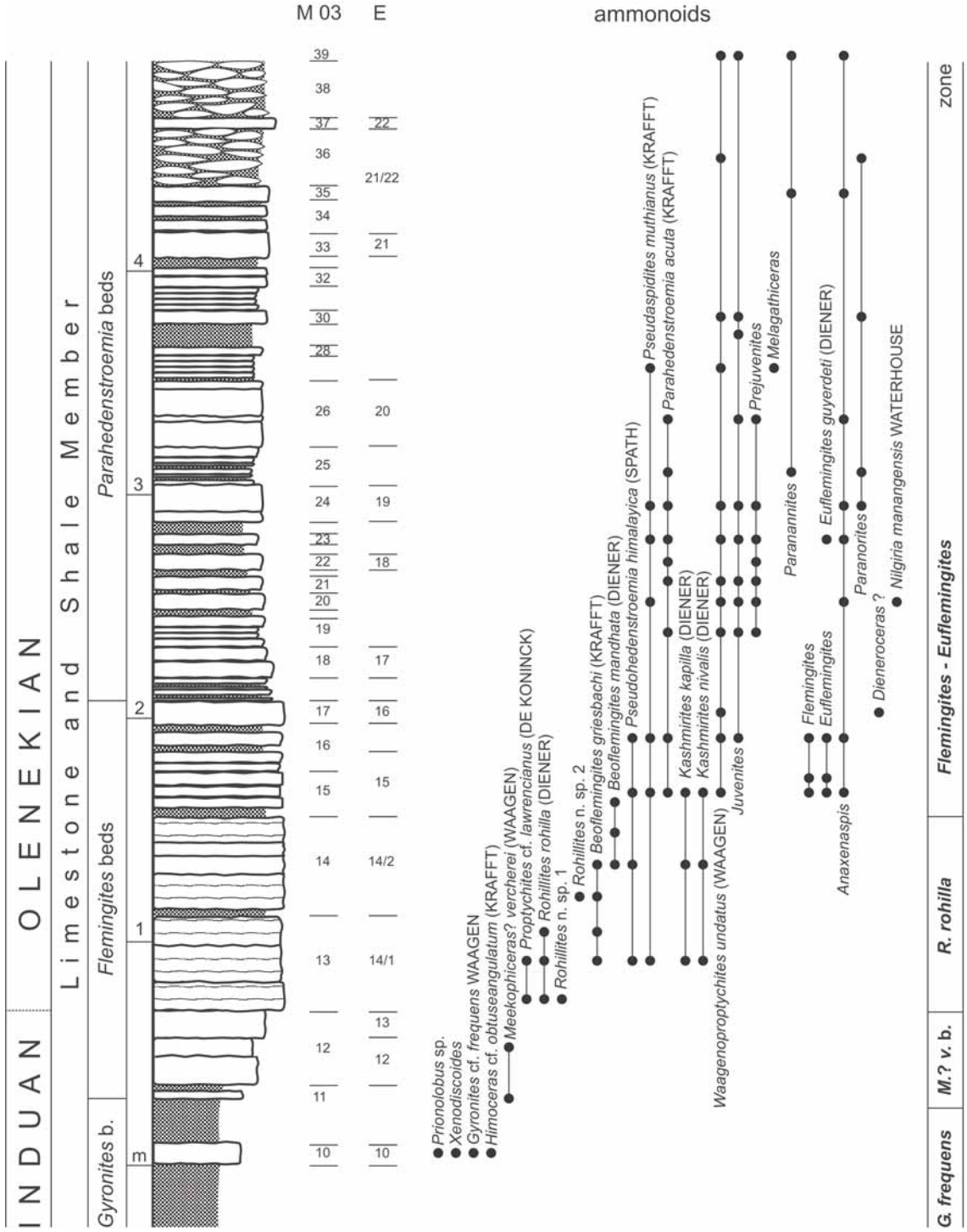

Fig. 11. Composite ammonoid fauna of the *Flemingites* beds in Mud.

faunas is rare in strata corresponding to beds 12-14 of Mud anywhere in the world. Evident ammonoid counterparts of the Spiti *rohilla* Zone are indicated only along the southeastern Tethys margin between Kumaon, Nepal (Waterhouse, 1996), Tibet (Wang and He, 1976) and Timor (Welter, 1922), usually without detailed sequential information. Most of the other low palaeolatitude areas contain either no (Salt Range, USA) or so badly preserved fauna (China: Chaohu) that precise ammonoid correlation within the critical interval becomes highly speculative (Fig. 13).

Comparison with Chaohu and northwestern Guangxi (South China)

A correlation with Chaohu (sections North Pingdingshan/N.P. respectively West Pindingshan/W.P., the other proposed candidate GSSP) is of special importance and can be confidently attempted on the basis of recently documented ammonoid (Tong et al., 2004; 2006) and conodont faunas (Zhao et al., 2007). Both the sections show an identical conodont record with appearance of *Ns. waageni* s.l. in top of bed 24 (W.P). versus mid-bed 49 (N.P.), a level tied together in terms of the ammonoid

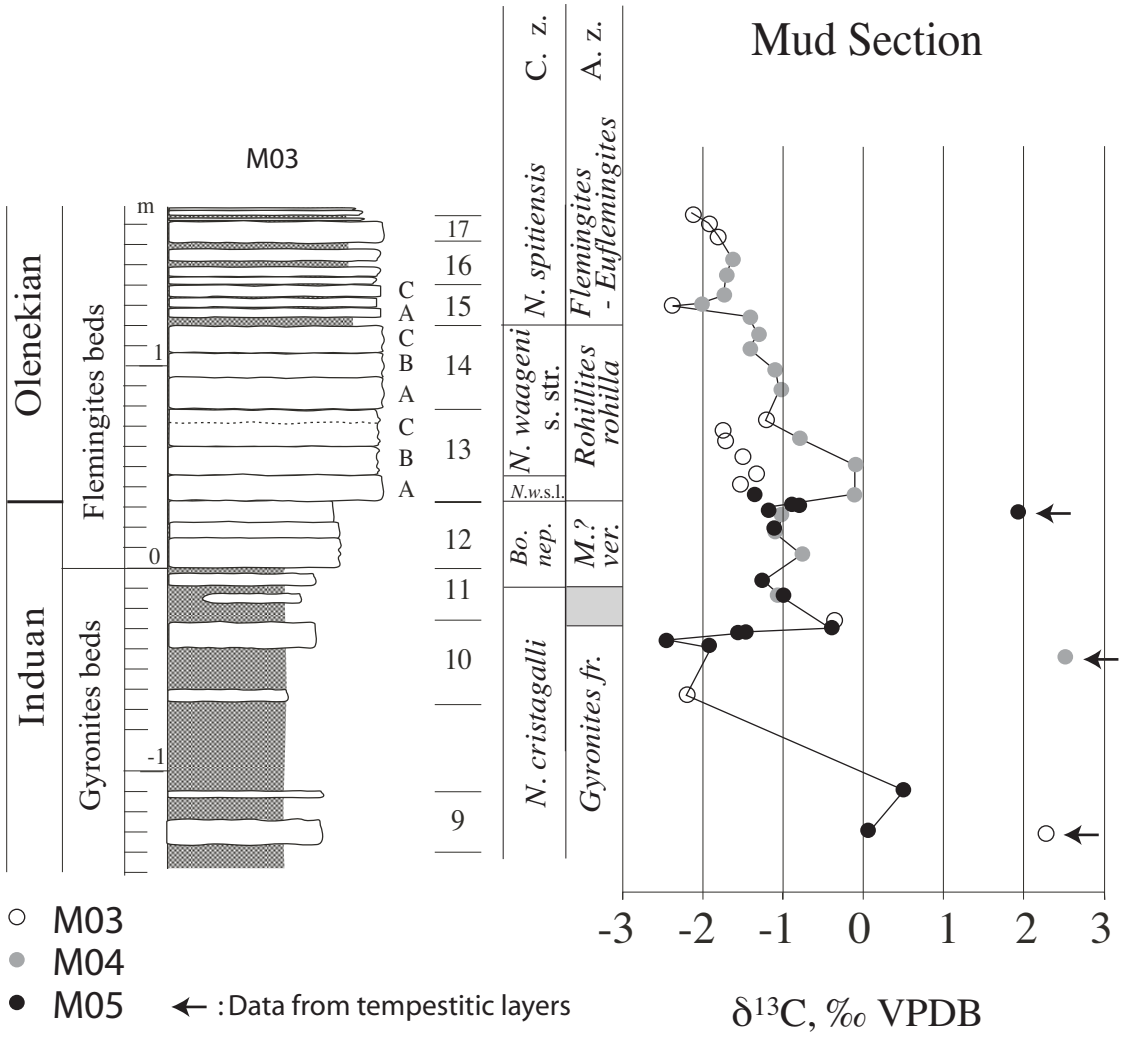

Fig. 12. $\delta^{13}C$ isotope curve of the I-O boundary beds in Mud. Note the positive peak and inflexion point in beds 13A and 13B close to the proposed boundary (from Richoz et al., this volume).

record with the *Flemingites-Euflemingites* Zone (Tong et al., 2003). The latter zone starts in a three times thinner Mud section one meter (1m) above *Ns. waageni* s.l. (Fig. 10) and contains *Ns. spitiensis*, a species otherwise found earliest in W.P. in bed 26 or four meters above the base of the *Flemingites-Euflemingites* Zone – a serious biostratigraphic paradox.

The above-mentioned inconsistencies impede the correlation of the integrated ammonoid-conodont zonal schemes of Chaohu and Spiti. These inconsistencies have to be resolved before a decision on the boundary biomarker(s) and the definite GSSP site are decided. As conodonts are common and taxonomically well documented in Chaohu, attention has been concentrated on the ammonoids, which in some levels are quite common (W.P. 24 and 25), while in others missing or, if present, not mentioned (W.P. 26). Exactly constrained ammonoids are figured in Tong et al. (2004) and in greater quantity in Tong et al. (2006). Of those deserving special attention – including taxonomic annotations – is in top of bed 24 (base of Olenekian):

- *Euflemingites* sp. (Tong et al., 2006, pl. 2, fig. 13) – due to inadequate preservation generically indeterminate.
- *Euflemingites* cf. *tsotengensis* Chao (Tong et al., 2006, pl. 2, fig. 14) – without any sign of the genus-typical spiral ornamentation, a to narrow umbilicus (just 15%) and through the unusually deep and slender lateral lobe, gyronitid-looking suture certainly no *Euflemingites*.

in bed 25 (basal Olenekian):

- *Preflorianites*? sp. (Tong et al., 2006, pl. 2, fig. 15) – could likewise be a *Rohillites*? sp.
- *Euflemingites*? sp. (Tong et al., 2006, pl. 3, figs. 4, 8, 13, 20) – all without spiral strigation and indeterminate.
- *Flemingites*? sp. (Tong et al., 2006, pl. 3, fig. 7) – could be a *Rohillites*? sp.

<table>
<tr><th colspan="2">bed Mud</th><th>Salt Range</th><th>NW Guangxi</th><th colspan="2">bed Chaohu</th><th>Primoriye</th></tr>
<tr><td>16
15</td><td colspan="2">Flemingites-
Euflemingites</td><td>Flemingites
flemingianus</td><td>Flemingites
rursiradiatus b.</td><td>52
26?</td><td>Flemingites-
Euflemingites</td><td>Hedenstroemia
bosphorensis</td></tr>
<tr><td>14C
14B
14A
13C
13B
13A</td><td rowspan="3">Rohillites
rohilla</td><td>Beoflem.
mandhata</td><td rowspan="3">?</td><td rowspan="3">Kashmirites
kapila beds</td><td rowspan="2">25</td><td rowspan="2">?
(“Flemingites-
Euflemingites”)</td><td rowspan="3">?
?
?</td></tr>
<tr><td>Beoflem.
griesbachi</td></tr>
<tr><td>R. n.sp.1</td><td rowspan="2">24</td></tr>
<tr><td>12
11</td><td colspan="2">Meekophiceras?
vercherei beds</td><td>Prionolobus
volutus</td><td>Clypeoceras
n. sp. A beds</td><td>Prionolobus
- Gyronites</td><td>Gyronites
subdharmus</td></tr>
</table>

Fig. 13. Regional ammonoid zonal correlation of the boundary interval and of the proposed boundary for the base of the Olenekian stage. Data from Chaohu reinterpreted, Guangxi sequence according to Brayard and Bucher, in press.

- *Flemingites*? sp. (Tong et al., 2006, pl. 3, fig. 17) – eventually a *Kashmirites*? sp.

in the coeval bed 50 of North Pingdingshan:

- *Flemingites* sp. (Tong et al., 2004, text-fig. 8, pl. 2, fig. 11) – a juvenile fragment of indeterminate generic position. The suture line shows a high second and third lateral saddle resembling more *Kashmirites* than flemingitids.

in bed 52 of North Pingdingshan (3m above bed 50):

- *Euflemingites* cf. *tsotengensis* Chao (Tong et al., 2004, pl. 2, figs. 13, 14) – by the well visible spiral strigation true *Euflemingites*.

The re-interpretation of the above discussed taxa leads to a conclusion that i) as in Spiti first true *Euflemingites* appears well above the *Ns. waageni* group and ii) for the most of the Chaohu specimens even a generic determination remains doubtful. Strong compression and extensive diagenetic de-carbonatisation have produced flattened, sometimes paper-thin imprints, where diagnostic features (shell sculpture, original cross-section and sutural details) have been lost. To distinguish between the genera *Gyronites, Rohillites, Beoflemingites, Flemingites* or *Euflemingites* under such conditions is practically impossible.

A diverse, well-preserved and stratigraphically detailed documented ammonoid fauna has recently been studied in the Luolou Fm. in northwestern Guangxi (Brayard and Bucher, in press) with a three-fold zonal division (“*Clypeoceras* n. sp. A beds”, “*Kashmirites kapila* beds”, ”*Flemingites rursiradiatus* beds”) that can be recognized in Mud too (Fig. 13). Taking aside the poorly constrained “*Clypeoceras* n. sp. A beds” and a short barren interval above, the“*Kashmirites kapila* beds” are linked by *K. kapila* with the *rohilla* Zone of Mud where this species is common. A second link between the upper parts of the “*Kashmirites kapila* beds” and of the *rohilla* Zone is established by *Rohillites* sp. indet., a morphological twin of *Rohillites* n. sp. 2 in Mud. Diverse and generically similar *Flemingites* faunas occur in both cases only above this bed. The Guangxi ammonoid record thus mirrors the Spiti succession and is a reasonable confirmation that the *Flemingites-Euflemingites* bearing interval is separated from Induan faunas by another ammonoid association, which can claim an independent status at the very base of the Olenekian stage and is currently not known or distinguished in Chaohu (Fig. 13).

Acknowledgements

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Table 1. Ammonoid distribution through the I-O boundary beds in Mud, sections M03 to M06.

	04/11	03/12B	04/12C	03/13A	04/13A	06/13A	03/13B	04/13B	05/13B	06/13B	04/13C	05/13C	06/13C	04/14A	04/14B	04/14C	04/15A	05/15A	06/15A	04/15B	05/15B	06/15B	04/15C	06/16A	03/16B	04/16B	05/16B	04/16C	06/16C	03/17
M.? vercherei	X	X	X																											
Prionolobus n. sp. 1					X																									
Proptychites cf. lawrencianus				X			X	X		X	X																			
Parakymatites discoides						X		X		X	X																			
"Meekoceras" pulchrum					X	X		X		X	X																			
Rohillites n. sp. 1						X																								
Rohillites rohilla					X	X	X		X	X		X	X																	
Rohillites n. sp. 2											X			X																
Beoflemingites griesbachi									X		X	X		X	X															
Beoflemingites mandhata												X			X	X														
Flemingites																X	X			X										
Euflemingites																	X			X			X							
Kashmirites sp.									X								X						X							
Kashmirites kapila								X			X			X			cf.			X										
Kashmirites nivalis									X		X			X	X	X	X		X	X		X	X			cf.		cf.		
Anaxenaspis																	X		X					X		X				
Waagenoproptychites undatus																	cf.						X		X	X				X
Juvenites																								X	X				X	
Pseudaspidites muthianus			X							X						X												X		
Parahedenstroemia acuta																										X				X
Pseudohedenstroemia himalayica									X	X	X			X	X	X			X	X				X		X		X		

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Plate 1
Fig. 1: *Prionolobus* n. sp. 1; M04-13A
Fig. 2: *Meekophiceras*? *vercherei* (Waagen)*;* M03-12B
Fig. 3-4: *Rohillites rohilla* (Diener); M04-13C

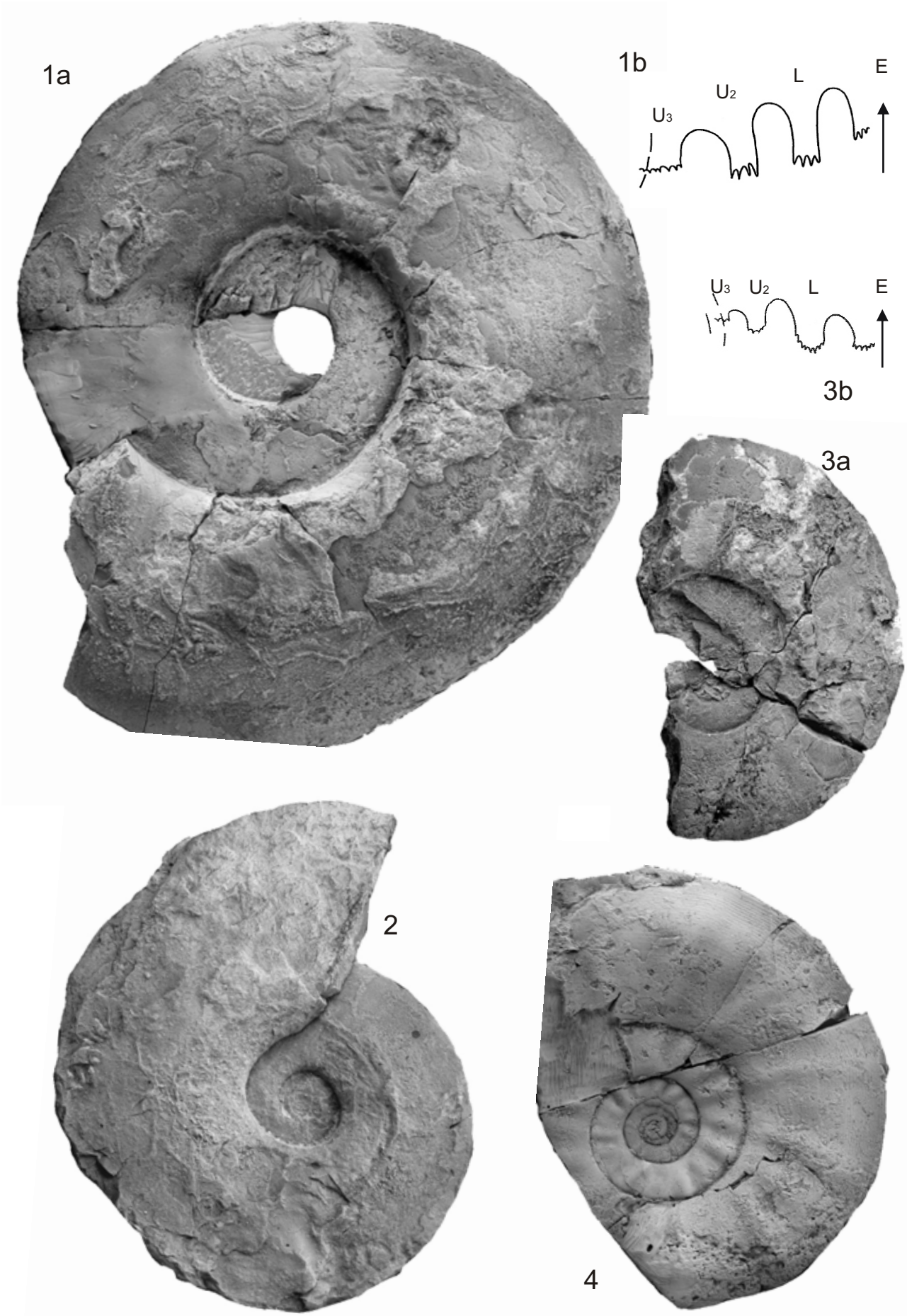
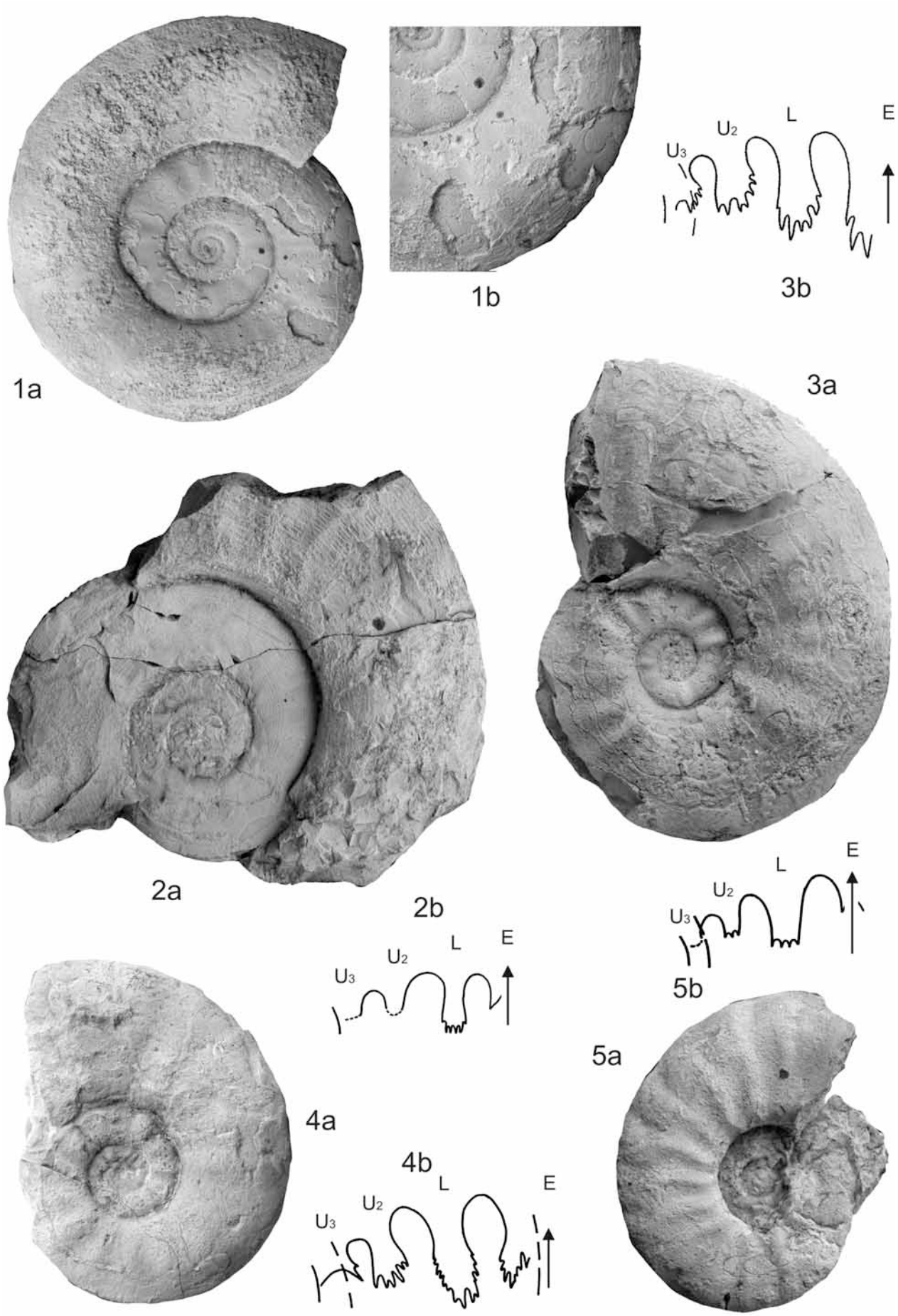

1a
1b
U3
U2
L
E
U3
U2
L
E
3b
3a
2
4

Plate 2
Fig. 1: *Rohillites* n. sp. 1; M06-13A
Fig. 2: *Rohillites* n. sp. 2; M04-14A
Fig. 3: *Beoflemingites mandhata* (Diener); M04-14B
Fig. 4: *Beoflemingites griesbachi* (Krafft); M04-14A
Fig. 5: *Flemingites* cf. *compressus* Waagen; M05-15B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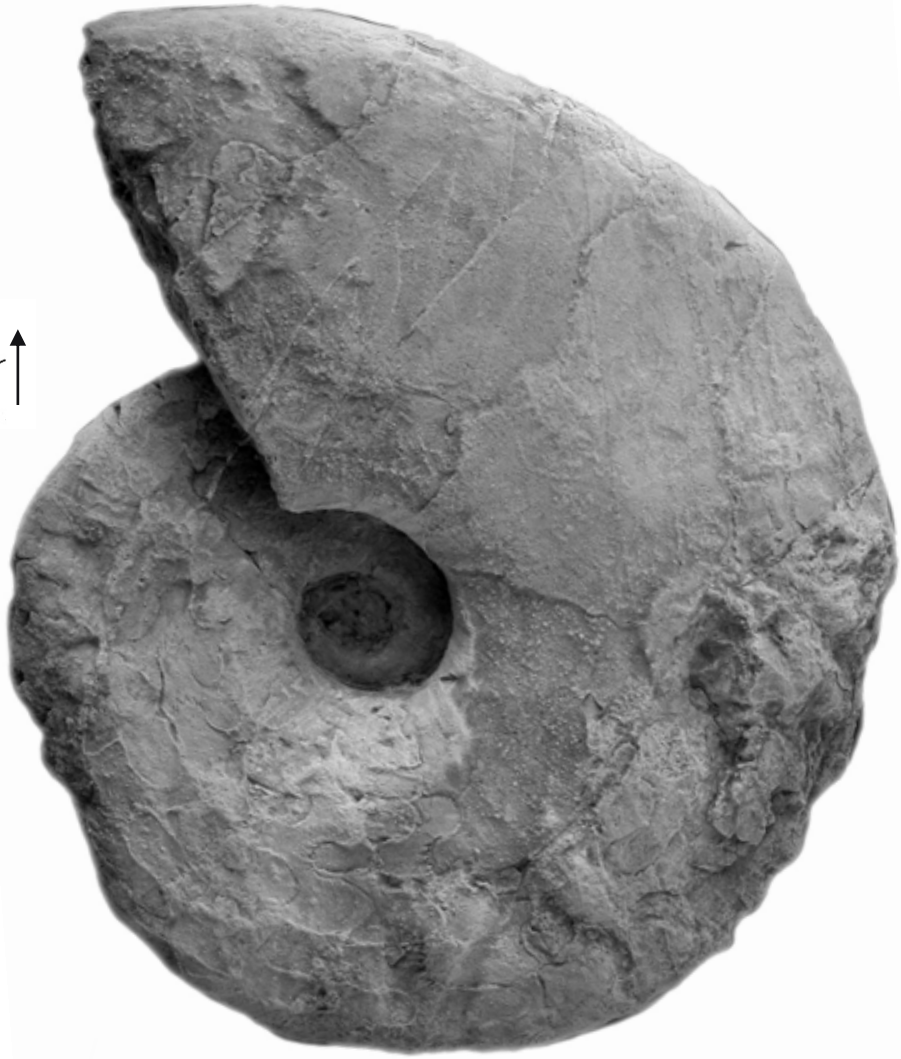
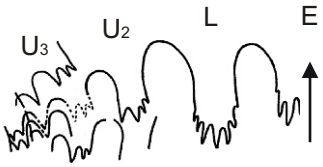
5a
4a
4b
U3
U2
L
E

Plate 3
Fig. 1: *"Meekoceras" pulchrum* Waagen; M04-13B
Fig. 2: *Proptychites* cf. *lawrencianus* (De Koninck*)*; M03-13B

1b



1a

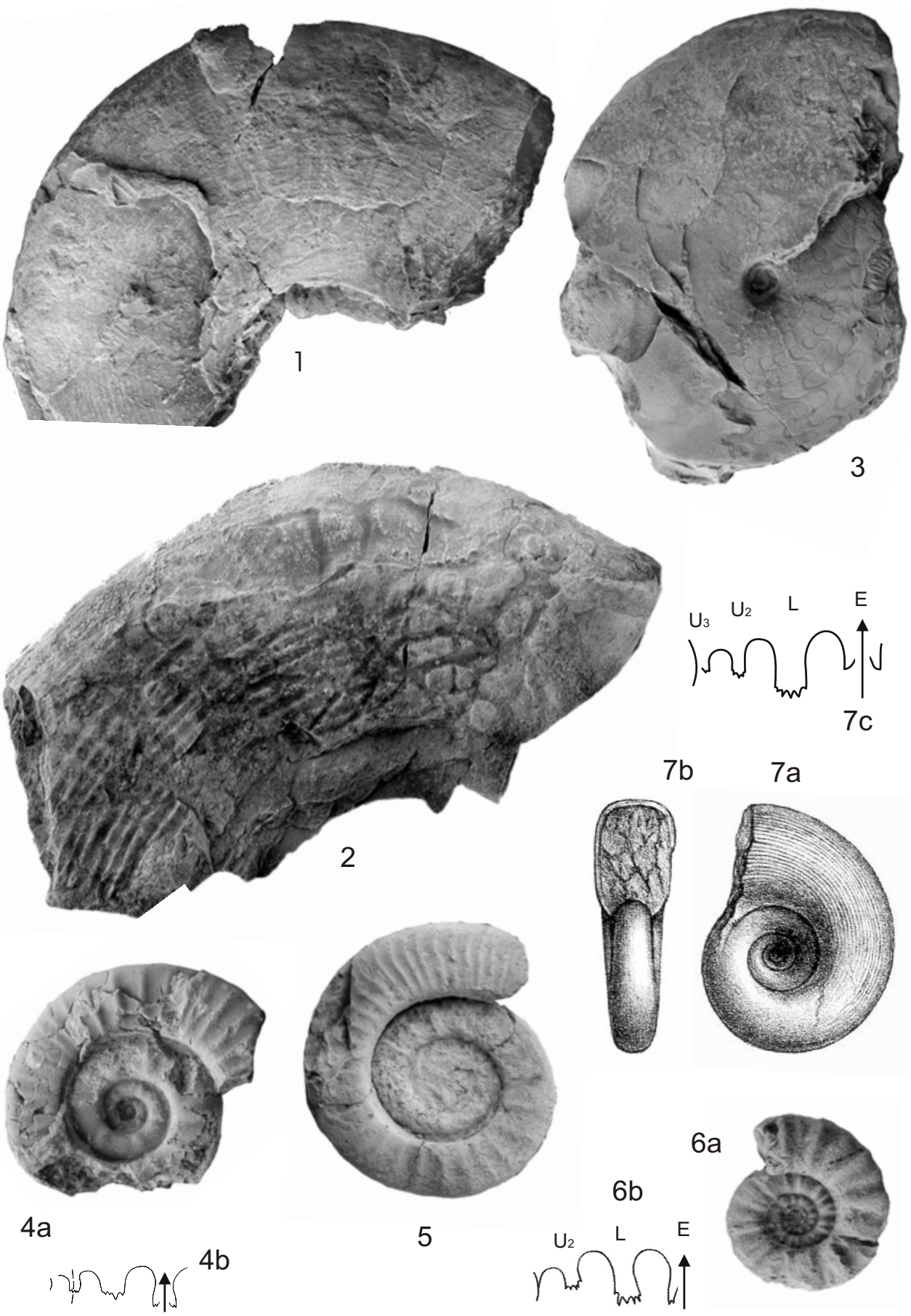


2b

2a

Plate 4
Fig. 1-2: *Euflemingites* sp.; 1: M04-16B, 2: M04-15B
Fig. 3: *Pseudohedenstroemia himalayica* (Spath); M04-15C
Fig. 4: *Kasmirites nivalis* (Diener); M04-13C
Fig. 5: *Kashmirites kapila* (Diener); M04-13C
Fig. 6: *Kashmirites* sp.; M04-16C
Fig. 7: *Euflemingites guyerdeti* (Diener); Mud, app. bed 23 - copy from Diener, 1897.

All specimens are figured in natural size and housed in the Department of Palaeontology, Vienna University.


1
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Conodonts from the Induan-Olenekian boundary interval at Mud, Spiti

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Introduction

Two localities are candidates for the GSSP of the Induan-Olenekian boundary (IOB): West Pingdingshanensis in Chaohu, Anhui Province, China (Tong et al., 2004), and the Muth section, situated in the Lahul and Spiti district of the northern Himachal Pradesh State of India in the Western Himalayas (Krystyn et al., 2005). The former has been the subject of several studies in which its fauna and other features have been described (Tong, 2005; Tong & Zacharov, 2004; Tong et al., 2005, 2006a, b). The conodonts from Chaohu are summarised by Zhao et al. (2004; in press). In order to make comparisons between the two candidiates, the conodont succession in Spiti is here summarized and compared with that from Chaohu.

The Lower Triassic in Spiti (Bhargava et al., 2004) is represented by the Mikin Formation (formerly Tamba Kurkur Fm.), which consists of three members named after their distinctive ammonoid fauna: 1) 3 m meters thick *Gyronites* beds (the former *Meekoceras* beds of Krafft); 2) 2 meters thick *Flemingites* beds (including the IOB beds); and 3) up to 10 m thick *Parahedenstroemia* beds. The Mikin Formation extends from Muth northwest along a tributary valley for several kilometers to the crest between the Pin and Parahio valleys. One of us (LK) sampled the continuously exposed beds at four sites on the northern valley slope, one 100 m above the village called M-03, and the others between 3900 and 4100m named M-04 to M-06. Strata covering the I-O boundary interval were assigned to beds 10 through 16, many of which were subdivided into sub-beds for sampling. A comprehensive geological description of the Muth site is to be found in Krystyn et al. (2004).

Ammonoid succession

The essential features of the ammonoid succession are described elsewhere (Krystyn, this volume). These can be summarized thus:

Bed 10 – assigned to the *Gyronites* (former *Meekoceras*) beds, and containing *Gyronites frequens* and *Himoceras*.

Beds 11-16 – assigned to the *Flemingites* beds and divided into the following layers:

Beds 11, 12A, 12B, 12C - the *Meekophiceras*? *vercherei* beds (0.4-0.6 m)

Beds 13A, 13B, 13C, 14A, 14B, 14C - the *Rohillites rohilla* Zone (0.9 m)

Beds 15A, 15B, 15C, 16A - the basal *Flemingites – Euflemingites* Zone (0.3m)

Conodont succession

Conodonts were recovered from a total of 21 samples (Table 1). A generally consistent conodont faunal succession was established in sections M-03 and M-04 in beds 12C, 13A, 13C, 14C, and 15 (A+B) with each showing a simultaneous appearance of *Ns. posterolongatus* Zhao & Orchard plus *Ns. waageni* Sweet sensu lato in bed 13, and a later appearance of *Ns. spitiensis* Goel in bed 15. Bed 11 showed some differences between M-03 and M-04 but they are not anomalous in the succession. Sections M-03 and M-06 yielded a similar fauna in bed 13B. Single samples from beds 10, 12A, 12B, 14A, 14B, and 16 in sections M-03 and M-04 showed no significant variance in terms of FADs and LADs.

The lowest horizon, bed 10, representing the *Gyronites* beds, contains a relatively diverse fauna consisting of three morphotypes of *Ns. dieneri* Sweet newly recognized by Zhao et al. (in press), plus *Ns. cristagalli* (Huckriede), and uncommon occurrences of *Ns. chii* Zhao & Orchard and *Ns. concavus* Zhao & Orchard. This association can be directly correlated with that at Chaohu, where the three morphotypes and the two new species recognized by Zhao et al. (in press) co-occur near the top of the *Prionolobus – Gyronites* Zone of both West and North Pingdingshan sections. Although the highest *Ns. concavus* occurs with *Ns. waageni eowaageni* Zhao & Orchard in both Chinese sections, no representative of the *Ns. waageni* group occurs at this level at Muth and therefore the conodont association of bed 10 is regarded as predating any prospective I-O boundary position.

Bed 11 yielded slightly different faunas at M-03 and M-04 although the long ranging *Ns. cristagalli* is common to both. At M-03, the latter species is accompanied by *Neospathodus dieneri,* but at M-04 *Ns. pakistanensis* Sweet and *Borinella nepalensis* (Kozur & Mostler) are dominant. This total fauna (+/- *Ns. dieneri*) is essentially the same throughout bed 12 at both sites, apart from a

single occurrence of *Eurygnathodus costatus* Staesche in collection M-04/12C. The conodont fauna of beds 11 and 12(A-C) at Muth, which is associated with the "*Prioniolobus*" *vercherei* ammonoid fauna, has no clear counterpart in Chaohu where *Borinella* is unknown. This may partly be explained by paleolatitudinal differences because the Spiti successions originated in higher latitudes compared with the equatorial ('Tethyan') Chaohu successions.

At Muth, the base of bed 13 marks the abundant appearance of *Ns. posterolongatus* and the FAD of *Ns. waageni* morphotype 1, both of which may have been formerly attributed to *Ns. waageni* and/or *Neospathodus novaehollandiea* McTavish. In this study, in addition to *Ns. posterolongatus*, 5 morphotypes of *Ns. waageni* are distinguished. Unlike the former species, all the morphotypes are characterized by round basal cavities. These are:

Morphotype 1 (Pl. 1, figs. 8-10). During growth, platform flanges are developed on the flanks of these elements, especially at the posterior end.

Morphotype 2 (Pl. 1, fig. 11). This corresponds to the holotype of *N. waageni* (=*N. w. waageni*) and has slightly reclined, subequal denticles forming an arcuate crest.

Morphotype 3 (Pl. 1, figs. 12). This small morphotype has a length to height ratio of about 1:1, upright denticles, and a variable basal margin that may be straight (as in *Ns. w. eowaageni* sensu stricto), upturned posteriorly, or upturned at both ends.

Morphotype 4 (Pl. 1, fig. 17, 18). In this form, there are a few posteriormost denticles that are abruptly smaller/lower than those to the anterior.

Morphotype 5 (Pl. 1, figs. 13-15). This form has an unusually large (sub)terminal triangular cusp.

Morphotype 6 (Pl. 1, fig. 16). This form has denticles that tend to radiate in a fan-like fashion from the base (= *Ns*. aff. *waageni* sensu Goel, 1977).

The first morphotype of *Ns. waageni* to appear in Spiti, in bed 13A, is morphotype 1, which mimics later growth stages of *Ns. pakistanensis* that have been called *Ns. novaehollandidea*. This underlies the suggestion (Orchard, in press) that *Ns. waageni* may have developed from *Ns. pakistanensis* by a decrease in relative length to height ratio, accompanied by upturning of the posterior basal cavity. An alternative derivation from *Ns. dieneri* morphotype 3 has been suggested by L. Zhao (pers. comm., 2006). *Neospathodus posterolongatus* is also thought to have developed from *Ns. pakistanensis*, in this case through the posterior elongation of the basal cavity (Orchard, in press). An argument against the origin of both *Ns. waageni* and *Ns. posterolongatus* in *Ns. pakistanensis* arises from the downturned posterior part of the latter species compared with upturning seen in both younger species. However, the basal profile is quite variable in morphotypes of both *Ns. pakistanensis* (including *Ns. novaehollandiae*) and *Ns. waageni* and the suggested development is not precluded by that feature.

Most other morphotypes of *Ns. waageni* makes their appearances later: morphotype 2, which is regarded as the central morphotype of the species, may occur concurrently with morphotype 1 but certainly occurs in bed 13B together with morphotypes 3 and 4. Morphotype 5 appears in Bed 14A, and morphotype 6 appears in bed 15 (Table 1). The conodonts *Eurygnathodus costatus*, *Eu. hamadai*, *Discretella* sp., and *Spathicuspus*? n. sp. C also occur uncommonly in beds 13 and 14, which carry the *Rohillites rohilla* Zone ammonoid fauna. In Chaohu, most of the conodont fauna present in Muth beds 13 and 14 characterize the basal part of the "*Flemingites – Euflemingites* Zone", which leads to the suggestion that the *Rohilla* beds of Muth are equivalent to the lowermost part of the "*Flemingites – Euflemingites* Zone" in Chaohu. Both Bed 25 in West Pingdingshan and Bed 13A in Muth contain typical Induan species – *Ns. cristagalli* and *Ns. dieneri* – associated with typical Olenekian species – *Ns. posterolongatus* and *Ns. waageni* s. l.

The next significant conodont appearance in both the Spiti and Chaohu successions is *Neospathodus spitiensis* Goel, which appears in Bed 15 at Muth and in Bed 26 at West Pingdingshan, both of which are assigned to the *Flemingites – Euflemingites* Zone. These levels in the two candidate sections are similar also in the presence of *Ns. waageni* s.l. and *Discretella*, and in the absence of the other conodont taxa known from deeper levels. The holotype and all figured paratypes of *Ns. spitiensis* came from Smithian levels at Khar in Spiti (Goel, 1977), and records of the species from questionable Dienerian strata is unsubstantiated. In North America, the species *Ns. conservativus* (=*Conservatella* Orchard 2005), a homeomorph of *Ns. spitiensis*, characterizes co-eval strata of the *Euflemingites romunduri* Zone along with its associates *Ns. waageni* and *Ns. posterolongatus*.

Summary and comparisons with Chaohu

In Spiti, the I-O boundary interval can be divided into three conodont zonal intervals by reference to the FADs of *Ns*. ex gr. *waageni* + *Ns. posterolongatus,* and of *Ns. spitiensis*. Together with the older *Ns. pakistanensis* +/- *Ns. dieneri*, these taxa provide an evolutionary continuum (Orchard, in press). The intervals are characterized by:

1) Strata dominated by *Ns. dieneri*, *Ns. cristagalli*, *Ns. pakistanensis*, and *Bo. nepalensis*, with uncommon *Ns. chii* and *Ns. concavus* restricted to the interval. This interval corresponds to *Gyronites* and *Meekophiceras*?-bearing beds 10-12.

2) Strata above the FAD of *Ns. posterolongatus* + *Ns*. ex gr. *waageni*, which are initially associated with elements of the underlying bed. This interval in beds 13-14 belongs to the *Rohillites* Zone.

3) Strata above the FAD of *Ns. spitiensis*, assigned to the

Flemingites–Euflemingites Zone of beds 15-16.

Compared with Chaohu, Zone 1 of Muth can be broadly correlated with the upper part of the *dieneri* Zone. The absence of *Borinella* and rarity of *Ns. pakistanensis* at these levels in the Chinese sections represents a major difference between the two successions. The FAD of *Ns. posterolongatus* can be recognized in both areas: in West Pingdingshan, Chaohu it falls in Bed 25 at 0.03 m below the appearance of *Flemingites* (Zhao et al., in press) compared with a position close to the base of the *Rohillites* Zone in Muth. A further difference about these levels is the order of appearance of *Ns. waageni* morphotypes 2 and 3. In West Pingdingshan: the appearance of *Ns. w. eowaageni* (~morphotype 3) is slightly earlier (top bed 24) than *Ns. w. waageni* (~morphotype 2, base bed 25), whereas the two forms appear either concurrently or in reverse order at Muth. The other morphotypes of *Ns. waageni* have not yet been differentiated in the Chaohu sections, and nor is it clear to what extent these morphotypes are variants related to growth or intraspecific variation. Use of an undifferentiated *Ns. waageni* may be a preferred datum for both correlation and definition. The base of Zone 3, identified by the FAD of *Ns. spitiensis*, begins in bed 15 in Muth and in bed 26 in the West Pingdingshan section. In both cases it corresponds to the *Flemingites – Euflemingites* Zone. There is good correspondence between the two areas in both ammonoid and conodont faunas at these levels.

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Plate

1, 2. *Neospathodus chii* Zhao & Orchard. Sample M04-10.
3. *Neospathodus dieneri* Sweet. Morphotype 1 Zhao & Orchard. Sample M03-11.
4. *Neospathodus concavus* Zhao & Orchard. Sample M04-10.
5. *Neospathodus cristagalli* (Huckriede). Sample M04-10.
6. *Neospathodus dieneri* Sweet. Morphotype 2 Zhao & Orchard. Sample M03-11.
7. *Neospathodus dieneri* Sweet. Morphotype 3 Zhao & Orchard. Sample M04-10.
8-10. *Neospathodus waageni* Sweet. Morphotype 1. Sample M03-13A.
11. *Neospathodus waageni waageni* Sweet (=Morphotype 2). M03-14A.
12. *Neospathodus waageni eowaageni* Zhao & Orchard (=Morphotype 3). Sample M03-14A.
13, 14. *Neospathodus waageni* Sweet. Morphotype 5. Sample M04-15B.
15. *Neospathodus waageni* Sweet. Morphotype 5. Sample M03-16.
16. *Neospathodus waageni* Sweet. Morphotype 6. Sample M03-15.
17, 18. *Neospathodus waageni* Sweet. Morphotype 4. Sample M03-16A.
19, 20. *Neospathodus pakistanensis* Sweet. Sample M03-13A.
21, 22. *Neospathodus posterolongatus* Zhao & Orchard. Sample M03-13.
23, 24. *Neospathodus spitiensis* Goel. Sample M03-15.

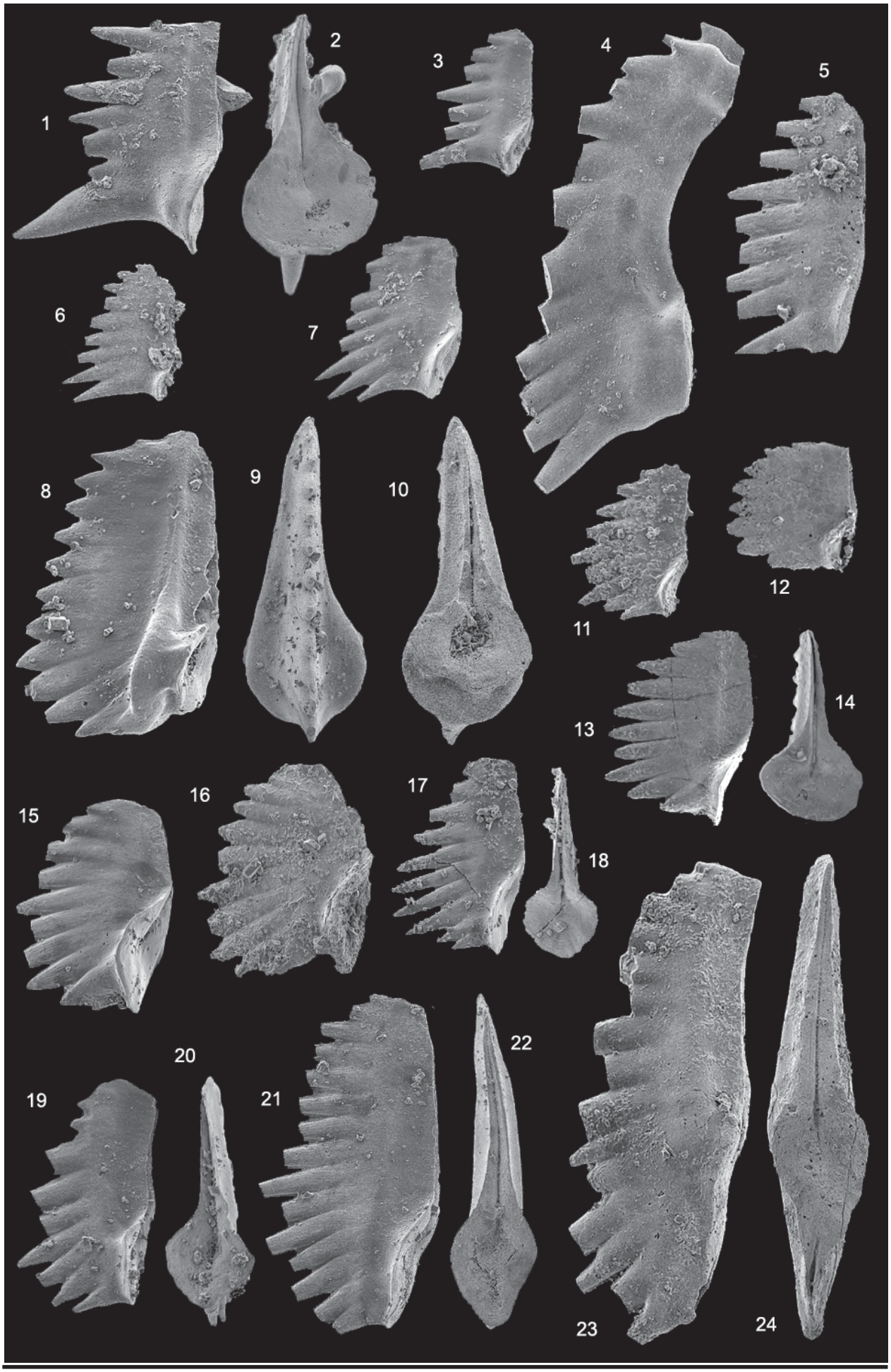
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Table 1: Conodont assemblages from the Muth section.

	04/10	03/11	04/11	04/12A	03/12b	03/12c	04/12c	03/13a	04/13a	04/13b	06/13b	03/13c	04/13c	03/14a	04/14b	03/14c	04/14c	04/15a	04/15b	03/15	03/16a
N. cristagalli	×	×	×	×	×		×	×	×												
N. dieneri M1	×	×			×			×		?		?								?	
N. dieneri M2	×	×			×				×												
N. dieneri M3	×							?							?						
N. chii	×	?																			
N. concavus	×																				
N. pakistanensis			×	×	×	×	×	×	×	×			×								
N. posterolongatus								×	×	×	×		×	×							
Borinella nepalensis			×	×	×	×	×	×	×	×											
Ng. ex gr. carinata								×													
Discretella discreta								×			×	×			×	×	×				
N. waageni M1								×	×	×	×		×							×	×
N. waageni M2										×	×	×	×	×	×	×	×	×	×	×	×
N. waageni M3										?		?		×							×
N. waageni M4														×		×	×		×		×
N. waageni M5																×	×		×		×
N. waageni M6														×						×	×
Spathicuspus? n. sp. C							?						×			×	×				
Eurygnathodus hamadai										×	×										
Eurygnathodus costatus						×			×		×										
N. spitiensis																			×	×	×
N. sp. nov. U																				?	×
N. sp. nov. S																				?	×

Carbon isotope record of the Induan-Olenekian candidate GSSP Mud and comparison with other sections

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Introduction

The Induan-Olenekian boundary interval is characterized by a positive $\delta^{13}C$ excursion marking the turning point from generally increasing to decreasing and negative values (Atudorei, 1999; Horacek et al., 2000; Tong et al., 2002; Payne et al. 2004; Richoz, 2006; Zuo et al., 2006; Horacek et al., 2007 a & b, Galfetti et al., 2007 a & b). Determining this inflexion point in relation to the different proposed boundary levels would allow a reliable and high-resolution isotope calibration of marine sections of the Tethys if not on a worldwide scale. We measured in detail the Induan-Olenekian boundary at Mud, a candidate GSSP in the Western Himalaya, and compared it with data from other sections.

Locality

The Mud section is situated in the Lahul and Spiti district, northern Himachal Pradesh State of India and was proposed by Krystyn et al. (2004) as candidate GSSP candidate for the Induan/Olenekian boundary. The reader is referred to Krystyn et al. (this volume) for details on the geological setting, sedimentology as well as biostratigraphy (see also Fig. 1).

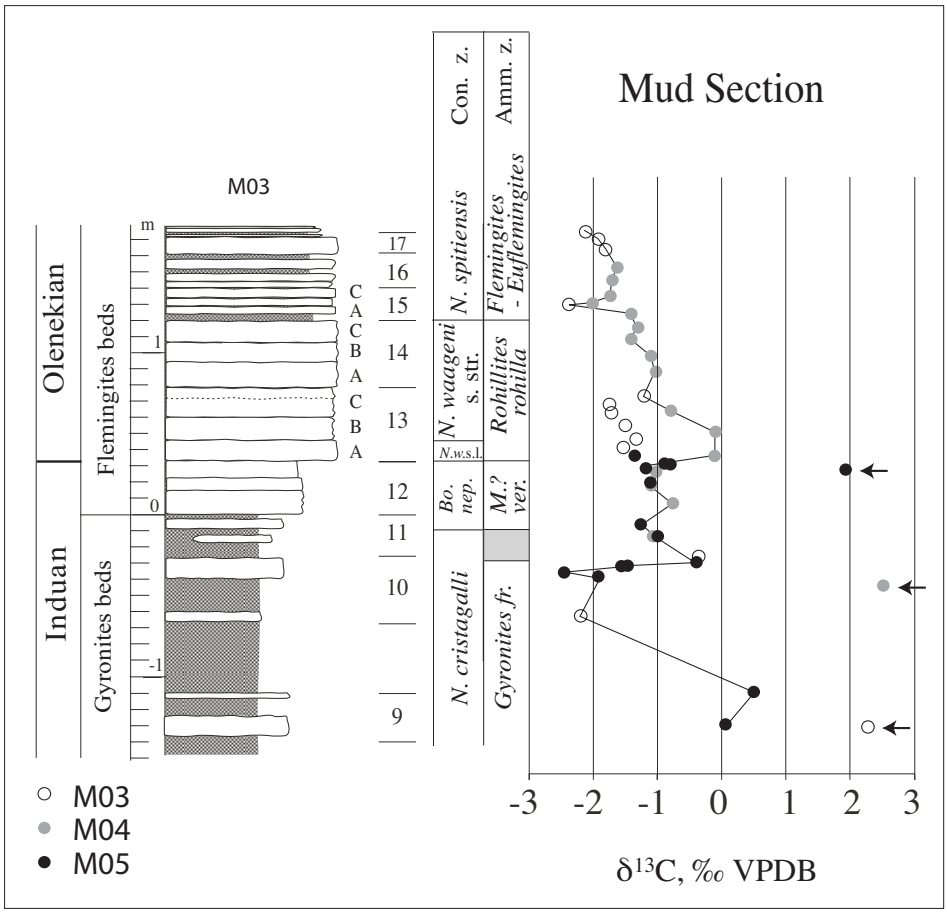

Fig 1. $\delta^{13}C$ curve of the Mud section, Spiti, Indian Himalaya. Data with an arrow represent values from tempestitic layers (see text for explanation). See Krystyn et al. (this volume) for litho- and biostratigraphic details.

For logistic reasons, work was focussed on three sites : M03 located at an elevation of 3800 m, 100 m above the Mud village, and M04 and M05 located at 3900 m and 4100 m, respectively . These outcrops show identical rock sequences and can be correlated bed-by-bed (Fig. 1).

Carbon isotope profile

a) Methods

The carbonate content was determined using a Müller-Gastner-Bomb system. For isotopic analyses, powders were produced from micrite samples using a diamond-tipped drill. Hand specimens were carefully examined to avoid cracks, veins and weathering features and drilled on the counterpart of the thin sections. Most of the thin sections were stained with Alizarin Red S to distinguish calcite and dolomite. The samples were analyzed using an automated carbonate preparation system connected to a Delta^{plus}XL mass spectrometer (Spötl and Vennemann, 2003). Reproducibility of replicate analyses was better than ±0.1‰ for standards and ±0.15‰ for sediment samples for both carbon and oxygen isotope values. All isotope results are reported using the standard δ notation, defined as per mil (‰) deviation vs. VPDB. The results are shown in Table 1.

b) δ^{13}C curve

The carbon isotope values were measured of samples from bed 9 to 17 (Fig. 1 and Table 1). In bed 9 values vary between +0.1‰ and +0.5‰, except for a tempestitic layer showing a value of +2.2‰. Above bed 9, values rapidly decrease to -2.2‰ in one small carbonate bed in the marly interval between beds 9 and 10 and remain low at the base of bed 10. The top of bed 10 records a steep increase to -0.4‰. A lateral lens in bed 10, with coarser grain size representing a tempestitic event shows a value of +2.6‰. Beds 11 and 12 show small variations between -0.6 and -1.2‰. In bed 12C a thin tempestitic layer records values around 2.0‰. A steep increase of 0.8‰ at the transition between 12C and 13A is followed by a plateau at -0.1‰ in beds 13A and 13B. From beds 13C to 18 the isotopic values decrease from -0.8‰ to -2.1‰. Compared to the ammonoid stratigraphy the most positive value in the I-O boundary interval in Mud occurs at the base of bed 13A in which *R. rohilla* and a rich *Kashmirites* fauna first occur. Above this point, and within the *R. rohilla* zone, the isotope values stay high in beds 13A and B before strongly decreasing (bed 13C). Values continue to decrease throughout the upper *R. rohilla* zone and the lowest part of the *Flemingites-Euflemingites* zone but with a smaller gradient.

Compared to the conodont stratigraphy, the maximum in δ^{13}C corresponds to the first appearance of *N. waageni waageni* in bed 13A. The first appearance of *N. spitiensis* occurs in bed 15A in the lowest part of the trend toward negative values.

Discussion

a) Degree of diagenetic alteration

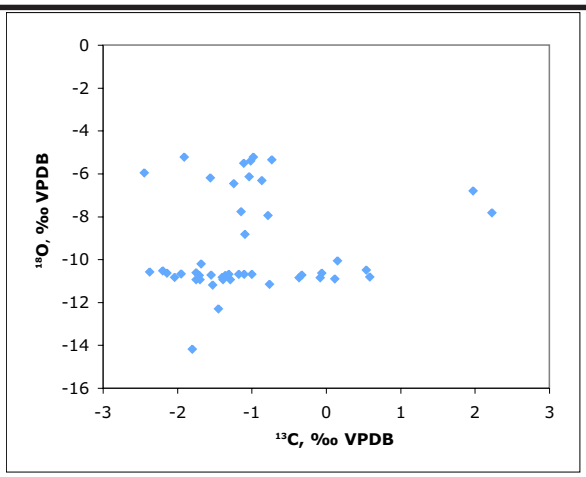

Fig 2. δ^{13}C / δ^{18}O cross-plot

In samples from Mud δ^{18}O values range from “5.1‰ to “12.3‰ and do not co vary with δ^{13}C (Table 1, Fig. 2). Given the rather low δ^{18}O values the question of primary marine signature versus diagenesis needs to be addressed.

The Mud area experienced strong thermal overprint during the Himalayan orogeny as suggested by conodont alteration indices (CAI 5, L. Krystyn, unpublished data). It is therefore likely that deep burial diagenesis lowered the δ^{18}O values, but the large spread of the data shows that this process was not pervasive. The lack of covariance between δ^{18}O and δ^{13}C values suggests that deep-burial diagenesis apparently did not affect the carbon isotopic composition the same way as it affected the oxygen isotope composition. This is consistent with modeling results which demonstrate that the carbon isotope composition of carbonate rocks is rather insensitive to water-rock interactions unless very high water/rock ratios are involved (e.g., Banner & Hanson, 1990). Decarbonatization reactions in the presence of silicate minerals might also affect the carbon isotope composition. We regard this process as unimportant, however, because the rocks barely reached the minimum temperature required to start these reactions. We found no relationship between the carbonate content and the isotopic composition. Such a relationship would be expected if

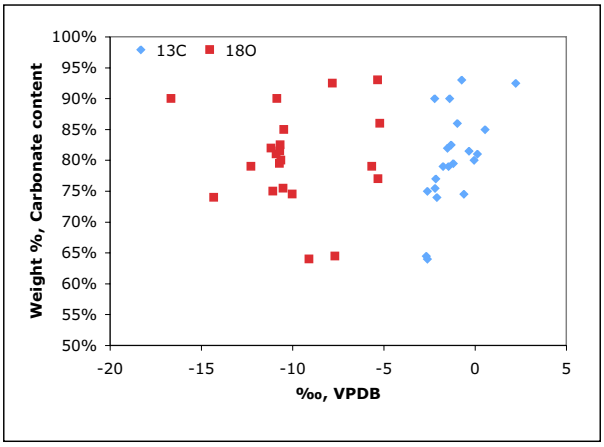

Fig 3. Carbonate content/ δ^{13}C - δ^{18}O cross-plot

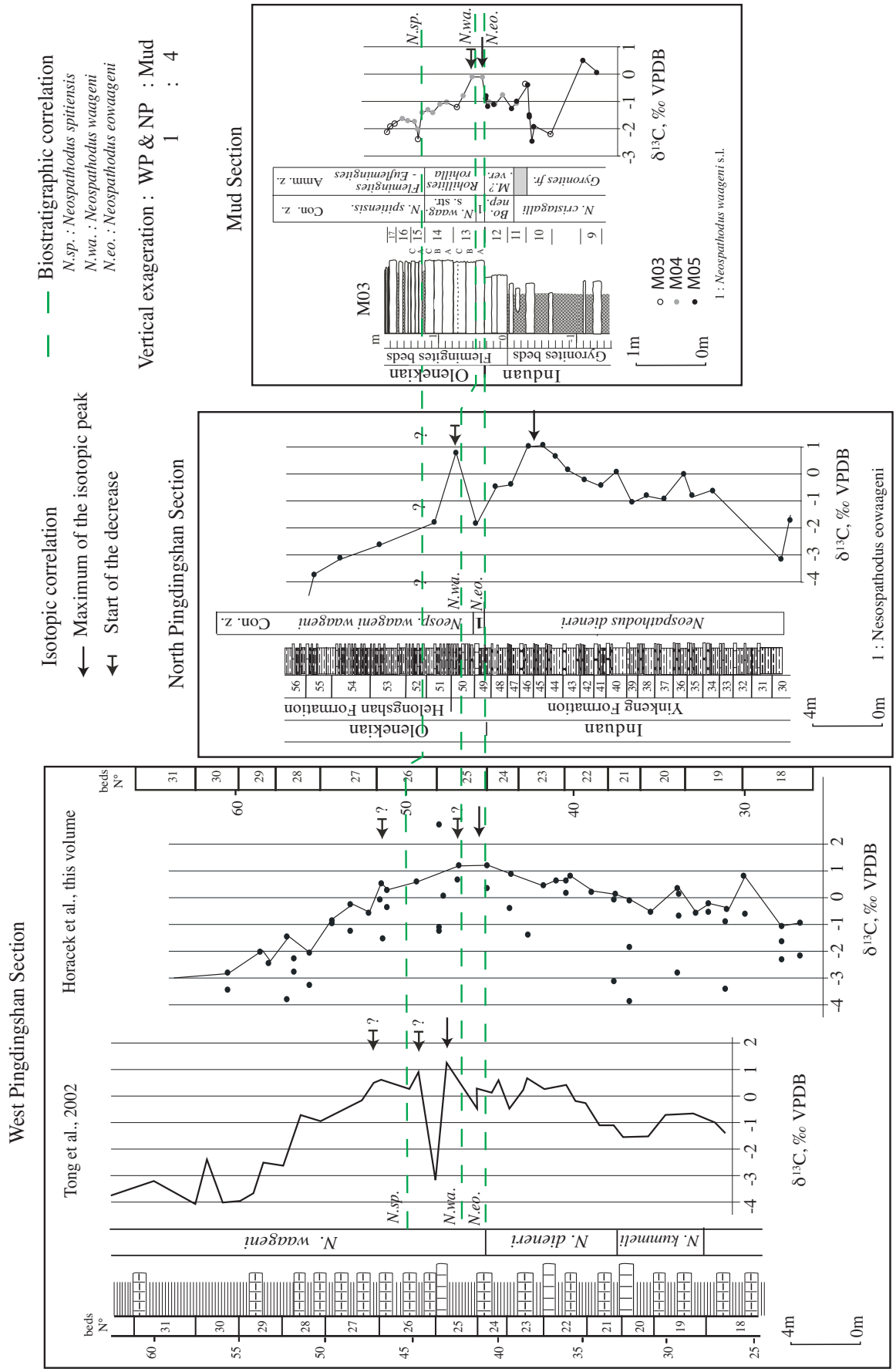

Fig 4. Comparison of the Mud section with the West Pingdingshan section (Tong et al., 2002 and Horacek et al., this volume) and the North Pingdingshan section (Tong et al., 2002), Chaohu, China.

decarbonatization affected these rocks (e.g., Kaufman and Knoll, 1995; Fig. 3 and Table 1). Finally, organic diagenesis might impart on the isotopic composition of carbonates, resulting in the precipitation of ^{13}C-depleted carbonate cements. We cannot exclude this process but we regard it as unlikely that thermal degradation of organic matter during deep burial played a major role given the overall low organic carbon content of this section.

We therefore regard the carbon isotope data as largely reflecting the initial isotopic composition. This is supported by the observation that the general shapes of the carbon isotope curves correlate well with other Tethyan carbon isotope profiles (e.g. Losar section, – Spiti, Atudorei, 1999 see Galfetti et al., 2007; Chaohu section – South China, Tong et al., 2003; Zuo et al., 2006; Great Bank of Guizhou – South China, Payne et al., 2004; Wadi Maqam and Wadi Wasit South – Oman, Richoz 2006, Abadeh and Zal – Iran, Horacek et al., 2007). Still, we adopted a conservative approach and considered the highest $\delta^{13}C$ values as the most reliable data, as diagenesis would tend to cause a bias toward lower values.

b) Tempestitic layers

Values above +1‰ are only found in 1-2 cm thin, coarse, tempestitic layers of beds 9 to 12C. These three values are interpreted as the signal of a shallower depositional setting, the sediment of which had been transported into the deeper bassin by current-induced redeposition. Therefore these values were not included in the isotope curve.

At Losar, Spiti valley, another section was measured 60 km NNW of the Mud section (Atudorei, 1999, also shown in Galfetti et al., 2007). Isotope data from Losar show a trend similar to our data but the curve is less detailed near the boundary interval. The Losar section shows the highest values of +2.6‰ below and at the base of the Flemingites beds, which correspond to the beds 10 to base of bed 12A in Mud. In the Mud section, the peak occurs in the lower and middle part of the Flemingites beds. If we attribute the highest values in Losar also due to allochtonous material, the peak is not well defined stratigraphically and appears to occur between the middle part of the Gyronites and Flemingites beds, respectively, und could thus be at the same stratigraphic level as at Mud.

c) Comparison with other Tethyan sections

In the Jinya/Waili section (Guangxi Province, South China) the most positive values also occur in the lower part of the *Kashmirites* beds with the major part of the isotope maximum in this level (Galfetti, pers. comm. 2006). The amplitude of the peak is ca. 1.5‰ both in Mud and the Jinya/Waili section.

The West Pingdingshan section (Fig. 4) shows a somewhat different isotopic signal, i.e. a large and long lasting positive plateau, featuring a weak positive peak, starting much earlier in the middle of the dieneri conodont zone and ending after the FAD of *N. spitiensis*. This curve, based on measurements by both Tong et al. (2002; Fig. 4) and Horacek et al. (this volume; Fig. 4), differs thus substantially from all other known profiles. The maximum of this isotope plateau is however reached in bed 25, which followed the first appearance of *N. waageni waageni*, and thus at the same biostratigraphic level as in Mud. The ammonoids in south China do not allow a good correlation (Krystyn, pers. comm.) and the biostratigraphic control relies on conodonts alone.

The North Pingdingshan section is even more difficult to interpret as there is a discrepancy between the curves published by Tong et al. (2002) and Zuo et al. (2006). The curve published by Tong et al. (2002 and 2005; Fig. 4) shows a first maximum in the *Ns. dieneri* M2 zone followed by a rapid decrease and a second peak (only one value) just after the FAD of *N.waageni waageni*. The curve published by Zuo et al. (2006) for North Pingdingshan is more similar to West Pingdingshan with the main peak after the FAD of *N.waageni waageni*, but unfortunately the figure is not useful for an exact comparison. As the West Pingdingshan curve was obtained by two different teams, it is considered as the more reliable one.

A positive peak was also reported with less biostratigraphic control around the I-O boundary from the Southern Alps (Uomo - Horacek et al., in press, and Pufels - Korte et al., 2005; Horacek et al., in press), Turkey (Taskent, shallow platform - Richoz, 2004 and 2006), Oman (Ba'id (exotic deepwater carbonates), Wadi Sahtan (Arabic platform), Wadi Maqam (slope deposits) and Wadi Wasit South (basin) - Richoz, 2004 and 2006), Iran (Zal, Abadeh and Amol - Horacek et al., in press), and South China (southern Guizhou sections (basin and platform) - Payne et al., 2004; and Hushan section .- Zuo et al., 2006; Horacek et al., this volume). In all these sections, the amplitude of the peak is between 1 and 6‰ and it is represented in various carbonate facies from shallow to deep water.

Conclusions

The Induan-Olenekian boundary interval reveals a positive excursion of the carbon isotope record marking a turning point from generally increasing to decreasing and negative values. In the Mud section this peak has been precisely correlated using biostratigraphy. There, the isotopic maximum ocurs in beds 13A and B. The same maximum is probably present in bed 50 in North Pingdingshan and probably in the middle of bed 25 in West Pingdingshan. In these three sections, the peak is found just after the FAD of *N.waageni waageni,* but the exact position of this peak in Chaohu remains unclear. The strong decrease starts in bed 13C in Mud, near the top of bed 50 in North Pingdingshan and probably at the base of bed 26 in West Pingdingshan, each time before the FAD of *N. spitiensis*.

Aknowledgments

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Table 1 : Carbon and oxygen isotopic composition and carbonate content in the Mud section, Indian Himalaya, **tempestitic layer.

Sample N°	$\delta^{13}C$, ‰ VPDB	$\delta^{18}O$, ‰ VPDB	weight %, carbonate content
MO3-18	-2.14	-10.62	
Mu3-17B	-1.95	-10.65	
Mu3-17A	-1.80	-14.18	
M04-16C1	-1.68	-10.19	
MO4-16B	-1.70	-10.93	
MO4-15C	-1.75	-10.93	
MO4-15B	-2.04	-10.83	
Mu3-15B1	-2.37	-10.58	
MO4-15A	-1.40	-10.82	
MO4-14C2	-1.29	-10.93	
MO4-14C1	-1.39	-10.94	
MO4-14B1	-1.10	-10.68	
MO4-14A	-1.00	-10.67	
Mu3-13C2	-1.18	-10.68	
Mu3-13C1Top	-1.75	-10.61	
Mu3-13C1	-1.71	-10.73	
MO4-13C	-0.77	-11.15	
Mu3-13B3	-1.55	-10.71	
Mu3-13B1	-1.36	-10.74	
MO4-13B	-0.06	-10.63	
Mu3-13A5	-1.53	-11.18	82.0%
Mu5-13A1	-1.31	-10.68	82.5%
MO4-13A	-0.09	-10.84	80.0%

Sample N°	$\delta^{13}C$, ‰ VPDB	$\delta^{18}O$, ‰ VPDB	weight %, carbonate content
Mu5-12C1T	-0.87	-6.31	
Mu5-12C1R	-0.78	-7.94	
Mu5-12C1PC	-1.14	-7.76	
Mu5-12C1PA **	1.97	-6.79	
M04-12C1	-1.02	-5.39	
Mu5-12B5	-1.10	-8.81	
MO4-12B	-1.11	-5.51	
MO4-12A	-0.73	-5.34	93.0%
Mu5-11B1	-1.24	-6.45	
MO4-11	-1.04	-6.13	
Mu5-11A2	-0.98	-5.21	86.0%
MO3-10	-0.33	-10.71	81.5%
Mu5-10A8	-0.37	-10.84	
Mu5-10A6	-1.56	-6.18	
Mu5b-10A	-1,45	-12,28	79,0%
Mu5-10A4	-2.45	-5.95	
Mu5-10A2	-1.91	-5.22	
MO4/10/1 **	2.61	-9.58	
Mu3-10B	-2.20	-10.52	75.5%
Mu5-9C4	0.54	-10.49	85.0%
Mu5-9A	0.11	-10.89	81.0%
Mu3-9 **	2.23	-7.81	92.5%

The carbon-isotope curve from the Chaohu section, China: different trends at the Induan –Olenekian Boundary or diagenesis?

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Abstract The West Pingdingshan section has been proposed as the GSSP (global stratotype sections and points) for the IOB (Tong, 2005). However, the carbon isotope curve from the Lower Triassic at Chaohu deviates partially significantly from the curves measured from other sections. We have remeasured the section and compare our results with the existing curves by Tong et al., 2005 and Zuo et al., 2006.

Introduction

The GSSP of the IOB has been in debate now since several years. At the meeting of the subcommittee for the IOB in Chaohu, China, the West Pingdingshan section near Chaohu/China has been proposed as a GSSP candidate. However, with a carbon isotope curve significantly deviating from other published curves (e.g. Payne et al., 2004, Richoz 2006, Horacek et al., 2007a, b) it becomes an interesting question, whether this curve represents primary or diagenetic information. As Chaohu is in competition with other candidates as potential GSSP the chemostratigraphy of the sections can become a critical criterium.

Locality

The section is located in southern China close to the village Chaohu approximately 250 km southwest of Nanjing (Fig. 1). The succession is exposed along a road leading to a limestone quarry. For a detailed description and map see Zhang et al. (2001) or Tong et al., (2002), where the section is described as the "West Pingdingshan Section".

Samples and methods

Rock samples have been cut with a diamond saw and the cut surface was investigated for veins, weathered parts and cavern fillings. These features have been sampled with a micro drill and marked as non-primary samples as well as the unsuspicious parts which have been expected to give primary isotope values. A few -grams of sample powder were introduced into an online CO_2 extraction line (Kiel II) and dissolved with 100% phosphor acid at 70°C for 10 minutes. The evolved CO_2 gas was cryogenically purified and analysed with a Finnigan Mat 251 mass spectrometer. Reproducibility is better than 0.1‰ (1s). All values are given in the d notation cali-

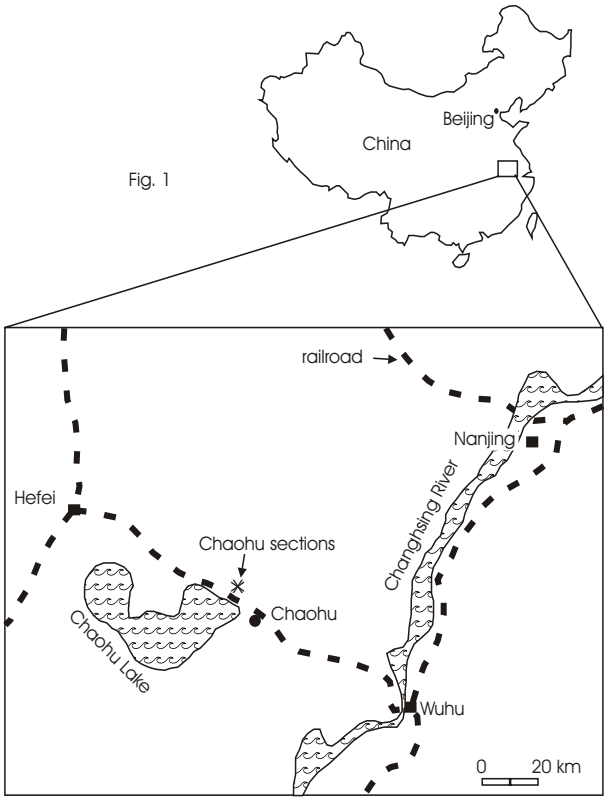

Fig. 1. Map of Chaohu region, Anhui Province. X marks location of section. Simplified after Zhang et al., 2001.

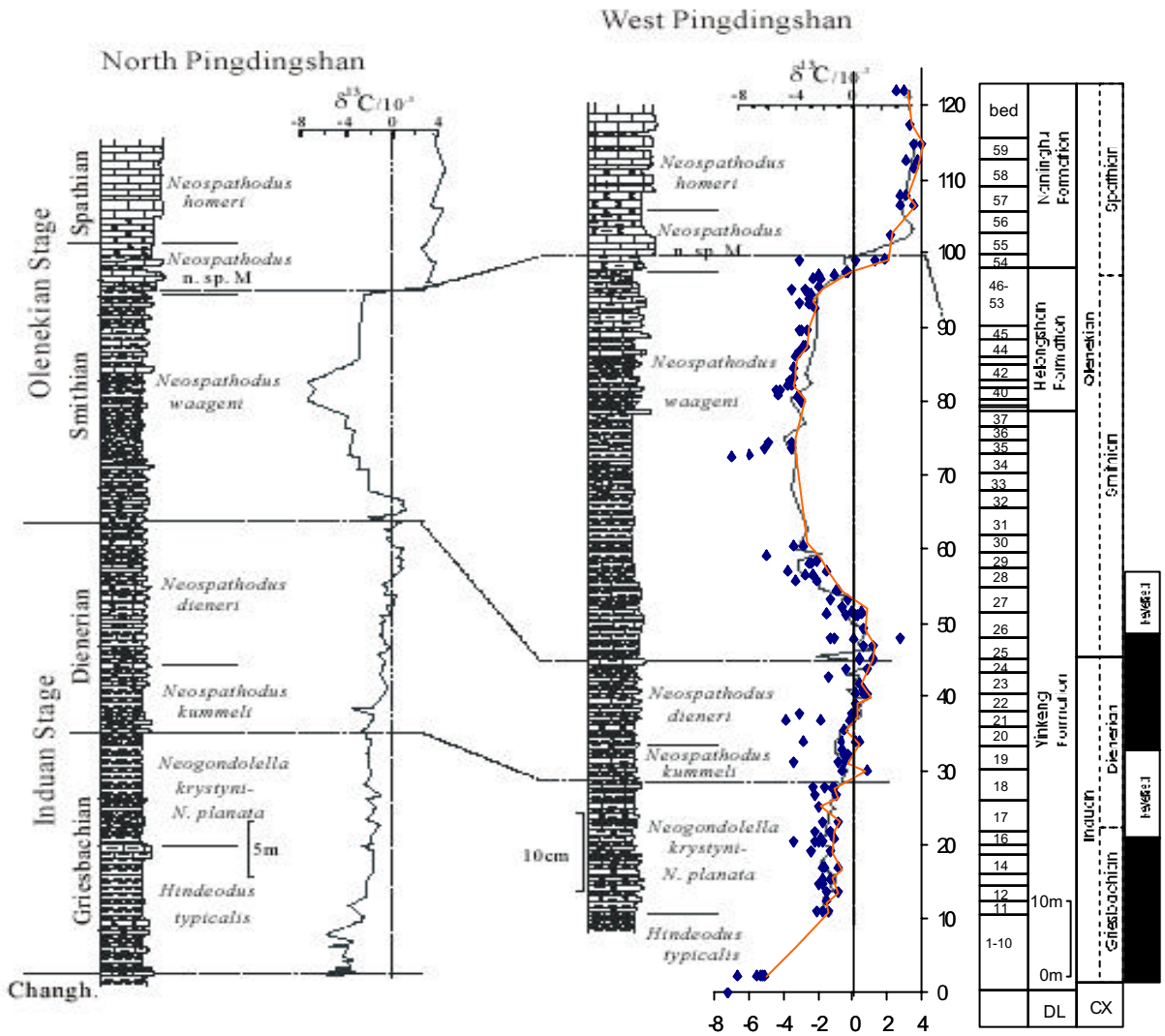

Fig. 2. $\delta^{13}C$ diagram of the Chaohu (West Pingdingshan) section correlated with $\delta^{13}C$ curves of the West and North Pingdingshan sections of Tong et al., 2005. Our curve verifies the results of Tong et al., 2005. Bed numbers after Zhang et al., 2001, magnetostratigraphy and carbon isotope curve from North Pingdingshan section are drawn after the Chinese Lower Triassic Working Group, 2002. CX = Changhsingian, DL = Dalong Formation. Diamonds and grey isotope curve represent our new data, black isotope curve is from Tong et al., 2005.

brated to the Vienna-Peedee belemnite (V-PDB) reference.

Some selected samples have been analyzed for their carbonate content.

Results

The section starts in the Permian in the uppermost Dalong Formation with negative $\delta^{13}C$ values below –5‰ (Fig. 2). However, as the rocks in the uppermost Permian consist of siliceous clay- and mudstones (Tong et al., 2002), which are more sensitive to alteration of the isotope signal by decarbonation reactions, they will not be discussed further. The immediate PTB is covered and has not been investigated. In the Griesbachian of theYinkeng Formation the values range approximately between –1.7 and –0.7‰ VPDB. In the Dienerian the carbon isotope values slowly increase to a maximum of ca. +1.5‰ at the Dienerian - Smithian boundary. It is followed by a decline in the Smithian to negative values with a minimum below –3‰. At its base the Helongshan Formation features values around –3‰ and jump to values around +2‰ at its top at the Smithian – Spathian transition. In the Nanlinghu Formation, which has been investigated only in its lower part, $d^{13}C$ values rise further to maximum values around +4‰. For the scope of this article we will discuss only the samples from the Yinkeng Formation.

Oxygen isotope values mainly range between -5 and -8‰ VPDB (Fig. 3). As $\delta^{18}O$ from bulk carbonate rocks are easily altered by diagenesis, analysis of oxygen isotopes are only used to control for concomitant changes of carbon and oxygen isotopes in the samples, which would be a sign for intense diagenesis and proof for non-primary carbon isotope values.

Discussion

As the section is located in a subtropical region, the rocks might have experienced strong alterations due to weathering. Therefore accurate screening of the samples is very important to ensure only consideration of unaltered al-

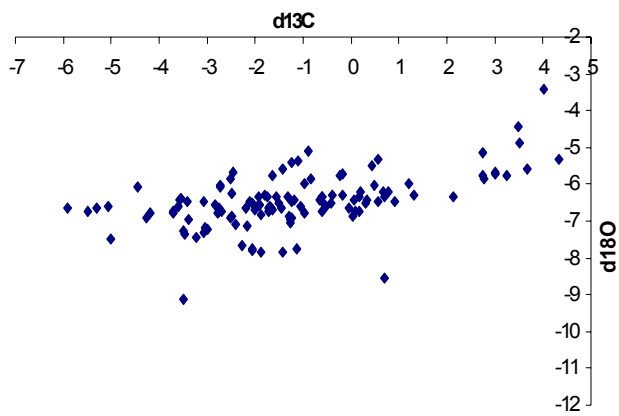

Fig. 3. Carbon versus oxygen isotopes.

tered samples. Generally the $\delta^{13}C$ signal of carbonates is regarded as insensitive to diagenetic alteration, as the amount of carbon present in a given diagenetic fluid is by far exceeded by the amount of carbon in the surrounding wallrock (Marshall 1992). However, as the investigated rocks are impure carbonates the amount of the carbonate in the wallrock is variable and might be in some samples quite small. Therefore some samples have been selected for analysis of C content. All selected samples (besides one) measured for C content have a carbonate content of at least 65% (assuming that all C in the sample emanates from $CaCO_3$). Evidence for a primary signal of the isotopic values is the absence of any correlation between carbonate content and $\delta^{13}C$ composition (Fig. 4) and the absence of a correlation of $\delta^{13}C$ and $\delta^{18}O$ (Fig. 3). Tong et al. (2002) came to the same conclusion by investigating the Mn/Sr ratio of the sediment to get information on possible diagenetic alteration, although Zuo et al., 2006 conclude that the Mn/Sr analyses of the Pingdingshan section do not give an unequivocal result and generally are not reliably applicable for impure

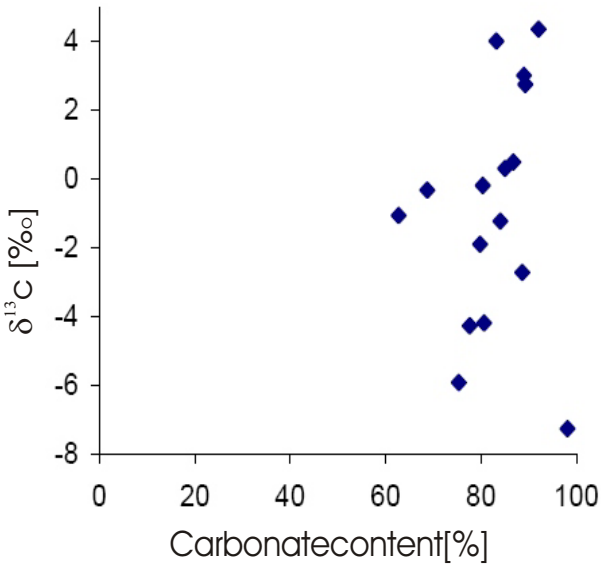

Fig. 4. Carbonate content versus $\delta^{13}C$ value (assuming all carbon from a sample emanates from calciumcarbonate). X-axis shows carbonate content, Y-axis gives the $d^{13}C$ value.

carbonates. A source for minor alteration of the rocks at Chaohu probably was the low grade temperature event the area experienced and that caused a CAI=3 and some minor grain boundary migration.

The isotope curve we have measured fits very well the curve by Tong et al., 2005. Deviations are almost all below 0.5‰, thus, for bulk carbonate curves, they can be regarded as near to identical.

Lower Triassic marine carbonate $\delta^{13}C$ isotope curves from the literature (e.g. Payne et al., 2004, Richoz 2006, Horacek et al., 2007a, b (Fig. 5)) feature at the IOB a pronounced positive excursion with values sometimes exceeding +8‰ VPDB. The reported amplitudes in the literature from the IOB carbon isotope maximum to the following minimum in the Smithian range around 9 - 11‰. There are a few other measured sections in the literature (in China: Galfetti et al., 2007, in India (Himalaya): Atudorei 1999, Richoz et al., this volume) that show an IOB $\delta^{13}C$ excursion of similar magnitude as at Chaohu. However, Richoz et al., this volume, show that the small positive excursion reported from Muth, India, is of shorter duration than the plateau peak around the IOB at Chaohu. This implicates that they have not been caused by identical processes.

We assume, as there is no evidence for significant diagenesis, that the carbon isotope curve from Chaohu represents a primary isotope pattern. Hence, there must exist two different isotope pattern at the IOB, the first giving a pronounced positive $\delta^{13}C$ peak, that can be counted among the biggest ones in the Phanerozoic (and certainly represents the biggest in the Mesozoic), and a second pattern, featuring just a minor increase in $\delta^{13}C$ and an approximately plateau-like shape. Possible causes for the existence of these different trends will be addressed in Horacek et al., in prep.

Conclusions

The $\delta^{13}C$ isotope curve from Chaohu presented by Tong et al., 2005 and Zuo et al., 2006 is confirmed by the data presented in this article. As there has been no evidence for relevant alteration of the carbon isotope composition, we conclude, that the isotope values represent primary signals. As the Chaohu isotope curve significantly deviates from most reported marine $\delta^{13}C$ curves around the IOB, it is assumed that two different trends of the Tethys-wide (or global?) isotope curve exist.

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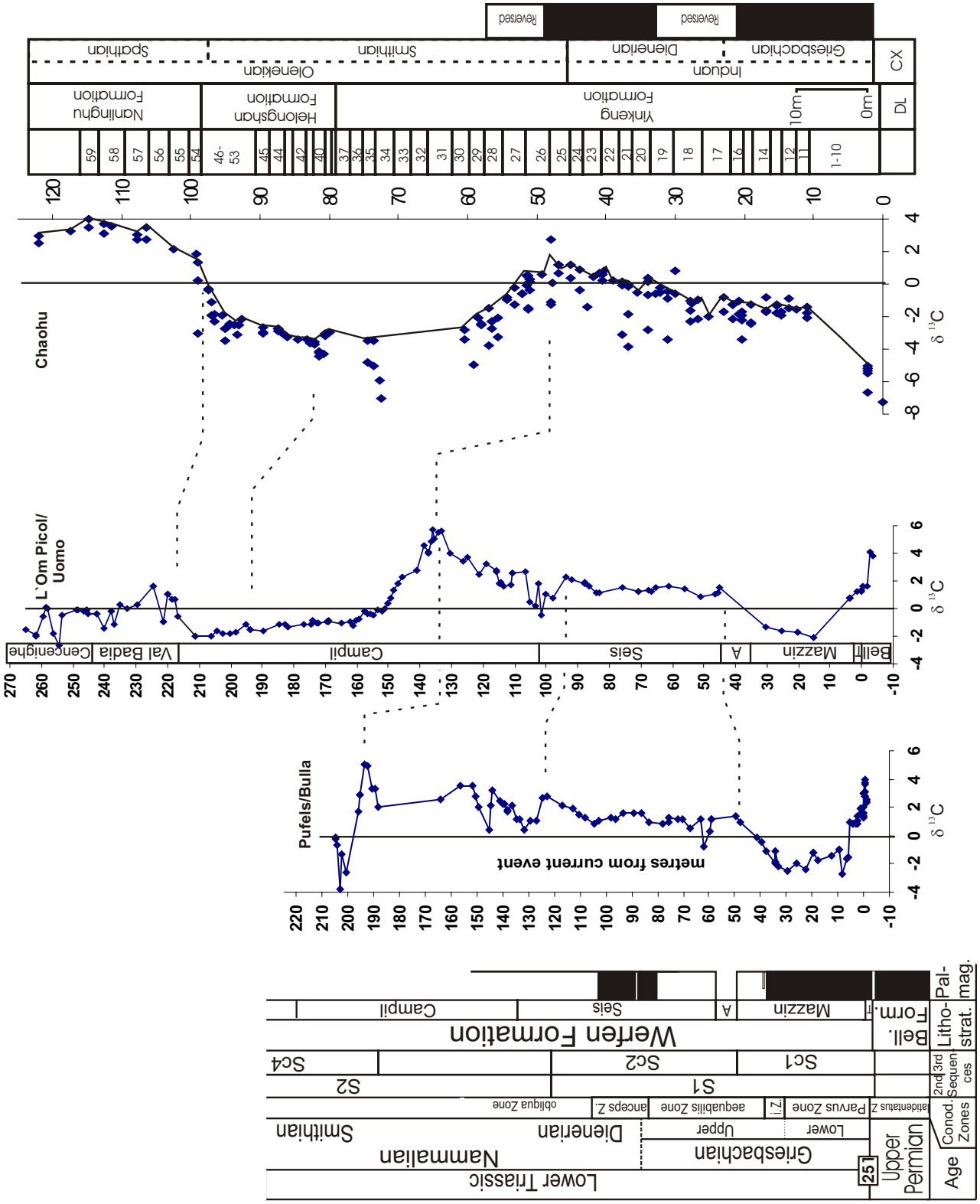

Fig. 5. Correlation of the Chaohu $\delta^{13}C$ diagram with $\delta^{13}C$ diagrams from sections in Northern Italy (Horacek et al., 2007a). The profound peak found in the Italian sections is absent in Chaohu, where only a very small excursion to positive values of "plateau-like" shape is detected. Solid curve is from Tong et al., 2005, dashed curve represents our data.

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Examples of Late Olenekian invertebrate successions: Paper 1. Western Tethys (Dolnapa, Mangyshlak)

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Abstract A review of a new data on the mid-Olenekian (*Tirolites cassianus–Kiparisovites carinatus* Zone) and upper Olenekian (*Columbites parisianus-Procolumbites carataueìkus, Arnautoceltites bajarunasi-Stacheites undatus* Zones) is given on the basis of new ammonoid and brachiopod findings.

Introduction

The basic Mid-Upper Olenekian sections in the Kazakhstan area locate in Mangyshlak Peninsula (Dolnapa and Tyururpa) (Fig. 1). Main information on Lower Triassic biostratigraphy of the Mangyshlak area was published by Vasilevsky (1909), Bajarunas (1911, 1936), Kiparisova (Voinova et al., 1947), Astachova (1960), Shevyrev, 1968, 1990, 2002), Gavrilova, 1980, 1989). But our knowledge on detail Mid-Late Olenekian ammonoid succession in the section Mangyslak is still limited.

Purpose of this study is to show main phases of Mid-Late Olenekian ammonoid analysis of mainly Late Permian-Early Anisian ammonoid succession in the Dolnapa (Angry Sister) section.

Fig. 1. Location of main Triassic sections (Dolnapa and Tyururpa) on Mangyshlak Peninsula, Kazakhstan.

Biostratigraphical results

In descending order, the middle Olenekian-lower Anisian sequence exposed near the Dolnapa-draw-well is (44°21'50.61"N, 51°24'12.02"E) (Fig. 2):

Lower Karaduanskaya Formation (Lower Anisian)

32 Intercalation of grey, fine-grained sandstone and greenish-grey mudstone no less than 130 m

31. Black and greenish-grey mudstone about 40 m

30. Intercalation black mudstone and grey, fine-grained sandstone about 100 m

29. Intercalation of grey, intermediate-grained and fine-grained sandstone 5 m

28. Grey, fine-grained sandstone10 m

27. Black siltstone with thin interlayers of siliceous rocks 17 m

26. Grey, intermediate-grained and fine-grained sandstone about 110 m

25. Intercalation of greenish-grey, fine-grained sandstone and mudstone with interlayers of limestone-coquina (bivalve mollusks) 17 m

24. Brown, intermediate-grained sandstone 30 m

23. Brown and grey intermediate-grained and fine grained sandstone 19 m

Thickness of the lower part of the Karaduanskaya Formation is about 478 m.

Karadzhatykskaya Formation (Upper Olenekian)

Eumorphotis Beds

22. Intercalation of greenish-grey siltstone and grey, fine-grained, calcareous sandstone (34 m).

Bivalves *Pteria* sp., *Leptochondria* sp. (409-11, 410-1).

21. Grey, fine-grained sandstone (7.5 m).

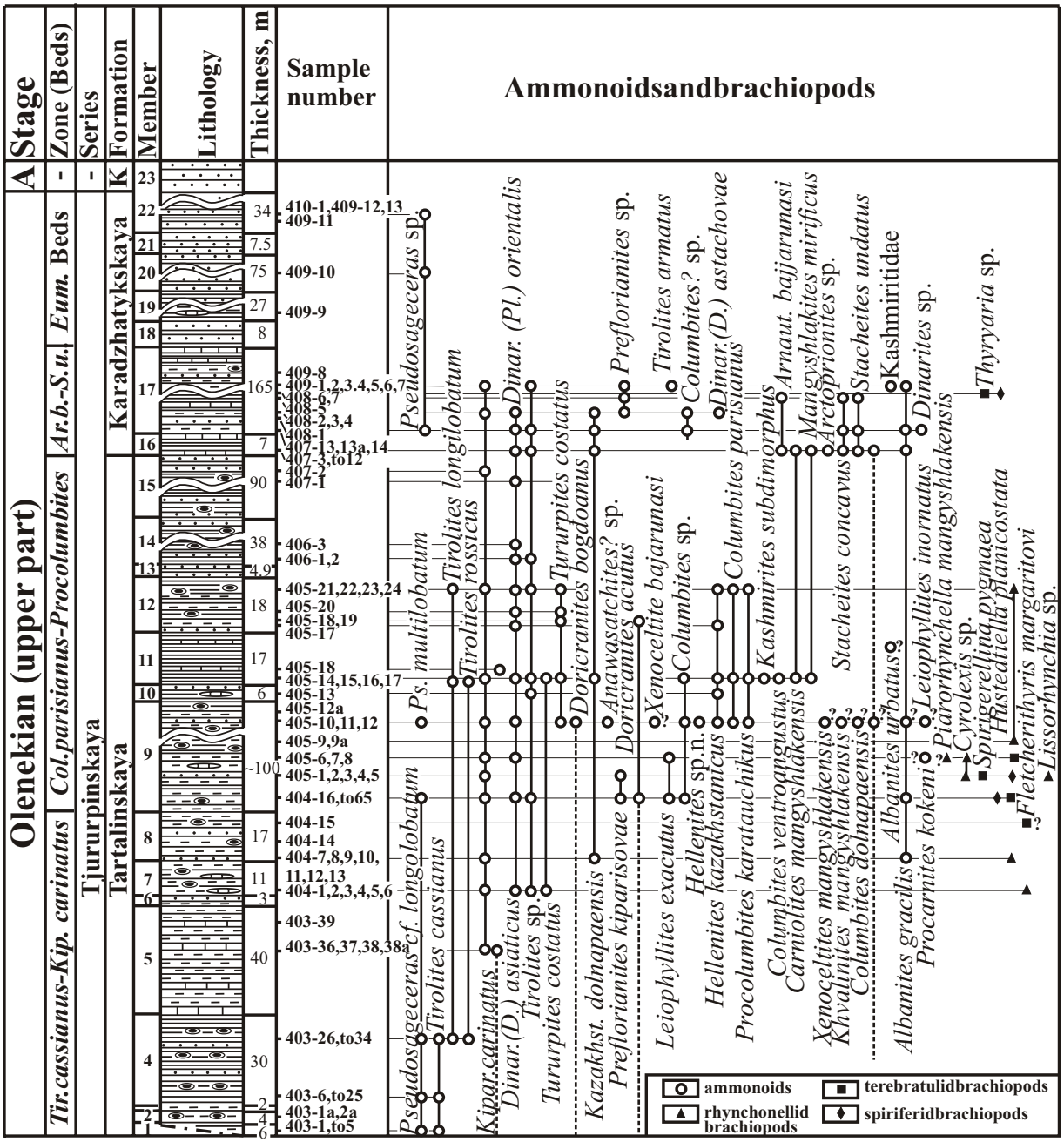

Fig. 2. Distribution of Late Olenekian ammonoids and brachiopods in the Dolnapa section, Mangyshlak Peninsula.

20. Grey, fine-grained sandstone with interlayers of mudstone and rare lenses of limestone (about 75 m).

Bivalves *Eumorphotis* sp. (409-13), nautiloid *Trematoceras* sp., ammonoid *Pseudosageceras* sp. (409-10).

19. Greenish-grey mudstone with rare interlayers (20-30 cm) of grey , fine-grained sandstone and lenses of limestone (27 m).

Bivalve *Pteria* sp. gastropods, nautiloids (Nautilida), bad preserved ammonoids (409-9,10).

18. Grey, fine-grained sandstone with interlayers of greenish-grey mudstone (8 m).

Arnautoceltites bajarunasi-Stacheites undatus Zone

17. Intercalation of greenish-grey mudstone with calcareous boulders, siltstone with plant detritus, and fine-grained sandstone with interlayers of light-grey limestone about 165 m

Fossils from the upper part: crinoids, spiriferid and rhinchonellid brachiopods (409-4), bivalves *Palaeonella* sp., *Neoschidosus* sp. (408-5), nautiloid *Trematoceras* sp. (409-1), ammonoids Kashmiritidae gen. et sp. indet., *Albanites gracilis* (Kiparisova), *Preflorianites* sp., *Stacheites concavus* Shevyrev, *S. undatus* (Astachova), *Dinarites (Plococeras) orientalis* Shevyrev, *Tirolites armatus* Shevyrev (409-1,4,5,6; 408-5,6,7).

Fossils from the lower part: spiriferid brachiopods (408-4), bivalves *Leda* sp., *Palaeonello* sp., *Uniites* sp., *Eumorphotis* sp. (408-1,2,3,4; 407-13), gastropods (408-1; 407-13), nautiloid *Trematoceras* sp. (408-4) and ammonoids *Pseudosageceras* sp., *Kazakhstanites dolnapaensis* Shevyrev, *Albanites gracilis* (Kiparisova), *Dinarites* sp., *Stacheites concavus* Shevyrev, *S. undatus* (Astachova), *Dinarites (D.) asiaticus* Shevyrev, *Dinarites (Plococeras) orientalis* Shevyrev, *Preflorianites* sp., *Tirolites* sp., *Kiparisovites ovalis* Shevyrev, *Tjururpites costatus* Shevyrev (408-1,2, 3,4; 407-13,14). Apparently in this level *Dinarites (D.) astachovae* Gavrilova was discovered (Gavrilova, 1989).

16. Greenish-grey mudstone with interlayers of limestone 7 m

Bivalve *Bakevellia* sp. (407-3), gastropods, ammonoids – *Arnautoceltites bajarunasi* (Astachova), *Kazakhstanites dolnapaensis* Shevyrev, *Arctoprionites* sp., *Stacheites concavus* Shevyrev, *S. undatus* (Astachova), *Dinarites (D.) asiaticus* Shevyrev, *Hyranites nodosus* Shevyrev (407-3,4,7,8,9,10,11,1213).

Total thickness of the Karadzhatykskaya Formation is 323.5 m.

Tartalinskaya Formation

Columbites parisianus-Procolumbites caratauchicus Zone

15. Intercalation of dark-grey mudstone with calcareous boulders, fine-grained sandstone with cross bedding 90 m

Small bivalves, gastropods and rare ammonoids *Dinarites (D.) asiaticus* Shevyrev and *D. (Plococeras) orientalis* Shevyrev (407-1,2).

14. Greenish-grey mudstone with rare interlayers of fine-grained, striate sandstone and calcareous boulders 38 m

Ammonoids –*Tirolites* sp. and *Dinarites (D.) asiaticus* Shevyrev (406-1,2,3).

13. Intercalation of greenish-grey, fine-grained sandstone (15-20 cm) and mudstone (10-20 cm) 15 m

12. Greenish-grey mudstone and siltstone with interlayers of fine-grained, striate sandstone and calcareous boulders 18 m

Brachiopods (405-24), nautiloid *Trematoceras* sp., ammonoids *Dinarites (D.) asiaticus* Shevyrev, *D. (Plococeras) orientalis* Shevyrev, *Tirolites armatus* Shevyrev, *T. longilobatum* Shevyrev, *Tirolites* sp., *Doricranites acutus* Mojsisovics, *Columbites parisianus* Hyatt and Smith, *Procolumbites karataucicus* Astachova, *Hellenites kazakhstanicus* Shevyrev, *Leiophyllites exacudus* Shevyrev, *Kiparisovites ovalis Shevyrev* (405-18,20,21,22,23,24), fish remains (405-19).

11. Greenish-grey mudstone with thin interlayers (2 cm) of limestone 17 m

Nautiloid *Sulioticeras* sp. (405-15), ammonoids – *Mangyshlakites mirificus* Shevyrev, *Procolumbites karatauchicus* Astachova, *Columbites ventroangustus* Shevyrev, *C. parisianus* Hyatt and Smith, *Columbites* sp., *Dinarites (D.) asiaticus* Shevyrev, *Hellenites kazakhstanicus* Shevyrev, *Dinarites (Plococeras) orientalis* Shevyrev, *Tirolites armatus* Shevyrev, *T. rossicus* Kiparisova, *T. longilobatus* Shevyrev, *Tirolites* sp., *Kashmirites subdimorphus* Kiparisova, *Kazakhstanites dolnapaensis Shevyrev,* and *Tjururpites costatus* Shevyrev (405-14,15,16,17,18).

10. Grey, fine-grained sandstone and greenish-grey mudstone with rare lenses of limestone (6 m).

Ammonoids – *Tirolites* sp., *Hellenites kazakhstanicus* Shevyrev (405-13).

9. Greenish-grey mudstone and siltstone with interlayers (5-15 cm) of fine-grained, striate sandstone and calcareous lenses and boulders about 100m

Fossils from the upper part: crinoids (405-10), rhynchonellid brachiopod *Hustedtiella planicosta* Dagys (405-9), bivalves *Bakevellia* sp., *Leptochondria* cf. *minima* (Kiparisova), *Eumorphotis* sp., Palaeoneilo sp., Mytilidae gen. and sp. indet. (405-9,10,11), gastropods (405-10,14), nautiloids *Phaedrysmocheilus* sp., Nautilidae gen. and sp. indet., *Trematoceras* sp. (405-10,11,12), ammonoids *Doricranites bogdoanus* (Buch), *Anawasatchites* sp., *Tirolites armatus* Shevyrev, *Tirolites* sp., *Dinarites (D.) asiaticus* Shevyrev, *Dinarites (Plococeras) orientalis* Shevyrev, *Columbites ventroangustus* Shevyrev, *C. parisianus* Hyatt and Smith, *Columbites* sp., *Procolumbites karatauchicus* Astachova, *Hellenites kazakhstanicus* Shevyrev, *Hellenites* sp., *Leiophyllites exacudus* Shevyrev (405-9,10,11,12,12a,18,22,23).

Fossils from the lower part: crinoids (404-61), spiriferid, rhynchonellid and spiriferid brachiopods, *Lingula* sp. (405-2,4, 404-47,49,50,59,61), bivalves *Eumorphotis* sp., *Entolium* sp. (404-19,35,59,61), gastropods (404-59,61), nautiloids *Phaedrysmocheilus* sp., *Trematoceras* sp. (405-4, 404-39), ammonoids *Pseudosageceras longilobatum* Kiparisova, *Doricranites acutus* (Moisisovics), *Anawasatchites* sp., *Dinarites (D.) asiaticus* Shevyrev, *Tirolites* sp., *Dinarites (Plococeras) orientalis* Shevyrev, *Albanites gracilis* (Kiparisova),*Columbites* sp., *Preflorianites kiparisovae* Shevyrev, *Leiophyllites exacudus* Shevyrev (405-1, 404-22,24,25,26,28,36,41,48,55,57,59,60,61,65, 405-2,9).

Total thickness of the *Columbites parisianus-Procolumbites caratauchicus* Zone is about 274 m/

Kiparisovites carinatus-Tirolites cassianus Zone

8. Greenish-grey siltstone with interlayers (10 cm) of fine-grained sandstone calcareous boulders 17 m

Sea-urchins (spines) (404-5), crinoids (404-5), rhynchonellid brachiopods (404-1,9,13), small gastro-

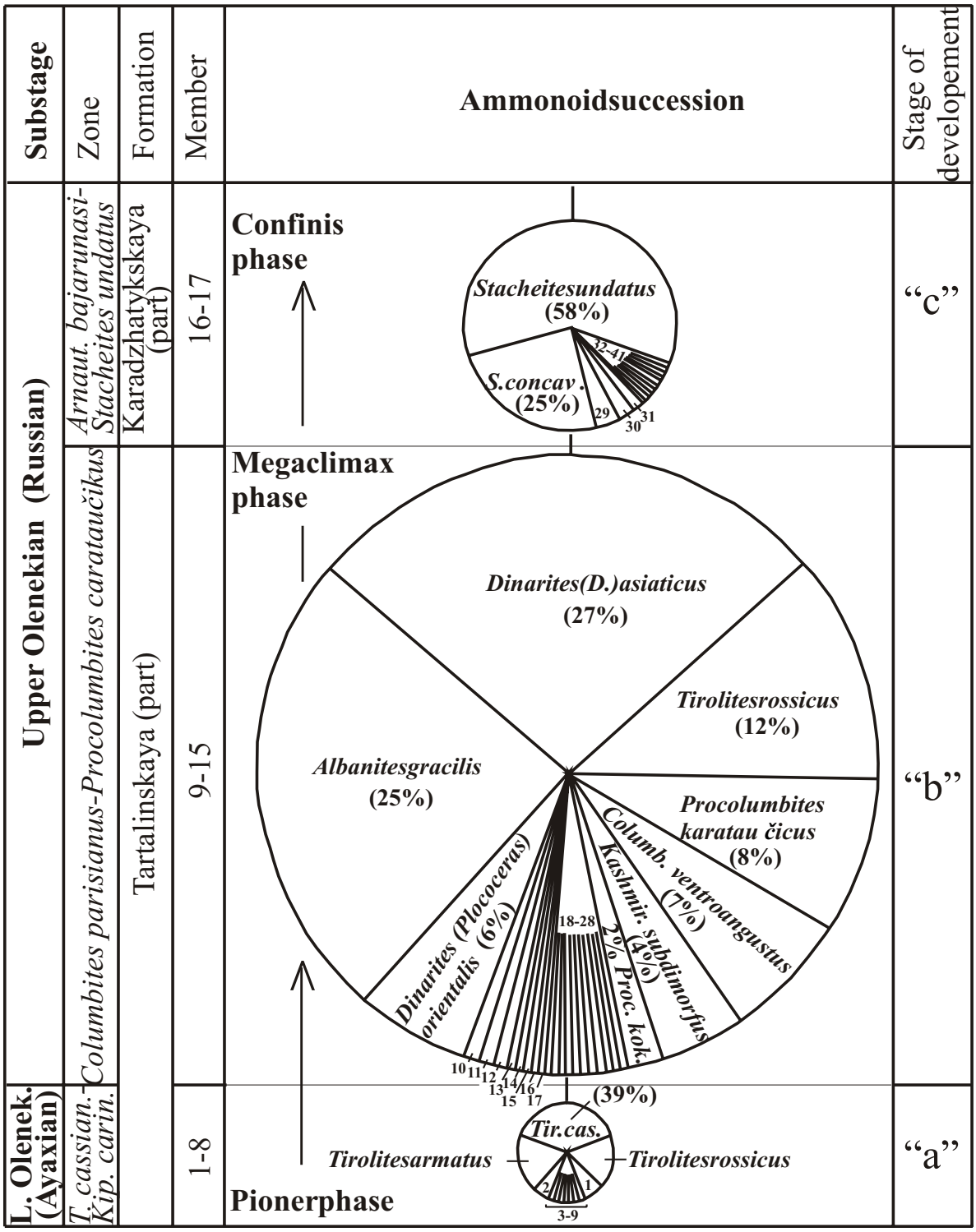

Fig. 3. Change of dominance in Late Olenekian ammonoid succession of the Dolnapa section, Mangyshlak Peninsula. 1 – *Dinarites (Plococeras) orientalis* Shevyrev, 2 – *Pseudosageceras* sp. , 3-9 – others (*Kiparisovites carinatus* Astachova, *Albanites gracilis* (Kiparisova), *Tjururpites costatus* Shevyrev, *Pseudosageceras* cf. *longilobatum* Kiparisova, *Tirolites* sp., *Dinarites (Dinarites) asiaticus* Shevyrev, *Kazakhstanites dolnapaensis* Shevyrev), 10 – *Kazakhstanites dolnapaensis* Shevyrev, 11 – *Tirolites* sp., 12 – *Tirolites armatus* Shevyrev, 13 – *Xenoceltites bajarunasi* Shevyrev, 14 – *Leiophyllites inornatus* Shevyrev, 15 – *L. exacudus* Shevyrev , 16 – *Hellenites kazakhstanicus* Shevyrev, 17 – *Columbites parisianus* Hyatt et Smith, 18-28 – others (*Kiparisovites ovalis* Shevyrev, *Doricranites bogdoanus* (Buch), *Pseudosageceras* cf. *longilobatum* Kiparisova, *P. multilobatum* Noetling, *Tirolites longilobatus* Shevyrev , *Tjururpites costatus* Shevyrev, *Anawasatchites* sp., *Preflorianites kiparisovae* Shevyrev, *Doricranites acutus* (Mojsisovics), *Columbites* sp., *Carniolites mangyshlakensis* Shevyrev, *Mangyshlakites mirificus* Shevyrev, *Xenoceltites mangyshlakensis* Shevyrev, *Khvalinites mangyshlakensis* Shevyrev, *Columbites dolnapaensis* Kiparisova, *Albanites arbanus* (Arthaber)), 29 – *Kazakhstanites dolnapaensis* Shevyrev, 30 – *Preflorianites* sp., 31 – *Dinarites (Dinarites) asiaticus* Shevyrev, 32 – *Albanites gracilis* (Kiparisova), 33-42 – others (*Arnautoceltites bajarunasi* Astachova, *Dinarites (Dinarites)* sp., *Tirolites armatus* Shevyrev, *Tirolites* sp., *Dinarites (Plococeras) orientalis* Shevyrev, *Pseudosageceras* sp., *Columbites?* sp., *Arctoprionites* sp., *Hyrcanites nodosus* Shevyrev, Kashmiritidae, *Dinarites* sp., *Mangyshlakites mirficus* Shevyrev).

pods (404-9), nautiloids *Trematoceras* sp., *Phaedrysmocheilus* sp. (404-6,9), ammonoids *Tirolites armatus* Shevyrev, *Albanites gracilis* (Kiparisova), *Kazakhstanites dolnapaensis* Shevyrev, *Tjururpites* cf. *costatus* Shevyrev, *Dinarites (Plococeras) orientalis* Shevyrev (404-1,7,9,15).

7. Greenish-grey siltstone with calcareous boulders and lenses (15 cm) of limestone 11 m

Rhynchonellid brachiopods (404-1), bivalves (404-1), gastropods (404-1), ammonoids *Tirolites* sp., *Dinarites (D.) asiaticus* Shevyrev, *D. (Plococeras) orientalis* Shevyrev (404-1, 2,3).

6. Intercalation of greenish-grey siltstone (50 cm), fine-grained, calcareous, wavy and cross-bedding sandstone (5-10 cm) 3 m

5. Greenish-grey siltstone with thin interlayers (2-5 cm) of brown limestone 40 m

Bivalves, small gastropods, ammonoids *Kiparisovites carinatus* Astachova, *Dinarites (Plococeras) orientalis* Shevyrev (403-37,38,38a).

4. Greenish-grey mudstone with thin interlayers (5-6 cm) of fine-grained sandstone and calcareous boulders about 30 m

Fossils from the upper part: bivalves *Neoschizodus* cf. *laevigata* (Zieten), *Leda* sp. (403-32,36), gastropods (403-31), ammonoids – *Pseudosageceras* sp., *Tirolites cassianus* Quenstedt, *T. rossicus* Kiparisova, *T. longilobatus* Shevyrev (403-26,27,28,32,34).

Fossils from the lower part: bivalve Mytilidae gen. et sp. indet. (403-21), gastropods (403-21), ammonoids *Pseudosageceras* sp., *Tirolites cassianus* Quenstedt, *Tirolites* sp. (403-14,17,19,21,25), amphibian remains (403-21).

3. Intercalation of greenish-grey siltstone (0.5 m) and fine-grained sandstone (5-20cm) 2m

2. Greenish-grey siltstone with calcareous boulders 4 m

Bivalves *Myophoria* sp., Ostreidae gen. et sp. indet. (403-2,8), fish remains (scales) (403-2).

1. Intercalation of greenish-grey mudstone, siltstone, brown, fine-grained sandstone with calcareous interlayers (10-15 cm) at 1-2 m above the base of the member 6 m

Bivalves Mytilidae, Monotidae (403-1,4), ammonoids *Pseudosageceras longilobatum* Kiparisova, *Tirolites cassianus* Quenstedt, and *Tirolites* sp. (403-3,5).

Thickness of the *Kiparisovites carinatus-Tirolites cassianus* Zone in the investigated tectonical block is 103 m.

Conclusions

During mid-Olenekian Pioner Phase (Stage "a") (Fig. 3), the main body of the community was composed of *Tirolites cassianus* Quenstedt. This was the time for the invasion of the first Triassic ammonoids in Mangyshlak. Other *Tirolites* ammonoids are represented by *Tirolites armatus* Shevyrev, *Tirolites rossicus* Kiparisova and *Tirolites* sp. associated with *Albanites gracilis* (Kiparisova), *Kazakhstanites dolnapaensis* Shevyrev, *Tjururpites* cf. *costatus* Shevyrev, and *Dinarites (Plococeras) orientalis* Shevyrev (*Doricranites bogdoanus* (Buch) and *Doricranites acutus* (Mojsisovics) (Bajarunas, 1936), appearing in the beginning of the Phase, were found, apparently, in the isolated block).

During the early Late Olenekian Megaclimax, Stage "b" (*Columbites parisianus-Procolumbites karatauchicus* Zone) *Dinarites (Dinarites) asiaticus* Shevyrev dominated in ammonoid succession of Mangyshlak. Diversed and abundent ammonoid asemblage is repesented by *Dinarites, Albanites, Tirolites, Dinarites, Procolumbites, Columbites, Kashmirites* and some ather genera.

Confinis Phase, Stage "c" (*Arnautoceltites bajarunasi-Stacheites undatus* Zone) is characteized by anabundance of *Stacheites undatus* associated with some typical latest Olenekian ammonoids for the Tethys (*Arnautoceltites*).

The main peculiarity of Olenekian sequences is development of the *Tirolites* fauna. *Tirolites,* the typical tropical element in the Tethys, arising during the middle Olenekian climatic optimum and reaching its fullest flower in that time, continued to exist some later during the Late Olenekian in Mangyshlak, as well as in many other regions of low (Idaho, Caucasus, Alps, Iran, Albania) and middle (South Primorye) latitudes.

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Examples of Late Olenekian invertebrate successions: Paper 2. Arctic Siberia (Mengilyakh Creek)

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Abstract To show the palaeontological characteristics of the upper Olenekian-lowermost Anisian sequences in the Boreal realm for purpose of global correlation, some original data from the stratotype of the Upper Olenekian (Mengilyakh Creek) are shown.

Introduction

First information on Triassic biostratigraphy of the Mengilyakh Creek and neighbor areas in Arctic Siberia (Karangati Hill and Stannakh-Khocho) was published by Mojsisovics (1886, 1888), Lazurkin and Korchinskaya, 1963; Popow (1968) and Zakharov (1978). But our knowledge on Upper Olenekian-Lower Anisian biostratigrapy in Arctic Siberia is still limited.

Purpose of this study is to analysis of LateOlenekian-Early Anisian ammonoid succession of Mengilyakh and Karangati (Swallow) Hill, lower reaches of the Olenek River.

Mengilyakh section and Late Olenekian- Early Anisian ammonoid succession

Some localities of Late Olenekian ammonoid fauna have been discovered in the Olenek River area (Fig. 1), but the most abundant and diversed ammonoids are known in the Mengilyakh Creek section (72°50'42.43"N; 120°58'53.94"E) (Fig. 2).

In descending order, the Upper Olenekian-lower Anisian sequence exposed at the mouth of the Mengilyakh Creek is (Fig. 3):

Lower Ulakhan-Krest Formation (Lower Anisian, *Grambergia taimyrensis* Zone)

41. Intercalation of black mudstone, intercalated with black siltstone and grey, fine-grained sandstone >20 m

40. Black mudstone and siltstone with thin layers (1-20 cm) of dark-grey, fine-grained sandstone 12 m

39. Black mudstone and siltstone with thin layers (1-20 cm) of dark-grey, fine-grained sandstone 7 m

Ammonoids – *Prohungarites tuberculatus* (Welter),

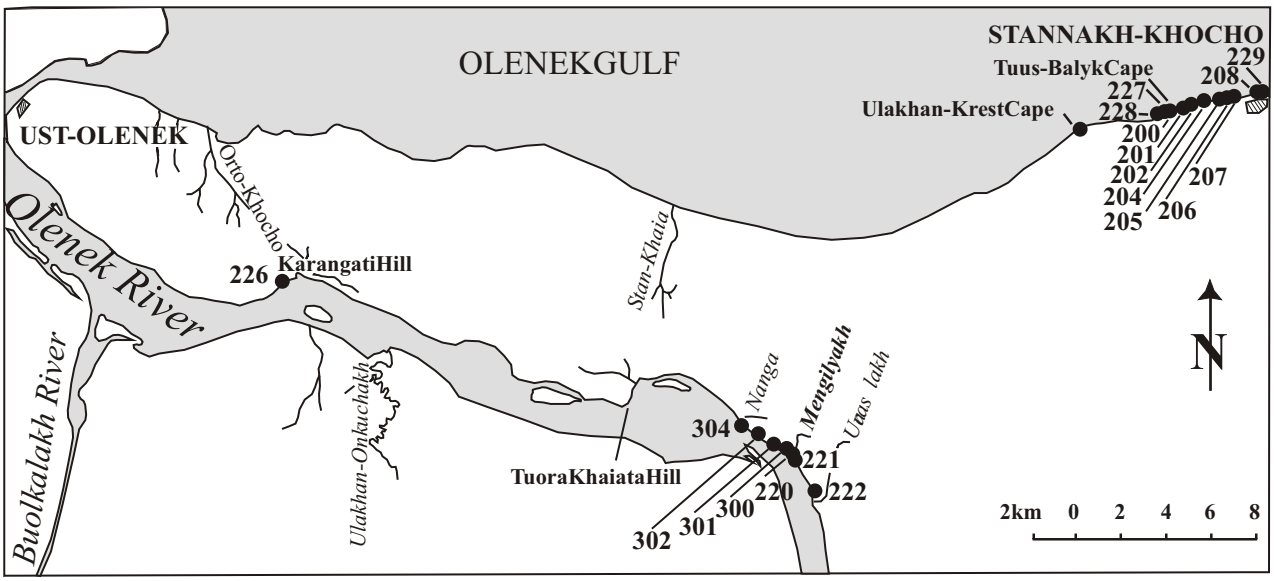

Fig. 1. Localities of Late Olenekian and Anisian ammonoids in the Olenek River area, Arctic Siberia.

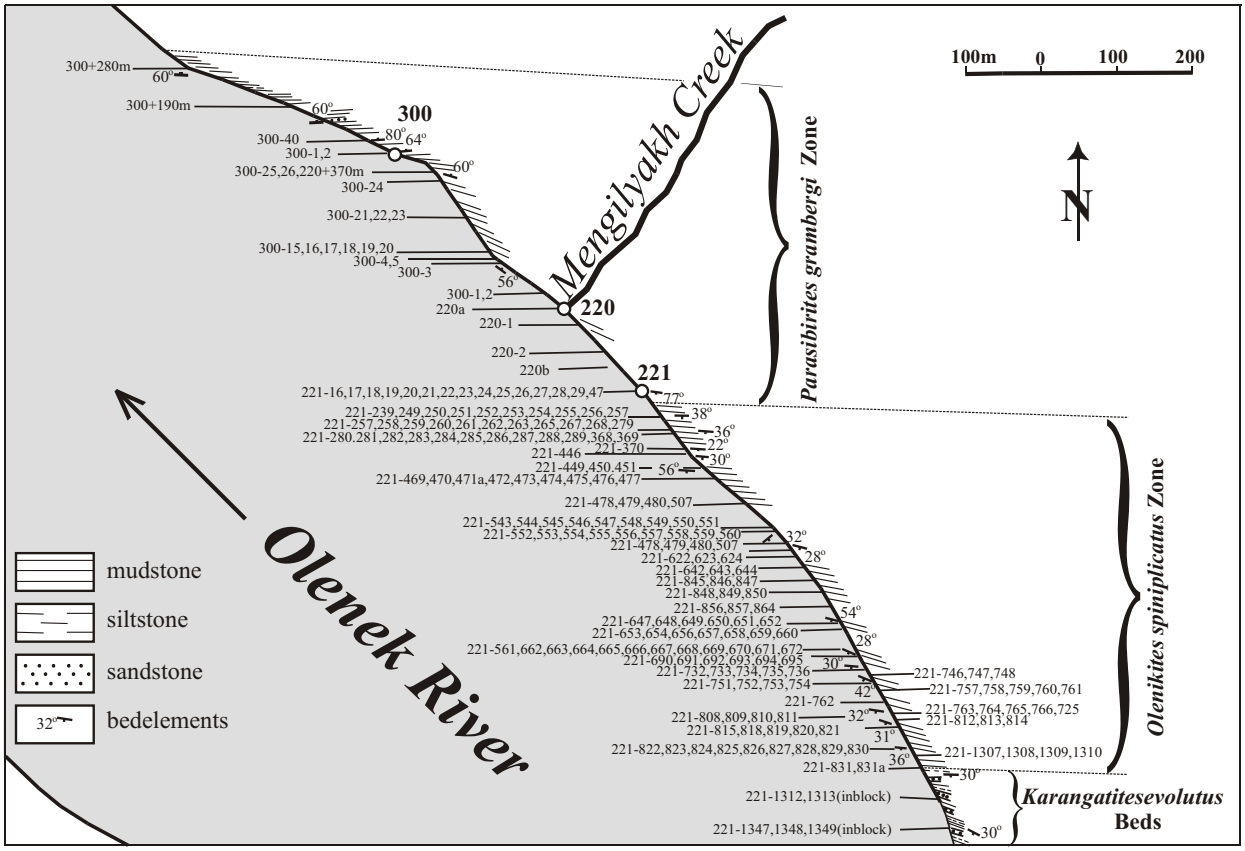

Fig. 2. Location of the Mengilyakh Creek section, Olenek River.

Prohungarites? sp.

In the Karangati Hill section, located about 24 km NW from the Mengilyakh Creek, lowest Anisian ammonoids more abundant. Just above the bed with Late Olenekian *Olenikites spiniplicatus* (Mojsisovics) and *Olenekoceras middendorffi* (Keyserling), *Karangatites evolutus* Popow and *Stenopopanoceras karangatiensis* (Popow) were discovered, about 4-5 m above *Stenopopanoceras karangatiensis* (Popow), *Stenopopanoceras mirabile*, *Grambergia olenekensis, Ussurites spitsbergensis, Neodalmatites kh., and Epiczekanowskites gastr*. were met (Popow, 1968; Zakharov, 1978).

The Lower Anisian in the Mengilyakh section is more than 40 m thick.

Pastanakhskaya and Ystannakhskaya formations (Upper Olenekian, *Olenikites spiniplicatus* Zone)

38. Black mudstone and siltstone with thin lenses of fine-grained sandstone and small, awkward shaped calcareous nodules 3.2 m

Ammonoids *Prosphingites czekanowskii* (dominant), *Northophiceras euomphalus* (Keyserling), *Subolenekites altus* (Mojsisovics), *Olenekoceras middendorffi* (Keyserling), *Pseudosvalbardiceras sibiricum* (Mojsisovics).

37. Black mudstone with rare large calcareous nodules (in restricted and very low outcrops) about 14 m

36. Black mudstone with large calcareous nodules 0.4 m

Bivalves *Posidonia*? sp., *Mysidioptera* sp., ammonoids *Keyserlingites subrobustus* (Mojsisovics), *Boreomeekoceras keyserlingi* (Mojsisovics), *Olenikites siniplicatus* (Mojsisovics), *Nordophiceras popovi* (Zakharov), *Nordophiceras schmidti* (Mojsisovics) , *Timoceras gracialis* (Mojsisovics), *Pseudosvalbardiceras sibiricum* (Mojsisovics), and *Prosphingites czekanowskii* Mojsisovics.

35. Black mudstone 4.5 m

Ammonoid *Olenikites spiniplicatus* (Mojsisovics).

34. Black mudstone with small calcareous nodules 0.3 m

Ammonoids *Olenikites spiniplicatus* (Mojsisovics) and *Nordophiceras schmidti* (Mojsisovics).

33. Black mudstone (in small outcrops) about 2.5 m

32. Black mudstone with large calcareous nodules 0.3 m

Ammonoid *Olenikites siniplicatus* (Mojsisovics)

31. Black mudstone with rare calcareous nodules 1.5 m

30. Black mudstone with large calcareous nodules 0.4 m

Brachiopod *Lingula* sp., bivalve *Palaeonneilo* sp., am-

monoids *Olenikites spiniplicatus* (Mojsisovics) (dominant) and *Nordophiceras schmidti* (Mojsisovics).

29. Black, striate mudstone with rare calcareous nodules 3.2 m

8. Black, striate mudstone with small calcareous nodules 0.3 m

Nuculid bivalves, nautiloid *Trematoceras* cf. *campanile* (Mojsisovics), ammonoids *Olenikites spiniplicatus* (Mojsisovics) (dominant), *Nordophiceras popovi* (Zakharov), *Boreomeekoceras keyserlingi* (Mojsisovics), *Olenekoceras middendorffi* (Keyserling), *Keyserlingites subrobustus* (Mojsisovics), and belemnitid *Atractites* sp.

27. Black mudstone with numerous calcareous nodules 9 m

Plant *Pleuromeia olenekensis* Krassilov, brachiopod *Lingula* sp., bivalve *Palaeonneilo* sp., scaphopods, ammonoids *Olenekoceras middendorffi* (Keyserling) (dominant), *Sibirites eichwaldi* Mojsisovics, *Northophiceras schmidt* (Mojsisovics) and *Boreomeekoceras keyserlingi* (Mojsisovics).

26. Black mudstone with rare calcareous lenses and nodules 13.0 m

Ammonoids *Olenekoceras middendorffi* (Keyserling) (dominant), *Pseudosageceras boreale* Zakharov, *Nordophiceras schmidti* (Mojsisovics), *Boreomeekoceras keyserlingi* (Mojsisovics), *Olenikites spiniplicatus* (Mojsisovics), *Subolenekites altus* (Mojsisovics), and *Sibirites eichwaldi* Mojsisovics.

25. Black mudstone with lenses of limestone, structure of which was determined as “cone in cone”, and rare calcareous nodules 20-25 m

24. Black mudstone with small calcareous nodules 3 m

Bivalves, small gastropods, ammonoids *Nordophiceras schmidti* (Mojsisovics), *Olenikites spiniplicatus* (Mojsisovics) and *Subolenekites altus* (Mojsisovics).

Closed interval (about 40-45 m).

23. Black mudstone with small, flat calcareous nodules 3m

Bivalves, small gastropods, ammonoids *Nordophiceras euomphalus* (Keyserling), *Olenikites spiniplicatus* (Mojsisovics), *Subolenekites altus* (Mojsisovics) and *Olenekoceras middendorffi* (Keyserling).

22. Black mudstone with lenses of limestone, structure of which was determined as “cone in cone”, and small calcareous nodules 9.0 m

21. Black mudstone with large calcareous nodules 1.0 m

Brachiopod *Lingula* sp., bivalve *Posidonia?* sp., ammonoids *Nordophiceras schmidti* (Mojsisovics), *Arctomeekoceras rotundatum* (Mojsisovics), *Sibirites eichwaldi* Mojsisovics, *Olenikites spiniplicatus* (Mojsisovics), and *Olenekoceras middendorffi* (Keyserling).

20. Black mudstone with lenses of limestone, structure of which was determined as “cone in cone”, and large calcareous nodules 16.0 m

19. Greenish-grey mudstone and siltstone with rare calcareous nodules 0.2 m

Ammonoid *Prosphingites czekanowskii* Mojsisovics.

18. Black mudstone with lenses of limestone, structure of which was determined as “cone in cone”, sandy limestone and rare calcareous nodules 4.0 m

17. Black mudstone with calcareous nodules 0.3 m

Nautiloid *Phaedrysmocheilus olenekensis* (Zakharov), ammonoids *Nordophiceras schmidti* (Mojsisovics) and Pseudos*valbardiceras sibiricum* (Mojsisovics).

16. Black mudstone 1.0 m

15. Black mudstone with numerous calcareous nodules 0.3 m

Ammonoids *Olenikites spiniplicatus* (Mojsisovics) and *Olenekoceras middendorffi* (Keyserling).

14. Black mudstone 1.0 m

13. Black mudstone with numerous large calcareous nodules 0.5 m

Bivalve *Mysidiopteraaurita,* nautiloids *Trematoceras* cf. *campanile* (Mojsisovics), *Phaedrysmocheilus olenekensis* (Zakharov), ammonoids *Nordophiceras schmidti* (Mojsisovics), *Nordophiceras euomphalus* (Keyserling), *Olenikites spiniplicatus* (Mojsisovics), *Timoceras gracialis* (Mojsisovics), *Olenekoceras middendorffi* (Keyserling) and *Keyserlingites subrobustus* (Mojsisovics).

12. Black mudstone 0.7 m

11. Black mudstone with lenses of limestone, structure of which was determined as “cone in cone”, and large calcareous nodules 0.3 m

Ammonoids *Nordophiceras schmidti* (Mojsisovics) (dominant), *Pseudosvalbardiceras sibiricum* (Mojsisovics), *Olenikites spiniplicatus* (Mojsisovics), and *Olenekoceras middendorffi* (Keyserling).

10. Black mudstone 2.2 m

9. Black mudstone with lenses of limestone, structure of which was determined as “cone in cone”, and calcareous nodules 0.5 m

Nautiloid *Phaedrysmocheilus olenekensis* (Zakharov), ammonoids *Nordophiceras schmidti* (Mojsisovics), *Olenikites spiniplicatus* (Mojsisovics) and *Timoceras gracialis* (Mojsisovics).

8. Black mudstone with rare calcareous nodules 3.0 m

Bivalves *Posidonia* sp., *Mysidioptera* sp., gastropods,

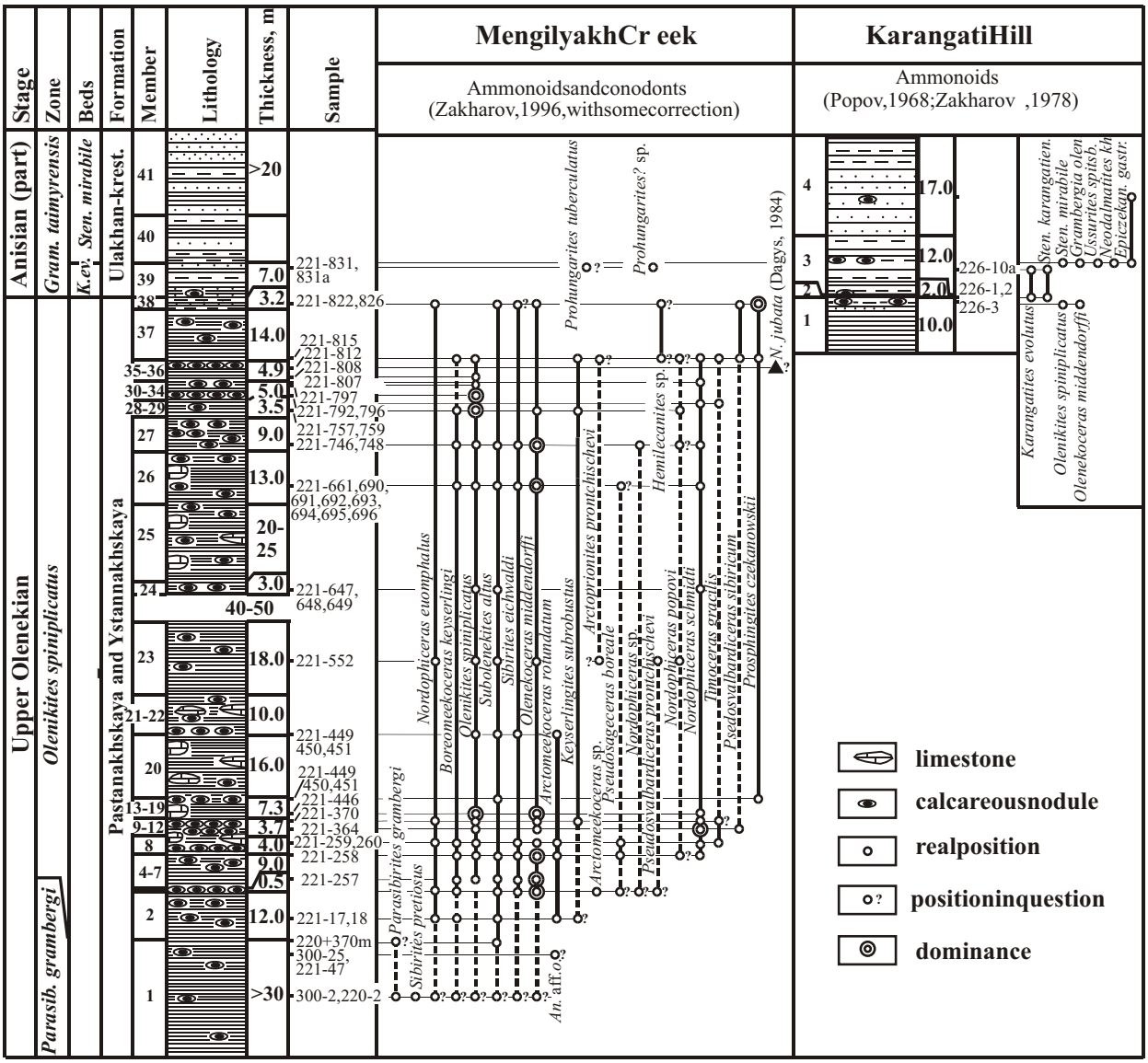

Fig. 3. Distribution of ammonoids and conodonts in the Mengilyak Creek and Karangati Hill sections, Arctic Siberia.

nautiloids *Trematoceras* sp., *Phaedrysmocheilus olenekensis* (Zakharov), ammonoids *Nordophiceras schmidti* (Mojsisovics), *Olenikites spiniplicatus* (Mojsisovics) and *Timoceras gracialis* (Mojsisovics).

7. Black mudstone with numerous large calcareous nodules 0.5 m

Gastropods, ammonoids *Olenekoceras middendorffi* (Keyserling) (dominant), *Pseudosageceras boreale* Zakharov, *Boreomeekoceras keyserlingi* (Mojsisovics), *Nordophiceras popovi* (Zakharov), *Arctomeekoceras rotundatum* (Mojsisovics), *Sibirites eichwaldi* Mojsisovics, *Subolenekites altus* (Mojsisovics), belemnite *Atractites* aff. *boecki* (Stürzenbaum}

6. Black mudstone with very rare calcareous nodules 6.0 m

5. Black mudstone with numerous calcareous nodules 1.0 m

Olenekoceras middendorffi (Keyserling) (dominant), *Boreomeekoceras keyserlingi* (Mojsisovics), *Sibirites eichwaldi* Mojsisovics, *Olenikites spiniplicatus* (Mojsisovics), and *Subolenekites altus* (Mojsisovics).

4.Black mudstone 1.5 m

3. Black mudstone with numerous large calcareous nodules 0.5 m

Blvalves, gastropods, ammonoids *Olenekoceras middendorffi* (Keyserlig) (dominant), *Nordophiceras euomphalus* (Keyserling), *Arctomeekoceras* sp., *Boreomeekoceras keyserlingi* (Mojsisovics), *Subolenekites altus* (Mojsisovics), and *Sibirites eichwaldi* Mojsisovics.

2. Black mudstone with rare small calcareous nodules 12.0 m

Ammonoids *Nordophiceras euomphalus* (Keyserling), *Arctomeekoceras rotundatum* (Mojsisovics), *Subolenekites altus* (Mojsisovics), *Boreomeekoceras keyserlingi* (Mojsisovics) and *Keyserlingites subrobustus*

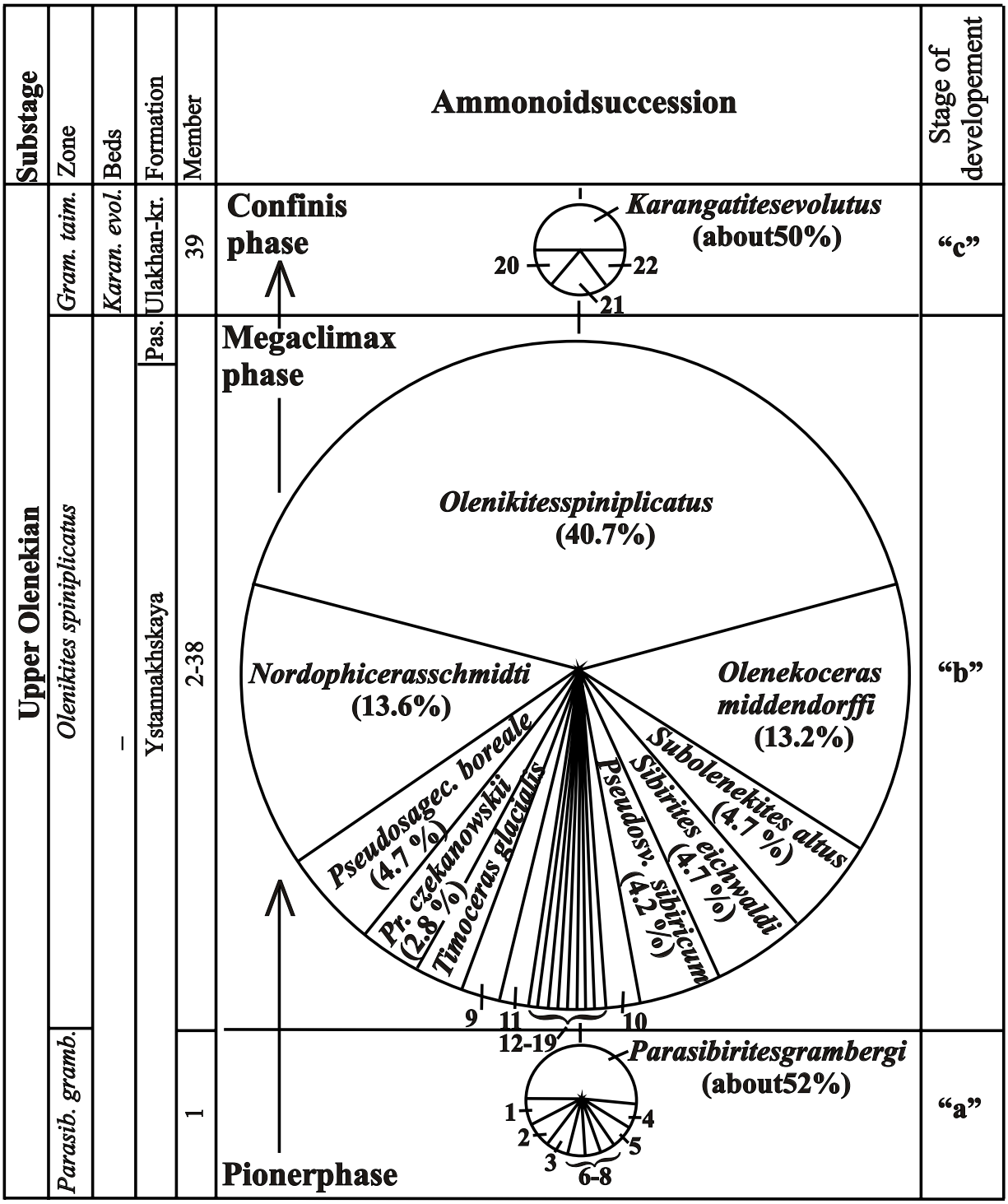

Fig. 4. Change of dominance in Late Olenekian-Earliest Anisian ammonoid succession of the Mengilyakh-Karangati area. 1 – ?*Nordophiceras euomphalus* (Keyserling), 2 - ?*Boreomeekoceras keyserlingi* (Mojsisovics), 3 – *Subolenekites altus* (Mojsisovics), 4 - ?*Sibirites eichwaldi* Mojsisovics, 5 - ?*Olenekoceras middendorfi* (Keyserling), 6-8 - others (*Sibirites pretiosus* Mojsisovics, *Parasibirites* sp., ?*Olenikites spiniplicatus* (Mojsisovics)), 9 – *Keyserlingites subrobustus* (Mojsisovics),10 – *Boreomeekoceras keyserlingi* (Mojsisovics), 11 – *Northophiceras euomphalus (*Keyserling), 12-19 – others (*Pseudosageceras* sp., *Prosphingites* sp., *Nordophiceras popovi* (Zakharov), *Nordophiceras* sp., *Svalbardiceras asiaticum* (Mojsisovics), *Arctoprionites pronchischevi* Zakharov, *Hemilecanites* sp., *Anaxenaspis* aff. *orientalis* (Diener)), 20 – *Stenopopanoceras evolutus* (Popow), 21 – *Prohungarites tuberculatus*, 22 – *Prohungarites* sp.

(Mojsisovics).

Upper Olenekian, *Parasibirites grambergi* Zone (upper part)

1. Black mudstone with small calcareous nodules (in restricted outcrops) 30.0 m

Ammonoids *Parasibirites grambergi* Popow and *Sibirites pretiosus* Mojsisovics. In removed nodules near outcrops ammonoids *Pseudosageceras, Nordophiceras, Boreomeekoceras, Olenikites, Subolenekites, Sibirites* and *Olenekoceras* were discovered (the real presence of *Nordophiceras, Boreomeekoceras, Subolenekites, Sibirites* and *Olenekoceras* in the *Parasibirites grambergi* Zone of Arctic Siberia was proved by Dagys and Ermakova (1988) by the example of some Lower Triassic section in Taimir).

The part of the Upper Olenekian in this section is about 135 m thick.

Conclusions

At first, *Parasibirites grambergi* beds in Arctic Siberia were considered by me to be the lower member of the *Olenikites spiniplicatus* Zone on the basis of some indirect data (a few *Olenikites spiniplicatus* were met by me in removed nodules near outcrops with ammonoids *Parasibirites grambergi* and *Sibirites pretiosus* in the Mengilyakh section) (Zakharov, 1978, 1996; Ehiro et al., 2006), but it was not confirmed by Dagys and Ermakova's (1988) and Dagys and Sobolev's (1995) data from the Taimyr area). Because the *Parasibirites grambergi* Zone is characterized by the first appearence of *Olenekoceras* and *Subolenekites* it may be correlated with the *Neocolumbites insignis* Zone in South Primorye (Zakharov, 1997), where several species of *Olenekoceras* are known in the early Late Olenekian sequences, and with the Lower Spathian of Arctic Canada (Tozer, 1994) characterized by a such typical representative of the genus *Subolenekites* as *Subolenekites pilaticus.*

In the Late Olenekian-Earliest Anisian ammonoid succession of the Olenek River the Megaclimax phase falls on the *Olenikites spiniplicatus* Zone, where *Olenikites spiniplicatus* is dominated (40.7%) (Fig. 4). Representatives of *Olenekoceras middendorffi* are significantly frequent in this succession than *Keyserlingites subrobustus* ones (13.2 and about 2%, respectivelly). According to Dagys and Ermakova's (1988) data, *Keyserlingites* has never was discovered in the *Parasibirites grambergi* Zone, therefore we correlate the *Olenikites spiniplicatus* Zone with the Upper Spathian (Zone of *Keyserlingites subrobustus*) in Arctic Canada (Tozer, 1994), late Late Olenekian member ("*Subcolumbites" multiformis* Zone) in South Primorye (Zakharov, 1997) and late Late Olenekian members (*Arnautoceltites bajarunasi-Stacheites undatus* Zone and *Eumorphotis* Beds) in Mangyshlak (Zakharov, 2007).

The main body of the community during Confinis phase of ammonoid succession in Arctic Siberia (Fig. 4) consists of *Karangatites evolutus* (about 50%), which associates with earliest Anisian representatives of *Prohungarites* and *Stenopopanoceras.* It allows us to correlate the *Karangatites evolutus* Beds (lower member of the *Grambergia taimyrensis* Zone) with the *Ussuriphyllites amurensis* Zone in South Primorye (Zakharov et al., 2005), characterized by *Ussuriphyllites amurensis* (dominant – 63.6%), *Leiophyllites praematurus* (9.1%), *Arctohungarites* sp. n. ((7.4%), *Megaphyllites atlasoviensis* (3.3%), *Prohungarites popowi, Arctohungarites primoriensis, Arctohungarites solimani,* Prionitidae gen. et sp. n., *Paradanubites* sp. indet., *Paracrochordiceras admaris, Salteites* sp. indet., *Tropigastrites sublahontanus, Parasageceras* sp., *Ussurites* sp.

It seems to be equivalented also to the *Paracrochordiceras-Japonites* Beds in North Dobrogea (Gradinaru, 2000; Gradinaru et al., 2006) and *Aegeiceras ugra* horizon in Chios (Fantini Sestini, 1981; Gaetani et al., 1992).

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Rhaetian (Upper Triassic) conodonts and radiolarians from New York Canyon, Nevada, USA

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Introduction

New York Canyon, on the southwestern flank of the Gabbs Valley Range in west-central Nevada (Fig. 1) has long been well known for its fossiliferous marine strata of latest Triassic and earliest Jurassic age (Muller & Ferguson, 1939). Taylor et al. (1983) and Guex et al. (1997, 2004) proposed the Ferguson Hill section on the north bank of Muller Canyon, the canyon immediately south of New York Canyon, as a candidate for the GSSP for the Triassic-Jurassic Boundary (TJB). Although the ammonites and their sequence from this section are well documented (e.g., Guex, 1995; Taylor et al., 2000, 2001; Taylor & Guex, 2002), other fossils are less well known. Here, we report the first records of latest Triassic conodonts and radiolarians from the uppermost Triassic strata of the New York Canyon area.

Stratigraphy and sampling

Muller & Ferguson (1936) established two lithostratigraphic units that encompass the TJB interval in New York Canyon: the (Triassic) Gabbs and (Jurassic) Sunrise formations. Muller & Ferguson (1939) published a more comprehensive geological description of the area and divided the Gabbs Formation into three members, which were later formally named by Taylor *et al.* (1983). The lower, Nun Mine Member, is mostly siltstone with interbedded limestone; the middle, Mount Hyatt Member, is mostly limestone; and the upper, Muller Canyon Member, is mostly siltstone with a few beds of limestone. The overlying basal member of the Sunrise Formation was named the Ferguson Hill Member.

Microfossil samples were collected from each of these units during three trips to New York Canyon, in 1986 (MJO, ESC, DGT), 2003 (SGL), and 2005 (MJO, SGL). The Nun Mine Member, which sits conformably on top of the Upper Triassic Luning Formation, is best exposed in Luning Draw where samples were taken from the ~100 m thick succession of dark mudstones and siltstones intercalated with black limestone (Taylor et al., 1983, p. 1599). Calcareous siltstones and bioclastic sandy limestones of the overlying Mount Hyatt Member were sampled east of Mount Hyatt (Taylor & Guex, 2002, Fig 7), where the member is about 70 m thick, and at the proposed GSSP site at Ferguson Hill, where the upper 21 m thick of the member are exposed. At the latter location the lithology is composed mostly of resistant, often bioturbated and fossiliferous calcareous siltstone and silty limestones. The Muller Canyon Member was sampled at Reno Draw (Taylor et al., 2000, Fig. 4), and at Ferguson Hill (op. cit., Fig. 3), where it is about 16.5 m thick and composed largely of weakly calcareous siltstones. The basal fossiliferous, thin- to medium-bedded limestones of the overlying Ferguson Hill Member of the Sunrise Formation were also sampled at the proposed GSSP site.

Micropaleontology

The main results of the microfossil sampling are summarized in Figure 1. Apart from conodonts and radiolarians, several other microfossil groups were recovered, though none were common. These included foraminiferans, ostracodes, micro-gastropods, sponge spicules and ichthyoliths, although only the latter are well preserved. It is likely that more targeted sampling and processing could produce better collections of these microfossils.

Conodonts

The Nun Mine Member yielded a conodont fauna (1986 sampling) consisting exclusively of representatives of the *Epigondolella bidentata* Mosher group, the last of which was recovered 4.5 metres above the base of the overlying Mount Hyatt Member. The most common representative of this group present is *E. mosheri* Kozur & Mostler, for which the Gabbs Formation is the type stratum. The species was originally assigned to *E. bidentata* by Mosher (1968) and, although Mosher (1973) later declined to separate it as an independent species, *E. mosheri* was recognized by Orchard (1991a) as being typical of collections from the *Cassianella* beds member (informal) of the Tyaughton Formation in south-central British Columbia (Umhoefer & Tipper, 1998), the type section of the *Cochloceras amoenum* Zone (Tozer, 1994).

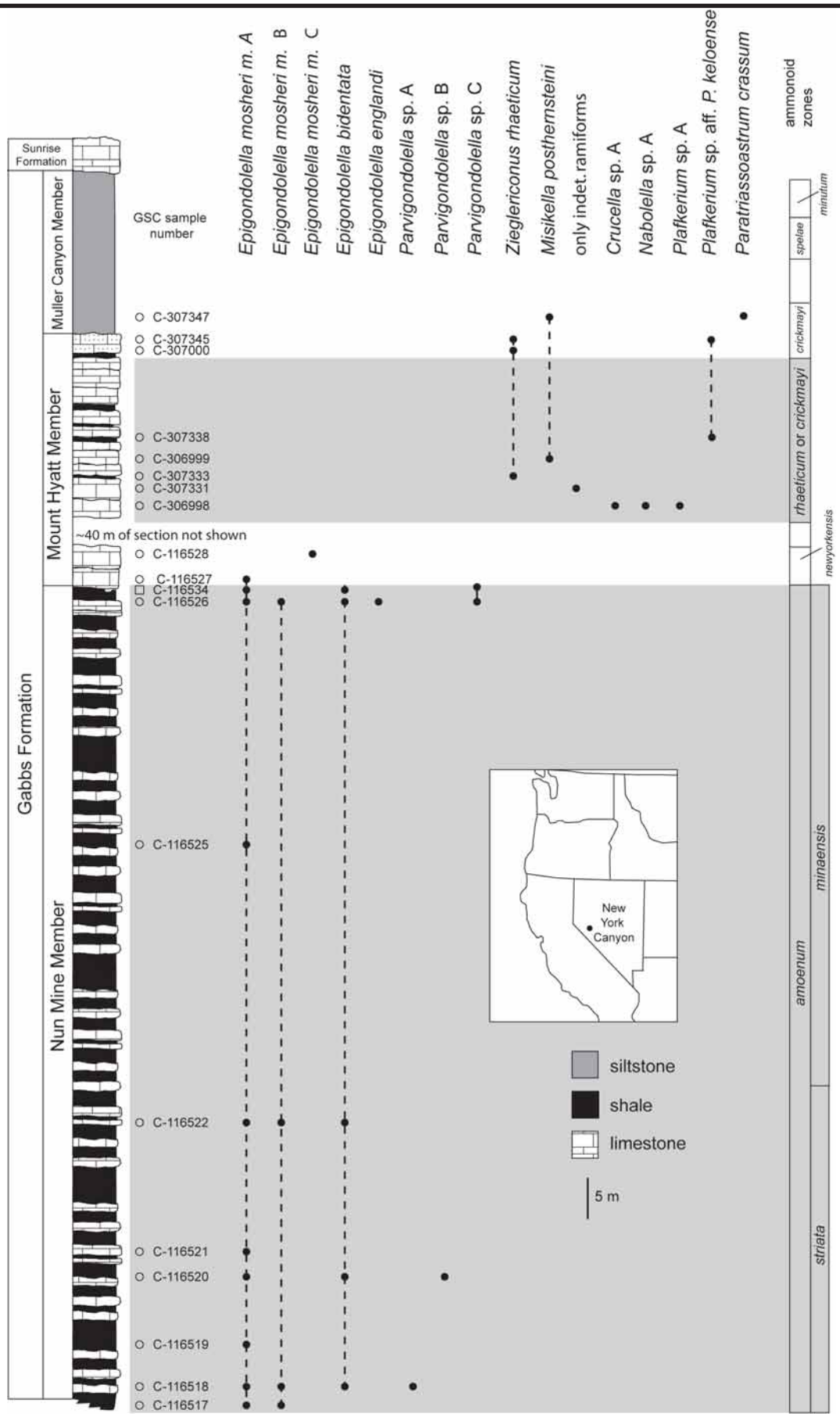

Fig. 1. Composite stratigraphic section of the Gabbs Formation in New York Canyon showing the position of conodont and/or radiolarian productive samples, and equivalent ammonoid zones. Inset, location in Nevada, western North America.

Epigondolella mosheri also occurs above Upper Norian *Monotis* beds in both the Pardonet Formation and Bocock Limestone in northeast British Columbia (Orchard, 1991a), and in the Sandilands Formation at both Kennecott Point and Kunga Island on Queen Charlotte Islands (QCI; Orchard, 1991b). The early Rhaetian age of *E. mosheri* is thus well established in western North America, although the species apparently does not occur, or is rare, in Eurasia. The upper limit of *E. mosheri* is uncertain: in both Tyaughton Creek and at Kennecott Point it disappears prior to the appearance of *Misikella posthernsteini* in the Crickmayi Zone, and prior to the appearance of the coeval radiolarian assemblage of *Globolaxtorum tozeri* Zone. However, on Kunga Island (QCI) and in Baja California (Whalen et al., 1998), forms allied to *E. mosheri* occur also within the *G. tozeri* Zone, implying that, at least locally, and in contrast to Tethys, the *Epigondolella* biofacies persisted almost to the end of the Triassic.

Orchard (1994) reported *E. mosheri* from the Pucará Group at Huanincocha, Peru, and compared it with examples of that species from QCI: two morphotypes, A and B, were differentiated based on their posterior platform ornament. The unornamented form, morphotype A (Pl. 1, figs. 16, 17, 23-25), corresponding to the holotype, was not found in Peru, but it is associated with a more ornate form, morphotype B (Pl. 1, fig. 19), in many collections, including some from the Gabbs Formation. Both morphotypes appear to have been included in *Epigondolella humboldtensis* Meek from "post-Dun Glen" strata in the Humboldt Mountains of western Nevada (Meek, 1984), but the holotype of that species (Meek, 1987) is unlike either. Other variations present within the *E. bidentata* group collections from the Nun Mine Member include rare forms corresponding to *E. englandi* Orchard (Pl. 1, fig. 18). This species was described from the Lewes River Group in Yukon Territory (Orchard, 1991a), where it occurs also with both morphotypes of *E. mosheri*.

Based on collections from QCI, there appears to be a morphological trend of posterior platform elongation in *Epigondolella* species through the latest Triassic so as to produce elements with 7-9 carinal denticles posterior of the lateral nodes compared with 5-6 nodes in typical *E. mosher*i, and 3-4 in *E. bidentata*. These strongly elongate forms are here assigned to a new informal taxon, *E. mosheri* morphotype C (Pl. 1, figs. 10, 11), which occurs in the lower Mount Hyatt Member. A second Rhaetian trend involves the suppression of platform nodes and the development of a *Parvigondolella*-like morphology in progressively larger specimens. In the lower Nun Mine Member, very early growth stages of *E*. ex gr. *bidentata* with lateral node development (Pl. 1, fig. 22) occur alongside similar-sized specimens with no nodes (Pl.1, fig. 21): the latter are distinguished as *Parvigondolella* sp. B. A single specimen from near the base of the Nun Mine Member is similar to *P*. sp. B but has a downturned posterior: this is assigned to *Parvigondolella* sp. A (Pl. 1, fig. 20). In the uppermost Nun Mine Member/ basal Mount Hyatt Member, there are larger elements without nodes but with lateral flanges or a narrow, nodeless platform: these are here referred to *Parvigondolella* sp. C (Pl. 1, fig. 12-15).

The discovery in 2003 and 2005 of both *Misikella* and *Zieglericonus* from the proposed GSSP site at Ferguson Hill within the upper part of the Mount Hyatt Member, and of the former taxon up to 2 m into the Muller Canyon Member, is remarkable. These genera have only been found previously in North America in allochthonous Cordilleran terranes with Tethyan affinities (Cache Creek, Wrangell, and Cadwallader terranes; Orchard, 1991c). Their occurrence in the Gabbs Formation presumably reflects its low paleolatitude rather than a distal westerly origin because the sediments are believed to have been deposited in a backarc basin not far outboard of the North American continental margin (e.g., Speed, 1978). However, the absence of *Misikella* and other 'Tethyan' taxa from the Nun Mine Member suggests that migration of those Tethyan taxa to North American low latitudes from Eurasia was not achieved until well after their early Rhaetian rise to dominance in the latter region.

Misikella posthernsteini Kozur & Mostler is a widespread species in Tethys, where it appears concurrently with the ammonoid *Cochloceras* in the Steinbergkogel section in Austria (Krystyn & Kuerschner, 2005), a datum that is favored for the definition for the Norian-Rhaetian boundary (e.g. Carter, 1993; Kozur, 1999). In North America, the FAD of *E. mosheri* seems to represent a proxy for the base Rhaetian in the absence of *Misikella posthernsteini*, which appears later. In Tethys, *Misikella posthernsteini* ranges close to the top of the Triassic as shown for Csövár, Hungary (Kozur & Mock, 1991; Pálfy et al., 2006), where it occurs alongside *M. ultima* and disappears about 10 m below the approximate level of the TJB. In Cordilleran allochthonous terranes, as well as in New York Canyon, *Misikella posthernsteini* is only known from the Crickmayi Zone sensu Tozer (1994). At Kennecott Point (QCI; Wrangel terrane), the species is known from a single bed in direct association with *Choristoceras nobile* (Tipper et al., 1994) and about 23 m below the radiolarian-defined TJB, and in Tyaughton Creek (Cadwallader terrane), it was found in the upper green clastic member of the Tyaughton Formation (Umhoefer & Tipper, 1998), the type locality for the Crickmayi Zone (Tozer, 1994). In England, *M. posthernsteini* occurs in the pre-*Planorbis* beds at Barnstone (Swift, 1995).

Zieglericonus rhaeticus Kozur & Mock has the same upper range as *Misikella posthernsteini* in its type locality at Csövár, Hungary, but first appears only in the upper part of the range of the latter species. Elsewhere in North America, the species is only known from the San Hipólito Formation in the Vizcaino Peninsula of Baja California Sur (Whalen et al., 1998), where it occurs with both the older *Misikella hernsteini* and radiolarians of the *Proparvicingula moniliformis* Zone, as well as with younger radiolarians of the *Globolaxtorum tozeri* Zone. This suggests the species ranges through much of the

Rhaetian. In England, *Zieglericonus* occurs in the Langport Member of the Lilstock Formation in the Normanton Hills (Swift, 1995).

Radiolarians

The Gabbs Formation was first sampled for radiolarians in 1986 without success, but recent collecting (2003, 2005) in the Mount Hyatt and Muller Canyon members at Ferguson Hill has yielded some poorly preserved specimens whose distinctive shape permits tentative assignment to several Rhaetian species. The age of these taxa is based primarily on comparison with well-preserved faunas from complete successions at Kennecott Point and Kunga Island, Queen Charlotte Islands (Carter, 1990, 1993), where lower faunas of the *Proparvicingula moniliformis* Zone are approximately equivalent to ammonoids of the Amoenum Zone, and upper faunas of the *Globolaxtorum tozeri* Zone are equivalent to the Crickmayi Zone. Sparse data from other areas further contribute to age assessment.

Radiolarians from the upper parts of the Mount Hyatt Member (Fig. 1) are referred to *Crucella* Pessagno, *Plafkerium* Pessagno, and *Nabolella* Petrushevskaya (= *Squinabolella* Kozur & Mostler). Those assigned to *Crucella* (Pl. 1, figs. 6, 7) are similar to *Crucella* sp. A sensu Yeh and Cheng (1996, pl. 1, fig. 5) from a single chert sample on Busuanga Island, Philippines. These authors indicate their fauna is probably late early Rhaetian in age and closely resembles Rhaetian radiolarian faunas from central Japan. The genus *Crucella* begins in the lower Rhaetian in QCI and occurs sporadically through the remainder of the stage. However, by the upper Hettangian/lower Sinemurian, *Crucella* is common in QCI (Carter et al., 1998) and Bavaria (Kozur & Mostler, 1990) and thereafter is one of the most diverse and abundant genera to range through the Jurassic and Cretaceous.

Specimens assigned to *Plafkerium* (Pl. 1, figs. 5, 9) are possibly *Plafkerium* sp. aff. *keloense* Carter and *Plafkerium* sp. A sensu Carter 1993, respectively. Both species range through most of the *Proparvicingula moniliformis* and *Globolaxtorum tozeri* zones in QCI, although the latter is more common in the upper zone. Similar species of *Plafkerium* are also known from the Fields Creek Formation in east-central Oregon (sample F35 of Yeh, 1989). The genus *Plafkerium* was first described from Norian beds of the San Hipólito Formation on the Vizcaino Peninsula, Baja California (Pessagno et al., 1979), and apparently went extinct at the end of the Triassic. A single specimen of the hat-shaped genus *Nabolella* (Pl. 1, fig. 8) seems closely related to *Nabolella* sp. A sensu Carter 1993 (previously *Squinabolella*). There are many species of this genus in the Rhaetian of QCI, Baja California, Japan and the Philippines, but more precise identification is limited by preservation.

A sample (C-307347) from near the base of the Muller Canyon Member contains a single poorly-preserved but distinctive specimen whose tetrahedral shape suggests *Paratriassoastrum crassum* Carter (pl. 1, fig. 4). In QCI, this species begins in the *Proparvicingula moniliformis* Zone but is more common in higher beds of the *Globolaxtorum tozeri* Zone. *Paratriassoastrum crassum* is also present in the San Hipólito Formation of Baja California, where it first occurs in highest beds of the *Proparvicingula moniliformis* Zone (Carter, 1998) and ranges upward. It is also present in the Fields Creek Formation of east-central Oregon (Yeh, 1989) and in central Japan, where it is assigned to the highest Rhaetian assemblage (TR 8D) of Sugiyama (1997). The genus *Paratriassoastrum* begins in the lower Carnian (Kozur & Mostler, 1981) and went extinct at the very end of the Triassic.

Biostratigraphic summary

Taylor and Guex (2002) assigned the Nun Mine Member to the Amoenum Zone and differentiated it into two subzones named after species of *Sagenites*: the Striata Subzone associated with *Peripleurites* and *Pinacoceras*, and an overlying Minaensis Subzone associated with *Cochloceras* and *Rhacophyllites*. The conodonts *Epigondolella bidentata* and *E. mosheri* morphotypes A and B occur throughout these two subzones, whereas *Parvigondolella* sp. A and *P.* sp. B occur only in the lower subzone, and *Epigondolella englandi* and *Parvigondolella* sp. C occur only in the upper subzone. No radiolarians were recovered from the Nun Mine Member.

The Mount Hyatt Member was divided into three ammonoid zones plus an intervening horizon by Taylor and Guex (2002). The lowest zone, characterized by *Vandaites newyorkensis*, occurs at the base of the unit and probably embraces the single occurrence of *Epigondolella mosheri* morphotype C. No conodonts were found in the interval characterized specifically as the *Cycloceltites tozeri* Horizon and *Choristoceras rhaeticum* Zone (not shown in Figure 1), although the latter zone may range higher. The oldest radiolarian species also occur above these levels in the Mount Hyatt Member: they are characteristic of the early to middle Rhaetian *Proparvicingula moniliformis* Zone.

The larger part of the upper Mount Hyatt Member has not produced zone-diagnostic ammonoid fauna but the uppermost part of that member and the basal part of the succeeding Muller Canyon Member are assigned to the *Choristoceras crickmayi* Zone of Taylor and Guex (2002). Beds both below and within this latter ammonoid zone have produced the conodonts *Misikella posthernsteini* and *Zieglericonus rhaeticum*. The radiolarian *Paratriassoastrum crassum* from the Muller Canyon Member is indicative of the late Rhaetian *Globolaxtorum tozeri* Zone and falls also within the Crickmayi Zone. The presence of like species in QCI, Oregon, Nevada, Baja California, Japan and the Philippines underscores the fact these radiolarians can be correlated globally, as emphasized by Carter and Hori (2005).

The FAD of *Psiloeras tilmanni* and the base of the pro-

posed base of the Jurassic occurs at about 8 m above the base of the Muller Canyon Member and 6 m above the highest conodonts and radiolarians. Sampling of beds above the FAD of *Psiloceras tilmanni*, including the base of the Sunrise Formation, failed to recover any additional elements.

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Plate description

All figures magnified x160

1, 2. *Misikella posthernsteini* Kozur & Mock 1974. Lateral and posterior views, GSC 120335 from GSC loc. C-307347, Muller Canyon Mb.

3. *Zieglericonus rhaeticus* Kozur & Mock 1991. lateral view, GSC 120336 from GSC loc. C-307000, Mount Hyatt Mb.

4. *Paratriassoastrum crassum* Carter 1993. GSC 120337 from GSC loc. C-307347, Muller Canyon Mb.

5. *Plafkerium* sp. aff. *P. keloense* Carter 1993. GSC 120338 from GSC loc. C-307338, Mount Hyatt Mb.

6, 7. *Crucella* sp. A sensu Yeh and Cheng 1996. GSC 120339 from GSC loc. C-306998, Mount Hyatt Mb.

8. *Nabolella* sp. A sensu Carter 1993. GSC 120340 from GSC loc. C-306998, Mount Hyatt Mb.

9. *Plafkerium* sp. A sensu Carter 1993. GSC 120341 from GSC loc. C-306998, Mount Hyatt Mb.

10, 11. *Epigondolella mosheri* (Kozur & Mostler 1976) Morphotype C nov. Upper and lower views, GSC 120342 from GSC loc. C-116528, Mount Hyatt Mb.

12, 13. *Parvigondolella* sp. C. Upper views, GSC 120343 and GSC 120344 from GSC loc. C-116534, talus from Nun Mine or Mount Hyatt Mbs.

14, 15. *Parvigondolella* sp. C. Upper and lateral views, GSC 120345 from GSC loc. C-116526, Nun Mine Mb.

16, 24, 25. *Epigondolella mosheri* (Kozur & Mostler 1976) Morphotype A Orchard, 1994. Upper view, GSC 120346, and lateral and upper views, GSC 120347 from GSC loc. C-116526, Nun Mine Mb.

17, 23. *Epigondolella mosheri* (Kozur & Mostler 1976) Morphotype A Orchard, 1994. Upper views, GSC 120348 and GSC 120349 from GSC loc. C-116534, talus from Nun Mine or Mount Hyatt Mbs.

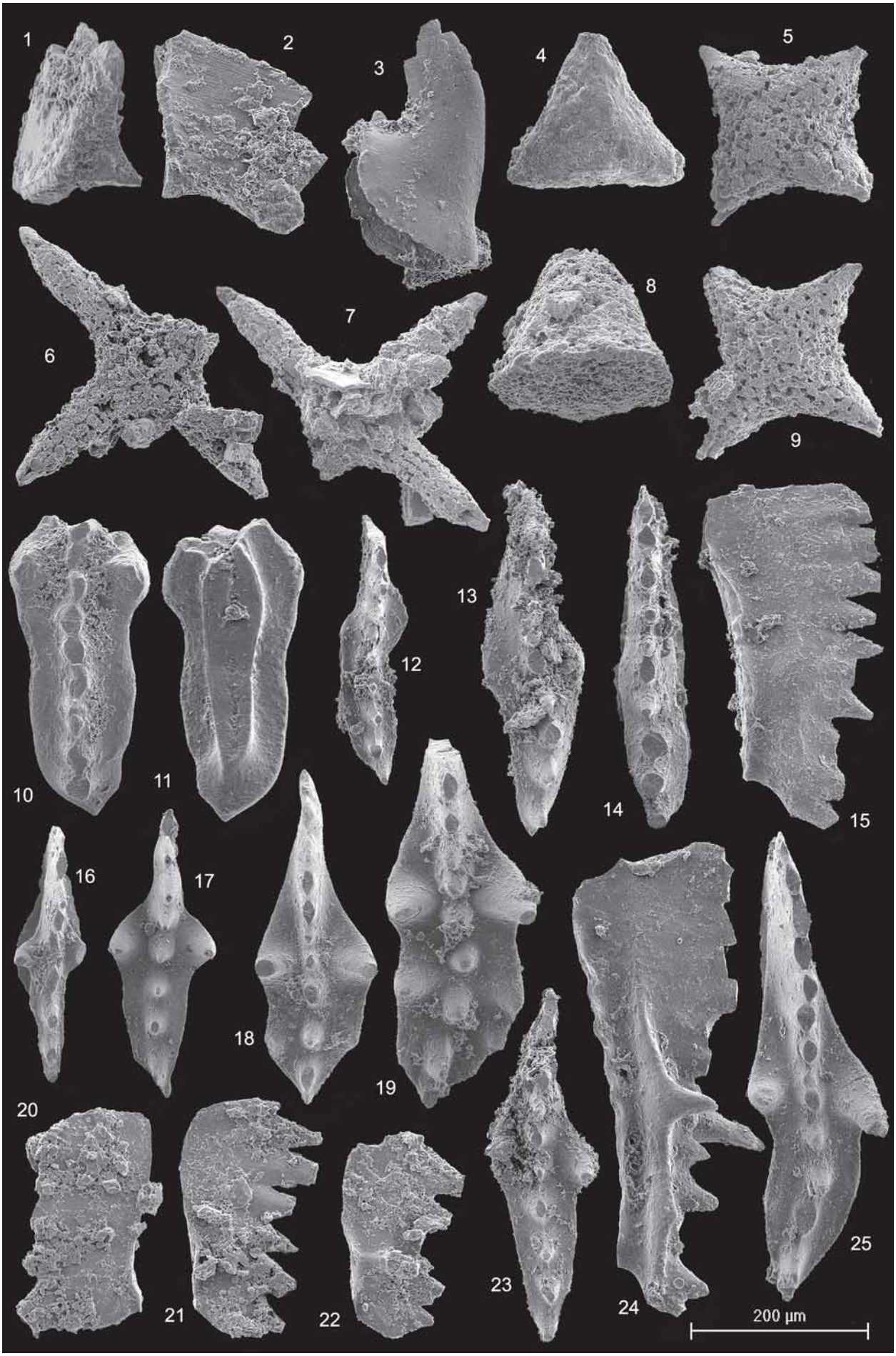
18. *Epigondolella englandi* Orchard 1991. Upper view, GSC 120350 from GSC loc. C-116526, Nun Mine Mb.

19. *Epigondolella mosheri* (Kozur & Mostler 1976) Morphotype B Orchard, 1994. Upper view, GSC 120351 from GSC loc. C-116526, Nun Mine Mr.

20. *Parvigondolella* sp. A. Lateral view, GSC 120352 from GSC loc. C-116518, Nun Mine Mb.

21. *Parvigondolella* sp. B. Lateral view, GSC 120353 from GSC loc. C-116520, Nun Mine Mb.

22. *Epigondolella bidentata* Mosher 1968. Lateral view, GSC 120354 from GSC loc. C-116520, Nun Mine Mb. Note lateral node.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New Triassic Literature

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British Triassic palaeontology: supplement 31

G. Warrington

Since the completion of the writer's previous supplement (No.31; ALBERTIANA, 34) on British Triassic palaeontology, the following works relating to aspects of that subject have come to his notice.

Barras, C. G. & Twitchett, R. J. 2007. Response of the marine infauna to Triassic–Jurassic environmental change: ichnological data from southern England. Palaeogeography, Palaeoclimatology, Palaeoecology, 244 (1-4): 223-241.

Duffin, C. J. 2006. William Buckland (1784-1856). Geology Today, 22 (3): 104-108

Edwards, A. L. & Pollard, J. E. 2006. Trace fossil collections at the University of Manchester. The Geological Curator, 8 (5): 243-246.

Gallois, R. W. & Porter, R. J. 2006. The stratigraphy and sedimentology of the Dunscombe Mudstone Formation (Late Triassic) of south-west England. Geoscience in south-west England, 11 (3): 174-182.

Gallois, R. W. 2007. A recent landslide on the east Devon coast, UK. Quarterly Journal of Engineering Geology and Hydrogeology, 40 (1): 29-34.

Hounslow, M. W. & Ruffell, A. H. 2006. Triassic: seasonal rivers, dusty deserts and saline lakes. Pp.295-324 *in* Brenchley, P. J. & Rawson, P. F. (eds). The Geology of England and Wales. The Geological Society, London.

Radley, J. D. 2006. Trace fossils: a smaller museum's perspective. The Geological Curator, 8 (5): 247-254.

Radley, J. D. & Pollard, J. E. 2006. *Chirotherium* footprints in Warwickshire: the Preston Bagot slab rediscovered. (Appendix to Radley, J. D. 2006, q.v.). The Geological Curator, 8 (5): 254.

Thulborn, T. 2006. On the tracks of the earliest dinosurs; implications for the hypothesis of dinosaurian monophyly. Alcheringa, 30 (2): 273-311.

Van de Schootbrugge, B., Tremolada, F., Rosenthal, Y., Bailey, T. R., Feist-Burkhardt, S., Brinkhuis, H., Pross, J., Kent, D. V. & Falkowski, P. G. 2007. End-Triassic calcification crisis and blooms of organic-walled 'disaster species'. Palaeogeography, Palaeoclimatology, Palaeoecology, 244 (1-4): 126-141.

Warrington, G. 2005. The Charmouth 16A borehole, Dorset, U.K.: palynology of the Penarth Group and basal Lias Group (Upper Triassic-Lower Jurassic). Geoscience in south-west England, 11 (2): 109-116.

Warrington, G. 2005. The chronology of the Permian and Triassic of Devon and south-east Cornwall (U.K.): a review of methods and results. Geoscience in south-west England, 11 (20; 117-122.

Whiteside, J. H., Olsen, P. E., Kent, D. V., Fowell, S. J. & Et-Touhami, M. 2007. Synchrony between the Central Atlantic magmatic province and the Triassic–Jurassic mass-extinction event? Palaeogeography, Palaeoclimatology, Palaeoecology, 244 (1-4): 345-367.

Wimbledon, B. 2007. Commercial exploitation *versus* Sustainable use. Earth Heritage, 27 (Winter 2006-2007): 7-9

Wings, O. 2004. Authigenic minerals in fossil bones from the Mesozoic of England; poor correlation with depositional environments. Palaeogeography, Palaeoclimatology, Palaeoecology, 204 (1-2): 15-32.

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Future Meetings

Second Circular
THE GLOBAL TRIASSIC
Albuquerque, New Mexico USA
23-25 May 2007

Organizing Committee:
Spencer G. Lucas, Albuquerque
Michael J. Orchard, Vancouver
Adrian P. Hunt, Albuquerque
Justin A. Spielmann, Albuquerque
Jim Jenks, Salt Lake City
Lawrence Tanner, Syracuse
Chris McRoberts, Cortland
Karl Krainer, Innsbruck

This international symposium will be devoted to all aspects of the Triassic System with particular focus on the Triassic timescale and Triassic biotic events. It will be an official meeting of the IUGS Subcommission on Triassic Stratigraphy, and a final meeting of IGCP 467 on Triassic Time and Correlation.

The meeting will be three days of talks and posters at the New Mexico Museum of Natural History in Albuquerque. Planning for pre-meeting and post-meeting fieldtrips is underway, and the trips will be announced in the second circular. They will afford an opportunity to visit several classic marine sections including Fossil Hill (A-L), South Canyon (L-C), and New York Canyon (T-J), as well as classic nonmarine Triassic sections in New Mexico-Arizona.

Further info at http://www.nmnaturalhistory.org/globaltriassic.html

Updated Information:

Please do not forget that the pre-registration deadline for the meeting is April 1. After that date, all registration fees increase!

If you are writing an abstract or paper for the meeting volume, March 28 is the absolute deadline for papers be received in Albuquerque in their final form.

There are still many places for fieldtrip 2 (New Mexico-Arizona nonmarine Triassic).

Fieldtrip registrations will close April 1, or before if the trips are full.

Questions, problems? Contact Spencer Lucas at spencer.lucas@state.nm.us

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Pan-European Correlation of the Epicontinental Triassic - International Field Workshop on the Triassic of Southern Poland

September 3-9, 2007

Upper Silesia – Holy Cross Mts.

A Field Workshop to Upper Silesia and the Holy Cross Mts (September, 3-9, 2007) will be organized by Joachim Szulc (Jagiellonian University, Cracow), Anna Roman-Becker (Polish Geological Institute, Warsaw), Maria Kuleta (Polish Geological Institute, Kielce), Jarek Kedzierski (AGH Cracow), Hans Hagdorn (Muschelkalk Museum, Ingelfingen, Niemcy) and Michael Szurlies (Geoforschungszentrum, Potsdam, Germany).

For further info contact Michael Szurlies szur@gfz-potsdam.de

Call for Papers

If you are interested in giving a lecture or in presenting a poster, please send your abstract in English per e-mail (as .doc file) to the conference secretary · geopomerania@fu-confirm.de.

Deadline for submitting abstracts is Thursday, **May 31st, 2007**.

Instructions for preparing abstracts:

To get the abstract template, please download it from the conference webpage http://www.geopomerania2007.org, or please send an e-mail to geopomerania@fu-confirm.de.
When sending your abstract(s) to geopomerania@fu-confirm.de, please state directly in the e-mail body additionally:

- Title of abstract
- The topic your abstract belongs to (number of topic is sufficient);
- State whether it is a lecture or a poster abstract;
- Full names and addresses of all authors including complete address, phone, fax, and e-mail address of the contact author.
- Please send figures if any separately as raw data (.jpg or .tif, at least 300 dpi).

(PhD) students who participate in GeoPomerania 2007 with a lecture or a poster presentation do not have to pay the conference fee (please send proof of your status as PhD student together with your registration form to the conference secretary).

Field Trips

We are going to offer an interesting excursion program to our conference participants. The following field trips are in planning (excursion fee € 40-50 per day):

Pre-Conference

- The Central European Basin System: From the Bottom to the Top (2 days)
- Neotectonic activity in the Gdansk area (2 days)
- Geology and geoarchaeology of Usedom, Wolin Islands (1 day)

Post-Conference

- Cenozoic geology of western Pomerania (1 day)
- Geology, geoarchaeology and geoecology of Rügen Island (2 days)
- Glacial and post-glacial evolution of the Odra/Oder Valley (1 day)
- Coastal dynamics and coastal protection NW Poland and NE Germany (2-3 days)

A form for booking excursions will be soon available for web download.

Conference program

An interesting and comprehensive conference program is foreseen that offers plenary and parallel sessions, poster and industry exhibition, panel discussions, and social program.

Registration

Enclosed please find the registration form with detailed information about conference fee and banking details.
For Polish colleagues, an account in Poland is in planning in order to avoid transfer fees.

Early registration fee (money transfer until May 31, 2007):

regular:	80 €
for students, unemployed, pensioners:	40 €

Late registration fee (money transfer after May 31, 2007, or payment on-site in Szczecin, cash):

regular:	110 €
for students, unemployed, pensioners:	55 €

Accommodation

Information on accommodation will soon be provided at http://www.geopomerania2007.org.

Field Trips

We are planning to offer a wide range of interesting technical excursions. Information on field trips will soon be provided at http://www.geopomerania2007.org.

Topics

1 Southern Permian Basin (SPB) / Central European Basin System (CEBS)

1.1 Sedimentary Basins (C. Breitkreuz, R. Littke, P.A. Kukla, A. Piotrowski) The Central European Basin System (CEBS) experiences a complex and dynamic evolution since the Late Carboniferous. Controlled by changing tectonic regimes, terrestrial and marine clastic sedimentation, volcanism as well as fluid and salt mobility makes the CEBS an unique site yielding natural resources and offering multiple geo-engineering tasks. Papers are wellcome from research groups of the CEBS (like the DFG SPP 1135) and of neighbouring basin systems.

1.2 Regional Geology, Structures and hydrocarbon potential (P. Hoth, J.H. Gerling, H. Doornenbal, M. Meschede) Regional Geology has always been a link between different geoscientific disciplines. This session will focus on the Northern European Region with special emphasis on new insights on the Tornquist-Teisseyre line crossing Central and Northeastern Europe. Contributions on all disciplines, e.g., tectonics, regional seismic studies, paleoreconstructions or stratigraphic relationships are welcome.

1.3 Regional stratigraphy (G.H. Bachmann, H.-G. Röhling, J. Szulc) This topic will focus on correlation of the major stratigraphic units of the entire Phanerozoic of Central and West Europe (United Kingdom to Poland) using all available stratigraphic methods to create a well balanced stratigraphic correlation chart for Central Europe and the project "Southern Permian Basin Atlas".

1.4 Global Devonian, Carboniferous and Permian correlations (M. Menning, S. Skompski, G. Warrington) This topic will focus on the correlation of the Regional Stratigraphic Scale (RSS) of Central and West Europe with the Global Stratigraphic Scale (GSS) and the RSS of East Europe, Tethys, South China, and North America as used in the

GUIDELINES FOR THE SUBMISSION OF MANUSCRIPTS TO ALBERTIANA

Albertiana is published twice a year. Contributions should be sent to the editor. In order to facilitate the production of this newsletter and reduce typing errors, authors are kindly requested to submit their contributions electronically, preferably by email. Those who are unable to submit a manuscript in electronic format are kindly requested to send flat (unfolded), clearly typed manuscripts in a 12-point typeface (sans serif) with single line spacing.

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 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.

Subcommission on Triassic Stratigraphy

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