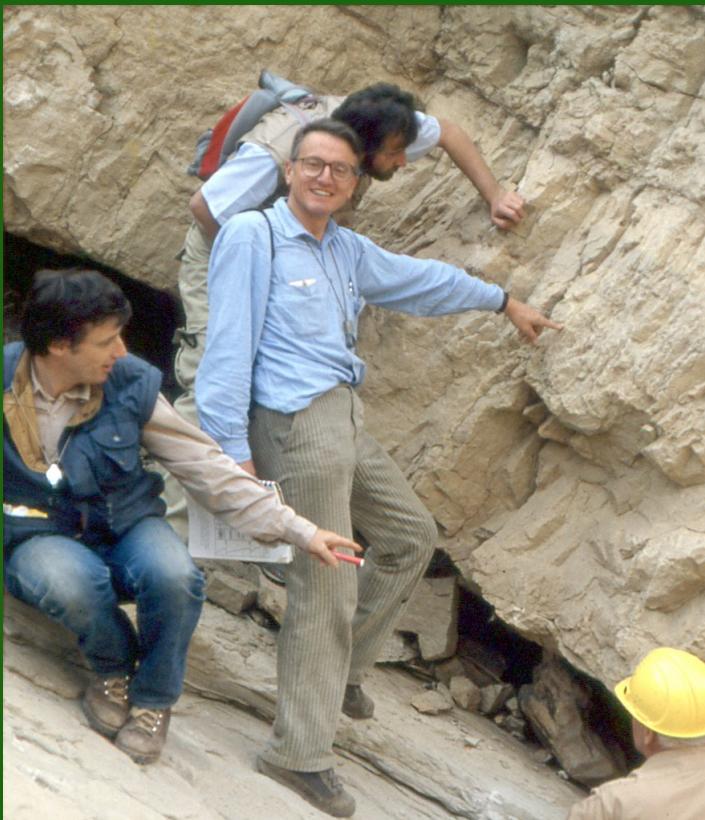


ALBERTIANA



44

January 2018
ISSN 0619-4324

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FINDING OF SKELETAL ATTACHING STRUCTURES OF EUCONODONTS (H-ELEMENTS) FROM THE LOWER TRIASSIC OF SOUTH PRIMORYE: ETOLOGICAL SIGNIFICANCE

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Abstract – Comparative-morphological analysis of hard rounded and rhomb- and trapezoid-like structures from the Lower Triassic deposits of South Primorye and the Polar Urals of Russia as well as from the Upper Ordovician of South Africa, from the Silurian of North America, and from the Lower Carboniferous of Scotland showed that they are located in the head part of euconodont animals in front of the tooth apparatuses symmetrically to its sagittal axis. It is suggested that a pair of such attaching H elements with the help of muscles connected the isolated tooth elements and governed them in the working process. All skeletal and tooth elements and their connective tissues were in the rounded food sac localized on the outer ventral side of the animal. In the process of the food sac functioning, probably, the food particles in it were filtered from water, which was removed through special holes, and then a food clot was formed and migrated into the food channel (gut). Some groups of the euconodont animals were, perhaps, swimming filtrators and dwelled in the benthic water layer.

INTRODUCTION

In the Lower Triassic deposits of South Primorye (siltstone bed of the Perevalnyi Creek, the Kamenushka River basin, 50 m thick) in the calcareous sandstone lens in 1979 the skeletal phosphatic elements looking like rings (up to 0.72–0.87 mm in diameter) and rhomb-like plates (Fig. 1 A, B) were found together with tooth conodont elements and ammonites of the Anasibirites nevolini zone. These rings and plate in color and structure of the surface are indistinguishable from the associated conodont elements (their color varies from transparent light-brown to dark-brown). Our attention to the extreme impotence of this finding for understanding the structure of the conodont animal was called by Dr. K. Budurov. Subsequently, the analogous skeletal elements were found in the euconodont imprints from the Upper Ordovician deposits in South Africa (Aldridge & Theron, 1993), Silurian of Wisconsin (North America) (Mikulic et al., 1985), the Lower Carboniferous of Granton (Scotland) (Briggs et al., 1983; Aldridge et al., 1986, 1993), and Polar Urals (Russia) (Buryi et al., 2010). Structure and role of these morphological structures of euconodont animals were for long time unknown, and some researchers (e.g. Aldridge et al. 1993, figs. 3, 4) considered them to be the remains of the eye capsules.

POSITION AND ROLE OF ATTACHING ELEMENTS IN MOUTH COMPLEX OF EUCONODONTS

The comparative-morphological analysis of the new morphological structures allowed us to establish that they are the hard cephalic elements located in front of the tooth apparatuses of euconodont animals symmetrically to their sagittal axis. These structures demonstrate both rounded and rhomb- and trapezoid-like contours that exclude their belonging to eyes (Aldridge & Theron 1993, figs. 1, 2, pl. 1). Some of them have preserved the remains of a soft muscle tissue (muscles) in the form of a cap (Müller et al., 1974), which appeared to be attached to the projections of the outer margin and ring crest of the described cephalic structures and served for the connection of the tooth conodont elements with each other and for governing them in the working process (Fig. 2 A, B). We proposed to call them the H head attaching elements (Buryi & Kasatkina, 2003, 2004). The data obtained allowed us to conclude that, apparently, the cephalic mouth complexes of the euconodont animals together with about 15 P, M, and S elements of the tooth apparatus appeared to incorporate a pair of the H attaching structures and soft connective formations (muscles). Further investigation of

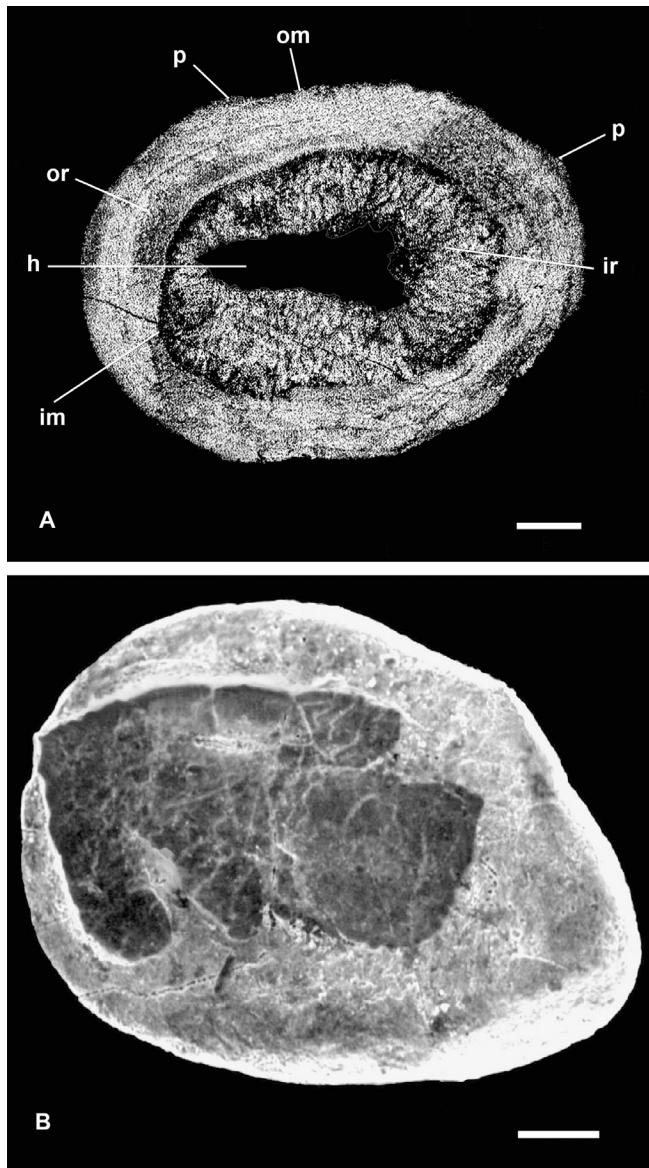


Figure 1 – Euconodont H skeletal elements from the Lower Triassic deposits of Primorsk Terr. **A**, rounded structure, specimen DVGI 3B-1 (om, outer margin; p, projection; im, inner margin; or, outer ring; ir, inner ring; h, hole); **B**, rhomb-like structure, specimen DVGI 3B – 4. Scale bars = 0.1 mm.

the Triassic and more ancient H attaching elements as well as the imprints of soft tissues of euconodonts made it possible to understand that the whole mouth complex of the animal was localized in its head part, and namely in the food sac (Guravskaya & Kassatkina, 2015). On the outer ventral part of the imprint from the Polar Urals (Russia) the same oval widening of its head part is observed, suggested to be a food sac. The analogous structure is described also in the head part of the fifth, best preserved imprint from Granton (Great Britain), uncovered along the inner plane (Guravskaya & Kassatkina, 2015) (Fig 3). On the ventral side the elements of the conodont tooth apparatus are surrounded by the muscle tissue of the anterior division of the gut forming a food sac stepping outside the animal trunk. Inside this food sac there is a soft lobe with a branched system of the muscular fibres, to which the ramiform and pectiniform

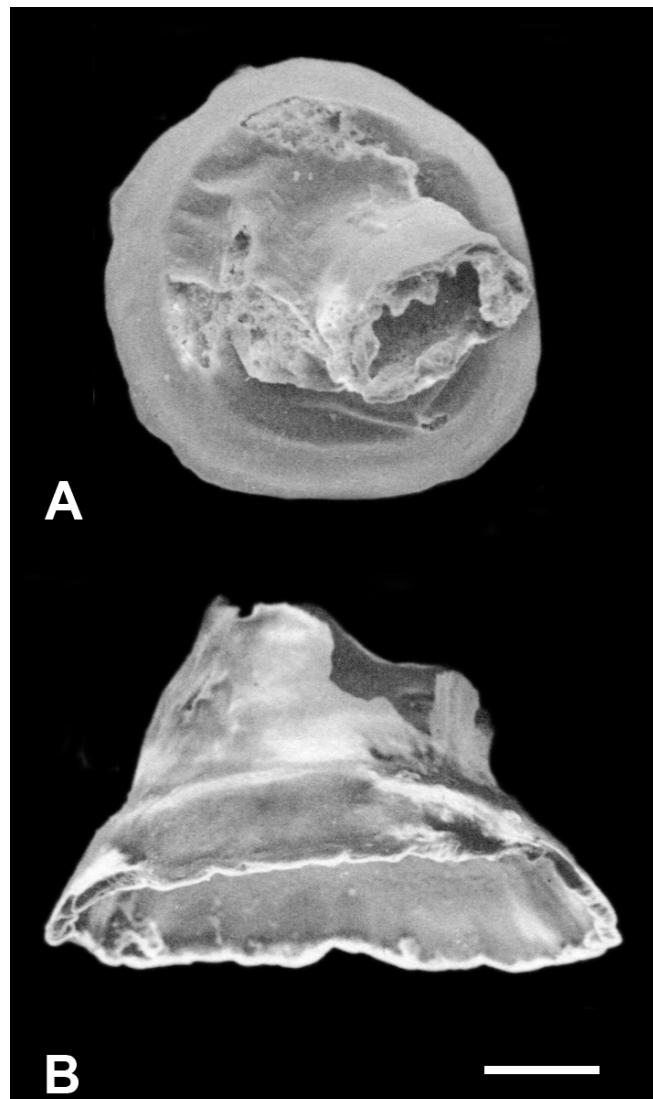


Figure 2 – Specimens with partly preserved tube-like structures from the Upper Silurian deposits of Germany, specimen UB no. 532 (after Müller et al., 1974): **A**, rounded structure coated with a soft connective tissue; **B**, cap of the soft connective tissue. Scale bar = 0.1 mm.

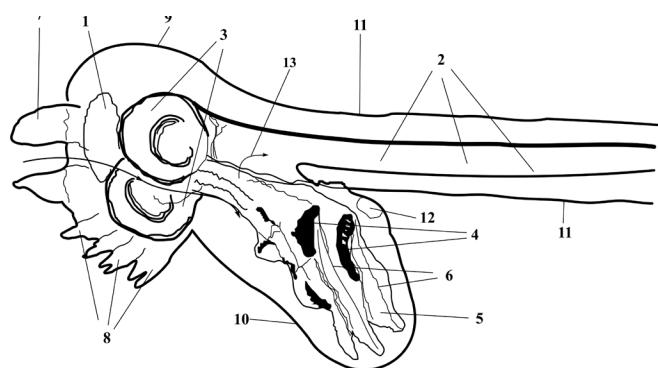


Figure 3 – Interpretative scheme of head region of specimen 5, RMS GY 1992.41.1, Granton, Scotland from Aldridge et al. (1993): **1**, mouth; **2**, putative food canal (gut); **3**, H skeletal elements; **4**, tooth elements; **5**, soft muscular lobe; **6**, muscular fibers; **7**, tentacles (tactile, sensitive, and for driving food items); **8**, head lobes; **9**, head boundary; **10**, boundary of food sac; **11**, wall of body; **12**, putative water outflow opening; **13**, gut entry opening.

tooth elements are attached (Fig. 3). In our opinion, these tooth elements with the help of the muscular lobe were connected with each other and with the H skeletal attaching elements. Most likely the same muscular fibres governed the position and sizes of the pharynx food sac. The soft food sac appeared to be able to extend and to take big volumes of food. When the pharynx sac was filled with water together with the food particles it stretched and expanded. Then when the muscles contracted the sac may pull up to the head and shrink.

The outer and inner morphology of the head part of euconodont animals suggests that originally the food together with water entered the pharynx through the slit-like mouth located between the H attaching elements. The food together with water with the help of tentacles and cephalic lobes was sucked up into the sac-like formation (food sac). Then it arrived onto the "sieve" of S elements, which performed the intricate movements in the food sac. With their help the fine food particles were filtered and moved towards the P elements where they were pressed to form a food clot necessary for further movement along the gut channel with the help of muscles. The water, possibly, may leave the food sac through the paired holes located on the animal sides.

CONCLUSIONS

It has been established that the H attaching and tooth elements were in the food sac located on the outer ventral side of the euconodont animal head. It was also suggested that in the sac the food particles were filtrated and excess water was removed. Data obtained on the structure and functioning of mouth apparatuses governed by the H attaching elements make possible a new interpretation of the behavior and feeding habits of euconodont animals. Some groups of euconodonts, most likely, adapted themselves to the benthic dwelling near the bottom substratum, in the places of the greatest concentration of organic material suitable for filtration. Such organ as the pharynx food sac appeared to be necessary for their adaptation to the environment. The euconodont animals were, probably, the swimming filtrators and dwelled in the water benthic layer that is indirectly supported by the data on the euconodont morphology. Their head division occupies a rather big part of the trunk – about 18 %, whereas in the predators, for example, in protoconodonts (*Chaetognatha*) the length of the head division is not more than 5–8 % of the whole body (Kassatkina & Stolyarova, 2010).

ACKNOWLEDGEMENTS

We thank Mrs. V.A. Piskunova for the linguistic improvement for the manuscript, Mrs. L.Y. Smirnova for the making of the computer graphics and Prof. Y.D. Zakharov for his kind review and helpful comments and suggestions.

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Obituary

GLORIA PASSERI 1950–2017

Gloria was born in Umbertide, a small town in central Italy, on the 10th March 1950.

When she was a teenager she started travelling daily to Perugia to attend the city's scientific high school. By coincidence, many years later she moved into a home directly overlooking her high school building, and she used to point out from her bedroom window "that was my class!". Gloria's passion for science was cultivated during her university years. She graduated in Natural Science at the University of Perugia in July 1974 and was awarded a 2-year research and teaching fellowship in Perugia that same year.

Gloria's first research projects involved studying and comparing evaporites of Triassic (Anidriti di Burano Formation) and Miocene age (Gessoso-Solfifera Formation). From the beginning of her scientific career Gloria felt the need to interact and exchange views with the international community. She participated to several national and international conferences dedicated to evaporites and in 1985 she organized an international short course on evaporites in Perugia, held by a colleague, C.B. Schreiber from the Department of Geology, Queens College New York. Experience gathered over many years of thin-section analyses on evaporites allowed Gloria and her co-authors to publish in 1985 a paper which is still today used as a manual for sulphate evaporites classification.

In parallel with the study of evaporites, Gloria started working on sedimentology and carbonate environments, a traditional focus of Perugia University's Geology department. Her first papers concerned sedimentary analyses of Triassic carbonate platforms outcropping in the Apuan Alps Metamorphic Complex (the Grezzoni Formation). This platform represented the margin of the evaporitic basin she was studying.

In subsequent years Gloria developed an even stronger interest in Triassic carbonate platforms. A study of Triassic carbonate build ups in Tuscany (the Rhaetavicula contorta Formation), characterized by encrusting organisms typical of low energy, poorly oxygenated, shallow water, widened Gloria's interest to include palaeoecology. Following this research project Gloria became a visiting professor in Erlangen Nurnberg University, Germany in 1983.

In the early 1980s Gloria encountered a stratigraphic dilemma while working in the Northern Apennines. The successions she was studying were barren of ammonites and conodonts but yielded undifferentiated Triassic foraminifers. Gloria was determined to gather as much information as possible and therefore contacted colleagues in Geneva University, Prof. P. Brönnimann and Prof. L. Zaninetti. That was the beginning of a long cooperation regarding Triassic Foraminifera, and also the start of a regular collaboration between geoscientists in Perugia and Geneva which benefitted many others.

During the 1980s Gloria studied and compared Triassic



carbonate platform sedimentary systems in the Alps and Apennines. Gloria and her husband and co-author Leonsevero Passeri (Lelo) studied sections in the Northern, Central and Southern Apennines. Gloria was an avid field geologist and spent a tremendous amount of time in the field throughout her career. She was renowned for her formidable memory of field sections, e.g. recalling the precise location of sedimentary structures 20–30 years later.

Gloria became Associate Professor in 1985. From 1990 onwards Gloria's research was enriched by the fascinating world of modern carbonate platforms. Between 1990 and 1999 Gloria and Lelo spent at least one month per year in the Maldives, Bahamas, Turks & Caicos and Florida. That was a pivotal period in her life. In the Maldives Gloria and Lelo were guests of a resort for a couple of months a year. In exchange for the hospitality they gave scientific talks to guests about marine life and geology of the Maldivian archipelago. Their interest in the Bahamas and Turks & Caicos developed as they compared tidal carbonate platform environments (Bahamas, Turks & Caicos, and Florida) with non-tidal systems (Maldives). This detailed experience studying modern carbonate platform environments transformed Gloria's approach to the fossil record forever. During her "Maldivian period" Gloria published several scientific papers describing living foraminiferal assemblages and a monograph illustrating Maldivian Coral Reefs.

Gloria's research projects in sedimentology, stratigraphy, and biostratigraphy were rooted in the wider context of palaeogeographic reconstruction. Resolution of the Triassic palaeogeography of the Italian peninsula was a strong driving element throughout her career. Initially she published papers



on the palaeogeographic evolution of the Central and Northern Apennines during the Triassic. She later developed a passionate interest in the puzzling but significant geology of the Lagonegro area. We cannot speak of Gloria without remembering the time and effort she spent deciphering the geology and paleogeography of that part of Southern Italy. Lagonegro is a relatively small area in which the Triassic stratigraphy reflects the opening of a Permo-Triassic ocean. The Lagonegro successions have been affected by both the Alpine and later Apennine orogeneses. Gloria worked tirelessly mapping and studying the Lagonegro sections, and also invested lots of effort guiding other Italian and international scientists who worked in this area. She shared her knowledge and uncertainties, organised conferences, and welcomed specialists of all disciplines to contribute. The results of these years of research are presented in papers published between 1998 to 2011.

Besides research, Gloria was also very active in teaching. She taught a variety of subjects including Geography, Sedimentology, Marine Geology, and Regional Geology. Her Regional Geology course was a challenging one for students. She expected detailed understanding of the geological evolution of the whole of Italy, from the Alps to Sicily, and spanning the Permian to Pleistocene. She was a demanding professor but her course was immensely rewarding.

Gloria was a member of the Italian Geological Society (IGS) since 1976. From 2006 she held several active roles, as Coordinator of the “Carbonates Group”, a member of the Italian Commission of Stratigraphy, a member of the IGS council, and in the editorial board of the Italian Journal of Geoscience. From 2009 Gloria was Editor in Chief of “Geological Field Trips”, an international journal she strongly believed in.

Gloria retired in 2010 but in fact she never stopped working. She joined her husband in Cervinia, a ski-resort at the foot of the Cervino/Matterhorn, the most iconic Alpine peak. They both became fascinated with the geology of the Western Alps. Gloria and Lelo joined a group of geologists guided by Prof. G.V. Dal Piaz who were working on the Geological Map of Italy – Matterhorn area. She contributed to their research,

discovering Upper Triassic benthic foraminifers within the Roisan metamorphic dolostones.

Gloria was diagnosed with pancreatic cancer in March 2015. She still maintained her concentration on geology, which became a welcome distraction during treatment. She even maintained her role of Editor in Chief of the “Geological Field Trips” journal and also started collaborating on a new area of the Geological Map of Italy, until she became too weak. She spent the last weeks of her life hand-writing her ideas about the difference between Bahamian carbonate systems dominated by trade winds and Maldivian carbonate systems dominated by monsoons.

Gloria's wide research contributions spanned the disciplines of Sedimentology, Stratigraphy, Biostratigraphy, and Paleogeography. She had studied diverse topics including modern Coral Reefs, evaporites, and metamorphism of the Western Alps, however, she never forgot her “Triassic origin”. On the wall of her University office she had a slab of Ladinian limestone mounted on a plaque, with a quote from her friend and colleague Prof. P. Mietto: “Good things in life are immoral, illegal....or Triassic!”.

Besides being an accomplished geologist, Gloria was a very generous woman and an outstanding cook. She enjoyed combining friends (many of them geologists) and good food. She was grateful to have spent her life studying the natural world. She selected this quote (from Charles Darwin, 1836) to summarise her view of life:

“We feel surprise when travellers tell us of the vast dimensions of the Pyramids and other great ruins, but how utterly insignificant are the greatest of these, when compared to these mountains of stone accumulated by the agency of various minute and tender animals! This is a wonder which does not at first strike the eye of the body, but, after reflection, the eye of reason.”



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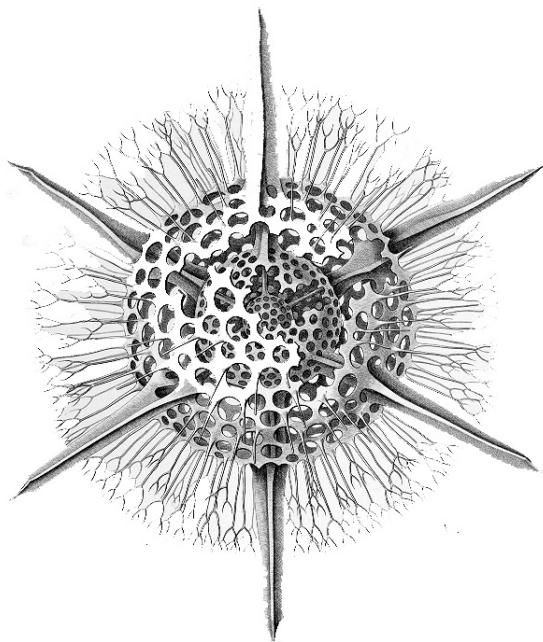
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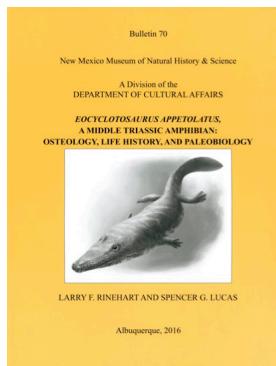
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Publication Announcements

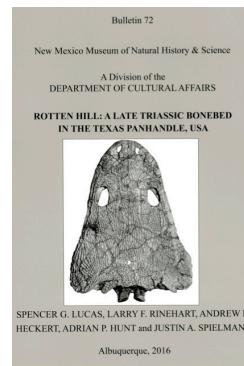
***Eocyclotosaurus appetolatus*, a Middle Triassic amphibian: Osteology, life history, and paleobiology by L. F. Rinehart and S. G. Lucas. New Mexico Museum of Natural History and Science, Bulletin 70: 1-118. 2016.**

This 97-page volume presents a complete analysis of the taphonomy, composition and paleobiology of a Late Triassic bonebed, including a large population sample of the temnospondyl amphibian *Koskinonodon*. If you are interested in ordering Bulletin 70, it costs \$20 and you can contact Beth Ricker, Store Manager for the NMMNH&S, at beth@naturalhistoryfoundation.org to place orders.



Rotten Hill: A Late Triassic bonebed in the Texas Panhandle, USA by S. G. Lucas, L. F. Rinehart, A. B. Heckert, A. P. Hunt and J. A. Spielmann. New Mexico Museum of Natural History and Science, Bulletin 72: 1-97. 2016.

This 118-page volume presents a complete osteology and paleobiological analysis of a large population sample of the Triassic temnospondyl amphibian *Eocyclotosaurus* from a bonebed in northern New Mexico. If you are interested in ordering Bulletin 72, it costs \$20 and you can contact Beth Ricker, Store Manager for the NMMNH&S, at beth@naturalhistoryfoundation.org to place orders.



Abstract—*Eocyclotosaurus appetolatus* is a recently named Middle Triassic (Perovkan: early Anisian) amphibian (Temnospondyli: Capitosauroidea: Cyclotosauridae) from the Moenkopi Formation of New Mexico. Here, we study a population of these animals from a single locality, the Tecolotito bonebed in San Miguel County, north-central New Mexico. This sample provides the first nearly complete postcranial skeletal material of *E. appetolatus* to be described and illustrated. This disarticulated, attritional assemblage reflects an all-adult population comprising animals in the 1.2 to 2.5 meter length range, and averaging 1.7 meters. The body proportions, and skull and jaw morphology of *E. appetolatus* was alligator-like, implying that they filled an ecological niche similar to that of some modern crocodilians. Our functional morphology study shows that they were generalist feeders; they probably took fish in the lakes and rivers that they inhabited and small- to medium-sized prey along the shorelines. Data indicate that juveniles grew quickly to sexual maturity in three to four years, after which their growth rate continuously slowed until death. Survivorship analysis indicates that mortality was probably high in the juveniles, was very low in mid-life, and continuously increased in old age. Very few individuals reached the ultimate age of perhaps 30 to 40 years. Based on limb bone allometry and stress-strength analysis, juveniles probably had significant terrestrial capability, allowing dispersal of the species, whereas the adults likely formed breeding populations that became increasingly water-bound. Well-preserved otic regions in some skulls allowed us to determine that impedance matching in the middle ear was excellent, but the high mass of the stapes and large area of the tympanum may have limited hearing to the low end of the audio spectrum, probably extending into the infrasound region.

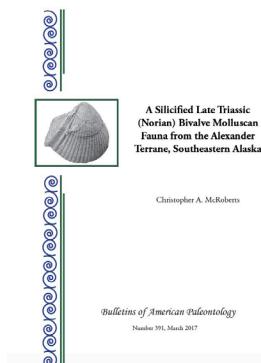
Abstract—The Rotten Hill bonebed is a Late Triassic fossil locality in the Texas Panhandle discovered by Floyd V. Studer in 1926, and collected primarily by WPA-funded excavations during the late 1930s and early 1940s. This locality is in the lower part of the Tecovas Formation (Chinle Group) and is of Adamanian (late Carnian) age. Forensic taphonomic analysis indicates it is a mass death assemblage that was hydraulically concentrated. The Rotten Hill bonebed is a low diversity multitaxic and monodominant bonebed; the vast majority of the bones are of the metoposaurid *Koskinonodon perfectum*.

It closely resembles other Chinle Group metoposaurid-dominated bonebeds that suggest aggregation of a group of metoposaurids, followed by catastrophic mortality, complete disarticulation and disassociation of the skeletons, culminated by rapid transport and burial. Fossil taxa from the Rotten Hill bonebed are the unionoidan bivalve *Plesioelliptio* sp., the coprolite ichnogenera *Alacocopros*, *Eucoprus* and *Heteropolacopros*; various fishes known from ichthyoliths; a rhynchosaur; a sphenodontid; the archosauriform *Vancleavea*; the trilophosaurs *Trilophosaurus* and *Spinosuchus*; the phytosaur *Smilosuchus*; a probable poposaurid (cf. *Postosuchus*), the aetosaurs *Desmatosuchus* and cf. *Stagonolepis*; a shuvosaurid; and the metoposaurids *Apachesaurus gregorii* and *K. perfectum*. *K. perfectum* is represented by numerous skulls, lower jaws, vertebrae, girdle and limb bones representing a minimum number of 68 individuals based on recovered interclavicles. We describe the osteology and variation of these bones, which allows us to present a revised diagnosis of *Koskinonodon* that employs new postcranial characters to differentiate it from

other metoposaurid genera. We also compiled and analyzed a morphometric database of the Rotten Hill *Koskinonodon* to conclude that bone growth varied from isometry to allometry and suggests a loss in limb robustness during ontogeny that likely indicates a transition from a partly terrestrial to a more aquatic lifestyle. Probability plotting to test for size groups in the Rotten Hill *Koskinonodon* identifies 10-11 groups that we interpret as yearly age cohorts and use to plot a growth curve. This indicates indeterminate growth in *K. perfectum* and that the Rotten Hill sample represents a population of breeding adults, some of which survived at least 10-11 years after reaching sexual maturity. This is a growth curve also characteristic of some living salamanders. We infer that *K. perfectum* employed some mechanism, such as disparate feeding strategies, or another ecological factor that enforced separation of adults and juveniles, to reduce predation on juveniles by conspecifics and minimize the competition for food resources between the ontogenetic stages.

A silicified Late Triassic (Norian) bivalve molluscan fauna from the Alexander terrane, southeastern Alaska by C. A. McRoberts. Bulletins of American Paleontology, 391: 1-108. 2017.

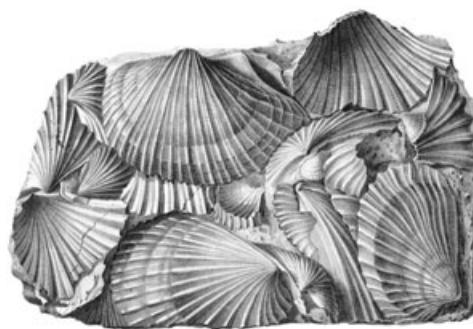
This 108-page volume presents a taxonomic description and taphonomic and paleoecologic analyses of a well-preserved silicified Late Triassic bivalve fauna from the Alexander terrane of southeastern Alaska. If you are interested in ordering Bulletin 391, it costs \$40 and may be purchased through the Publications Office of the Paleontological Research Institution at publications@museumoftheearth.org.



Abstract—A taxonomically rich and ecologically diverse silicified bivalve-dominated fauna is critically examined from the upper Norian Hound Island Volcanics of Kuiu Island, southeast Alaska. More than 1000 silicified bivalve specimens isolated by acid digestion of carbonate blocks yield a wealth of taphonomic, paleoecologic, paleogeographic, and taxonomic information. Petrographic analyses and scanning electron microscopy reveal specimens are preserved with silicification fabrics of quartzine-lutecite bladed masses and spherulitic chalcedony conserving fine details of original skeleton by both selective and complete replacement. Taphonomic indices indicate the fauna represents a parautochthonous storm condensed assemblage of a shallow subtidal and relatively soft-bottom carbonate setting. Bivalves, ammonoids, conodonts, and the hydrozoan *Heterastridium* largely suggest a late Norian (*Gnomohalorites cordilleranus*

ammonoid zone) age for the fauna.

The assemblage is taxonomically rich, containing 31 recognizable bivalve species (or equivalent taxa in open nomenclature) distributed amongst 11 orders, 17 superfamilies, 24 families, and 30 genera. Of the 31 taxa, 12 are incompletely known and left in open nomenclature and the following 11 are new: *Palaeonucula mufflei* n. sp., *Pinna keekwaaensis* n. sp., *Plagiostoma scallanae* n. sp., *Entolium alaskanum* n. sp., *Filamusium walleri* n. sp., *Harpax articulatum* n. sp., *Erugonia boydi* n. sp., *Minetrigonia newtonae* n. sp., *Myophorrigonia parva* n. sp., *Palaeopharar orchardi* n. sp., and *Tancredia norica* n. sp. The Erugoniidae n. fam. is proposed for smooth shelled trigonioids with trigoniid grade dentition but lacking marginal carina. The fine-scale preservation and large sample size revealed previously unrecognized morphologic details permitting revision of two bivalve families (Palaeopharidae Marwick, 1953 and Palaeocarditidae Chavan, 1969) and one genus (*Septocardia* Hall & Whitfield, 1877). The most diverse group is the Pteriomorphia with 16 species (51.6% of species and 69% of individuals), followed by the Heteroconchia with 12 species (38.7% of species and 28% of individuals) and Protobranchia with three species (9.7% of species and 2.8% of individuals). The assemblage is dominated by the pterioid *Cassianella cordillerana* McRoberts in McRoberts & Blodgett, 2002, which, taken with other declining suspension-feeding species, accounts for 43.9% of individuals. Shallow infaunal burrowers comprise the second most common trophic group (27.6% of individuals), followed by epifaunal cementing forms (15.5% of individuals). The assemblage is dominated by endemic taxa, yet several species are known from other Norian faunas of the South American Cordillera and, to a lesser extent, North American terranes (Wrangell, Nixon Fork, and Wallowa). The biogeographic relationship with the Norian molluscan faunas of South America supports a southerly paleolatitude for the Alexander terrane with some biogeographic connection with other tropical terranes of eastern Panthalassa.



TRIASSIC LITERATURE – 2015

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This compilation is based on the contents of over 500 serial titles and other publications. It is a continuation of the New Triassic Literature contributions that appeared in Albertiana up to April 2016 (43: 33–65), and includes items dated 2015, together with some pre-2015 titles that were not included in earlier compilations.

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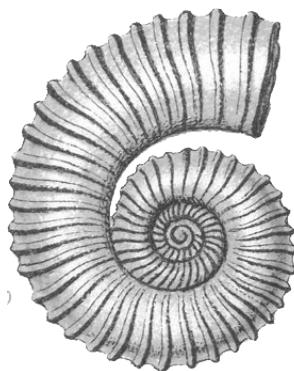
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FIRST WORKSHOP ON THE CARNIAN PLUVIAL EPISODE (LATE TRIASSIC): A REPORT

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Abstract – In the late early Carnian (Late Triassic) an important, but yet poorly understood, phase of global climate change occurred. This is roughly coincident with a time of major biological turnover. Many important groups diversified or spread during the Carnian, e.g., dinosaurs, calcareous nannofossils, and modern conifers. Abrupt environmental changes are observed in the geological record worldwide during this interval. These phenomena were roughly synchronous with a carbon-cycle perturbation and could be linked to Large Igneous Province volcanism. Palaeoclimatologists, stratigraphers, geochemists, carbonate sedimentologists, palaeontologists, and modellers met at the Hanse-Wissenschaftskolleg, Institute for Advanced Study in Delmenhorst (Germany), to discuss this intriguing episode of climate change, and the associated effects on the environments and biota. The main aims of the workshop was to summarise the current understanding of the Carnian Pluvial Episode, and discuss future research directions.



Figure 1 – Workshop participants.

INTRODUCTION

Isotopic records suggest a global carbon cycle perturbation during the Carnian (Late Triassic). This is specifically revealed by a sharp negative carbon-isotope excursion in terrestrial and marine organic matter, and in marine carbonate carbon (Dal Corso et al., 2012, 2015; Mueller et al., 2016a, 2016b; Sun et al., 2016; Miller et al., 2017). In the same time interval, oxygen-isotope analyses of conodont apatite indicate an increase in the sea-surface temperatures (Hornung et al., 2007; Rigo & Joachimski 2010; Trotter et al., 2015; Sun et al., 2016). Carbon cycle disruption and global warming were coincident with complex environmental changes and biotic turnover (e.g., Dal Corso et al., 2015; Sun et al., 2017). This “most distinctive climate change within the Triassic” (Preto et al., 2010), which in the published literature is known by several different names (Ruffell et al., 2015) and here is named the “Carnian Pluvial Episode” (CPE; see discussion below), is recorded in stratigraphic sections worldwide and is often described as a shift from arid to more humid conditions (Simms & Ruffell, 1989). The onset of the CPE is very well constrained in many stratigraphic sections (e.g., in the Southern Alps of Italy, Northern Calcareous Alps of Austria, Transdanubian Range of Hungary, and in the Nanpanjiang Basin of the South China block) and is placed at the Julian 1 – Julian 2 boundary (i.e., *Trachyceras* – *Astrotrachyceras austriacum* ammonoid zones boundary; sensu Gallet et al. 1994). In the marine sedimentary basins of the Tethys realm, the sudden arrival of huge amounts of siliciclastic material, the establishment of anoxic conditions in the restricted basins, and an abrupt change of carbonate factories mark the beginning of the climate change (e.g., Simms and Ruffell 1989; Hornung et al., 2007a,b; Rigo et al., 2007; Preto et al., 2010; Dal Corso et al., 2015; Gattolin et al., 2015; Mueller et al., 2016; Sun et al., 2016; Shi et al., 2017). On the continents and at different latitudes, palaeobotanical evidence shows a shift of floral associations towards elements more adapted to humid conditions (e.g., Roghi et al., 2010; Preto et al., 2010; Mueller

et al., 2016b), and increased resin production (Gianolla et al., 1998; Roghi et al., 2006; Schmidt et al., 2012). This climatic perturbation is also closely associated with biological turnover among many marine groups. One of the most important turnovers in the Triassic ammonoid fauna, with the extinction of the Trachiceratinae and the radiation of the Tropitidae, occurred during the CPE (Balini et al., 2010). Conodonts went through a major crisis (Rigo et al., 2007; Martínez-Pérez et al., 2014). Other groups, like bryozoans and crinoids, show a sharp decline during the Carnian (Simms and Ruffell 1989). On land, key herbivorous groups such as dicynodonts and rhynchosaurs, which had represented 50% or more of faunas, disappeared or dwindled, and their places were taken by dinosaurs, which had been around from the Early-Middle Triassic, but at low abundance and low diversity. Most intriguingly, the CPE seems to be linked to major evolutionary innovations. For example, it acted as the trigger for the diversification of the dinosaurs and the transformation of terrestrial ecosystems for the remainder of the Mesozoic. The beginning of abundant and continuous pelagic calcification is placed during the Carnian (Bown, 1998; Erba, 2004; Preto et al., 2012). The origination and radiation of bona fide modern conifer families and bennettitaleans falls also within this interval (e.g., Willis and McElwain, 2002; Kustatscher et al., 2018, and references therein).

The carbon-cycle disruption, climate change, and biological turnover are roughly coincident with the eruption of the Wrangellia Large Igneous Province (LIP), whose basalts today outcrop in British Columbia, Yukon, and Alaska (Furin et al., 2006; Greene et al., 2010; Dal Corso et al., 2012). Biostratigraphic, radioisotopic, and geochemical data suggest that Wrangellia volcanic activity had a maximum age spanning from the latest Ladinian to the early late Carnian (Tuvalian) (Greene et al., 2010; Xu et al., 2014). Thus, Wrangellia LIP activity, as with other LIPs in the geological record, could have triggered the abrupt phenomena observed during the Carnian. The CPE was also coincident with other substantial volcanic episodes, including the Huglu-Pindos

series in Greece, the Kara Dere basalts in Turkey and the Taimyr Complex in Russia, all or some of which could have enhanced the effects of Wrangellia (Muller et al., 2016; Sun et al., 2016).

In the last years, the interest of the scientific community in the “mysterious” (Ogg, 2015) CPE has increased. Many papers have been published, significantly broadening our knowledge on the phenomena that occurred during the Carnian. Some authors suggested the CPE could be an analogue for today’s climate change, warming, and ocean acidification (e.g., Dal Corso et al., 2012). The study of the CPE is a fast-growing field and, despite the advances of the last years, many aspects of this fascinating time period are still poorly understood. Given the importance of the topic and the knowledge gaps, a first workshop completely focused on the CPE has been organized in 2017 with the aims of outlining the state-of-the-art, understanding the open problems, and identifying future research priorities.

THE WORKSHOP

The workshop on “The Carnian Pluvial Episode (Late Triassic): Climate Change and Evolutionary Innovations” was organized by Jacopo Dal Corso and Agostino Merico and took place on the 16th–17th of May, 2017 at the Hanse-Wissenschaftskolleg (HWK), Institute for Advanced Study in Delmenhorst (Germany). A total of 27 scientists from Europe, USA, and China participated in the workshop.

The workshop was structured around two days of oral presentations and discussions, and a final round-table. Invited speakers, who are the authors of this report, gave oral presentations. The talks covered different facets of the CPE, from stratigraphic problems (bio-chronostratigraphic framework, magnetostratigraphy, chemostratigraphy) to siliciclastic and carbonate sedimentology, and palaeontology (marine and terrestrial). All talks raised interesting discussions that also continued during the coffee breaks, the lunches, and the social dinner in the wonderful venue of the HWK.

After the welcome from Doris Meyerdierks, research manager for the area “Earth” at the HWK, Jacopo Dal Corso gave a brief introduction to the CPE, summarizing its main characteristics. He also discussed the carbon-isotope records across the CPE, their correlation, and the links to Wrangellia LIP volcanism. A list of the talks with a brief description of the content follows.

The History and Palaeogeography of the Carnian Humid Episode

Alastair Ruffell (*Queen’s University, Belfast, UK*) and Michael J. Simms (*Ulster Museum, UK*)

The evolution of theories surrounding palaeoenvironmental changes during the Carnian roughly mirrors the geographic spread (globally) of the broad idea of increased humidity during this time. The initial focus of the theory was the Germanic Keuper basins (Germany, subsurface Low Countries, North Sea, England, Simms & Ruffell, 1989), subsequently extending

to the Italian and Austrian Alps (Roghi, 2004), thence to Iberia and the Eastern Seaboard of North America (Arche & Gomez-Lopez, 2014). Subsequent publications showed evidence of this change in depositional systems in the Himalayas, China, Japan and Svalbard. A recent review by the authors (Ruffell et al., 2016) indicated that the Carnian of southern USA, parts of S America (Argentina), offshore NW Australia and parts of Antarctica may contain evidence of this palaeoenvironmental change. It may be that this humid episode was at least three phases, as evidenced by discrete clastic intervals in successions of the Austrian Alps. Examination of thick deep water successions in the Palaeotethys may resolve this: some of the terrestrial Keuper successions do show more than one grey sandstone interval within the red, evaporitic mudstones. Research on the Southern Hemisphere successions, especially South America, where the link to dinosaur evolution could be resolved, should be a future target for Carnian workers.

Tethyan Record of the Carnian Pluvial Episode: The Bio-Chronostratigraphic Framework

Piero Gianolla (*University of Ferrara, Italy*)

The marine and marginal marine sections of Western Tethys records in detail the timing and the effect of the Carnian climate destabilization. The sharp negative carbon-isotope excursion (CIE), which coincides with the onset of CPE, is well defined in the Dolomites (Italy), Northern Calcareous Alps (Austria), and Transdanubian Range (Hungary), and is bio-stratigraphic constrained at the Aonoides/Austriacum boundary interval. The CIE is also coincident with the abrupt demise of high-relief microbial carbonate factories. Sequence stratigraphic analysis of sections from the Dolomites shows that a significant sea level fall followed the onset of the CPE (Gattolin et al., 2015) with a delay not yet resolvable in terms of time. This sea-level fall was probably driven by the formation of vast endorheic basins as a consequence of increasing precipitations. The excellent biostratigraphic control permits to date the different phases of the perturbation, two in the Julian and two in the Tuvalian. The entire CPE is constrained between the Aonoides/Austriacum boundary and the Subbulatus Zone (Tuvalian), but the definition of its absolute duration remains open. Only one radiometric age from Lagonegro Basin is available for this time interval (Furin et al., 2006), and it sets the upper boundary of CPE in Western Tethys at 230.91 ± 0.33 Ma. Cyclostratigraphic analysis of the marine succession of the South China Block (China) and of the continental succession of Devon (UK) suggests the CPE lasted for about 1.2 Myrs (Zhang et al., 2015; Miller et al., 2017).

Cycle-calibrated magnetostratigraphy of the Carnian and implications for the Global Coincidence of the Carnian Humid Episode

James G. Ogg and Yang Zhang (*Purdue University, USA*)

A cycle-tuned magnetic polarity scale spanning ~2.4 myr was established featured by a relatively long (~1.3 myr) reversed-polarity zone with brief normal-polarity intervals that is consistent with the significant reversed-dominated interval striding the boundary of T. aonoides and A. austriacum ammonoid zones

(late Early Carnian) from three Carnian sections in South China (Zhang et al., 2015). The distinctive upward change from a dominance by reversed to normal polarity just after the onset of clastic-rich influx over the Yangtze Platform is also recorded in magnetostratigraphy of the lower Schilfsandstein in the Germanic Basin and verified by our further sampling in three new Carnian sections in South China and three boreholes in the Germanic Basin. Therefore, we conclude that the termination of the Yangtze Platform is coeval with the Carnian Pluvial Event. The Carnian time scale from South China and our initial work from the Germanic Basin support the “short-Tuvalian/long-Norian” age model of the Late Triassic, implying that the base of the cycle-tuned polarity pattern from the Newark Supergroup of eastern North America lies in Tuvalian.

The Schilfsandstein in the North German Basin: Stratigraphy, facies, drainage systems and controls.

Matthias Franz (*University of Göttingen, Germany*)

Basin-wide re-evaluation of the Schilfsandstein, commonly considered the type-example of the “Carnian Pluvial Episode”, revealed repeated transgressions from Tethyan waters into the Central European Basin (CEB) followed by progradations of fluvio-deltaic environments. The sea-level fluctuations recognised in the CEB are well correlated with contemporaneous NW Tethyan sea-level fluctuations suggesting an eustatic control (Franz et al., 2014). Results of high-resolution subsurface facies mapping and provenance studies point to an endo-rheic drainage pattern of routing systems tributating sediments from surrounding source areas towards the basin centre. This is in strong contrast to the exo-rheic drainage pattern and export of detrital sediment to the Tethyan realm as proposed in earlier works (e.g., Wurster, 1964; Beutler & Häusser, 1984). The very low maturity of the Schilfsandstein, petrographic studies revealed lithic arkoses and feldspathic litharenites, and presence of mature aridisols are not in agreement with a substantial shift towards a more humid climate.

Waxing and waning of carbonate production during the Carnian Pluvial Episode: a role for ocean acidification?

Nereo Preto (*University of Padova, Italy*)

Anisian, Ladinian and lower Carnian carbonate platforms of the Dolomites are mainly microbial, but turn to carbonate ramps with skeletal grains and ooids after the main isotopic excursion of the CPE. Roughly at the same time, calcareous nannofossils become abundant in open marine environments. Microbial carbonate production would return dominant by the Norian, while calcareous nannofossils remained common in hemipelagic periplatform successions until the end of the Triassic. This sequence of events may be explained by ocean acidification at the CPE, but the prolonged duration of the carbonate factory turnover seems to exclude this explanation. It is proposed however that multiple episodes of carbon cycle perturbation may compose the CPE, and it is suggested that the occurrence of calcareous nannofossils and non-microbial carbonate platforms at the CPE should be tested globally.

The demise of the sponge mounds along the northwestern margin of the Yangtze Block, South China: links to the Carnian Pluvial Phase.

Zhiqiang Shi (*Chengdu University of Technology, China*)

Carnian marine sections in the NW margin of Upper Yangtze Region of China show a lithological change from oolitic grey limestone into a sponge-mound limestone to black-grey and dark grey siltstone and sandy shale. Conodonts and ammonoids give a Tuvalian 1 age for the lower part of the black-grey shale above the siliceous sponge mounds. The deposition of the shale may be related to the onset of the Carnian Pluvial Phase. The sponge mounds’ demise in the NW Upper Yangtze Region could have been caused by the combined effect of fresh water input linked to the Carnian Pluvial Phase and a relative sea-level change caused by local tectonism during the Indosinian orogeny.

The Carnian pluvial party event for plants

Evelyn Kustatscher (*Museum of Nature South Tyrol,
Bozen/Bolzano, Italy & Department für Geo- und
Umweltwissenschaften, Paläontologie und Geobiologie,
Ludwig-Maximilians-Universität, München, Germany*)

The Carnian successions yield one of the most abundant and diverse floras of the Triassic. Typical hygrophytic elements such as ferns and sphenophytes, are often the most abundant groups in the flora, bennettitaleans become more and more abundant in the fossil record. Paralic and lagoonal environments permit an exceptional preservation of the plant fossils as well as findings of amber, megaspores and charcoal associated with the macroremains. Conifer remains become more abundant in allochthonous assemblages of marine sediments and reflect a high transport bias. Several families and orders make their first appearance or start at least their first radiation during the Carnian. This includes bennettitaleans, modern fern (e.g., Dipteridaceae) and conifer families (Pinaceae, Araucariaceae, Cheirolepidiaceae) as well as putative angiosperms (e.g., Furcula, Sanmiguelia) although angiosperm-like pollen have been described already from Middle Triassic successions (Kustatscher et al., 2018).

Amber inclusions in deep time: arthropods, plant remains and microorganisms preserved during the Carnian Pluvial Episode

Alexander R. Schmidt (*University of Göttingen, Germany*)

The oldest biological inclusions found preserved in amber come from the Carnian. The amber containing these preserved organisms is found as thousands of small (2-6 mm) droplets from a well-preserved palaeosol in the Italian Dolomites. The amber contains a diverse microcosm of organisms: arthropods, plant remains, microorganisms including bacteria, fungi, algae, ciliates, and testate amoebae together with spores and pollen grains (Schmidt et al., 2006, 2012). Most of tiny arthropods are diverse representatives of the Triasacaroidea, a new superfamily of highly specialized, four-legged, phytophagous mites (Sidorchuk et al., 2015).

Palynological indication of upper Carnian hygrophytic associations in European and extra-European Areas

Guido Roghi (*Institute of Geosciences and Earth Resources, IGG - CNR, Italy*)

Palynological study of the CPE reveals humid pulses characterized by qualitative and quantitative increase of hygrophytic associations recognized not only in Tethysian successions but also in many successions of the Laurasia and Gondwana. This global palynological change is thus interpreted as having climatic origin. Moreover, humid climatic pulses are evidenced by southwards shifting of the hygrophytic associations during the CPE, when palaeoenvironmental conditions became favourable for its proliferation in the Tethys realm. The occurrence of four palynological assemblages within the Carnian represents a potential tool for worldwide Upper Triassic correlation.

Testing today's resin-rich plants to try to understand Triassic amber deposits

Leyla J. Seyfullah (*University of Göttingen, Germany*)

Although trace amounts of amber are reported from the Carboniferous onwards, amber in significant amounts in the fossil record appears for the first time during the CPE. The cause(s) of these resin outpourings are not yet known, nor whether they are linked. Using stress tests on today's modern conifers and hunting for specific stress biomarkers should help us unlock the reason(s) for amber deposits during the CPE.

Late Triassic and origin of dinosaurs

Michael J. Benton (*University of Bristol, UK*)

The origin of the dinosaurs marks a major transformation in terrestrial ecosystems, a switch from the rather slow-moving, sprawling tetrapods of the Palaeozoic, to upright, faster-moving, and even warm-blooded tetrapods. Not only did dinosaurs take over and expand rapidly in Late Triassic ecosystems, but all other modern vertebrates appeared about this time, including frogs, lizards, crocodilians, turtles, and even mammals. The dinosaurs had originated in the Early to Middle Triassic, as part of the rebuilding of ecosystems following the Permian-Triassic mass extinction, 252 Ma, but they existed at low abundance and low diversity for 20 myr before diversifying rather explosively after the CPE, as originally suggested by Benton (1983).

Multi-proxy constraints to dinosaur first dispersal

Massimo Bernardi (*MUSE – Science Museum, Trento, Italy; University of Bristol, UK*)

Until recently, it had proved difficult to exactly correlate the expansion of dinosaurs with the CPE, but new data from the extremely well dated rock sequences of the Southern Alps (Italy) allowed to identify a significant mid Carnian shift in the composition of archosaur ichnoassociations. A review of all known Late Triassic archosaur body and trace fossil evidence suggests that the first dinosaur dispersal in the eastern Pangaea is synchronous with the CPE and that

dinosaurs became dominant in the ecosystems only after this perturbation (Bernardi et al., submitted). The proposed model is in agreement with a gradual process of ecological replacement of crurotarsans and other tetrapods by early dinosaurs (reviewed in Brusatte et al., 2010), but highlights the importance of a specific, relatively brief, interval in the mid Carnian as buster in the early evolution of dinosaurs (Bernardi et al., submitted).

Mathematical modelling of geological events: challenges and opportunities

Agostino Merico (*Leibniz Centre for Tropical Marine Research, Bremen, Germany*)

A number of mathematical models of varying complexity have been developed in the last decades to study the interaction of complex Earth Systems processes also over geological time scales. All these models provide opportunities and pose challenges. Four of these models have been briefly reviewed: (1) the Long-term Ocean-atmosphere-Sediment Carbon cycle Reservoir model (LOSCAR) by Richard Zeebe, (2) the Grid Enabled Integrated Earth system model (GENIE), by Andrew Price and co-workers and the cGENIE version by Andy Ridgwell, (3) the Global Environmental and Ecological Simulation of Interactive Systems (GENESIS), by David Pollard and co-workers, and (4) a Simple Box model by Merico and co-workers. Agostino Merico argued that intermediate- or high-complexity models (such as GENIE and GENESIS) are difficult to use and maintain, take very long to run (months to years for simulating processes over centennial to thousands of years), generate results that can be huge in size (requires energy and space to store data), but have nonetheless, helped to greatly improve our understanding of the physical processes and feedbacks in the climate system. In contrast, simple models (such as LOSCAR and other box models) are easy to use and maintain, run over short times (for example, a 3-million-year run can take less than 20 hours), generate results that are easily to manage and store, but they consider only a very crude representation of the physical processes.

Evolutionary aspects of pelagic calcification

Sönke Hohn (*Leibniz Centre for Tropical Marine Research, Bremen, Germany*)

The CPE marks the first massive appearance of calcareous nannoplankton that became extremely abundant during the Cretaceous and is still important carbonate producers in today's ocean. Sönke Hohn reviewed the potential reasons why pelagic, intracellular calcification evolved and persisted. He concluded that intracellular calcification represents an energetically cheap mechanism to alleviate calcium cell poisoning (Müller et al., 2015). The same cellular requirements, i.e. to get rid of excess intracellular calcium, cause an indirect predator poisoning when calcified cells are ingested (Harvey et al., 2015).

ROUND TABLE

In the afternoon of the last day of the workshop we had a roundtable discussion. We examined the different topics

presented by the speakers during the workshop, with particular emphasis on open problems. The research around the CPE is still relatively “young”. Our understanding of the phenomena that occurred during this time interval is still fragmentary and very limited. Many fundamental questions remain open and need to be addressed. We outlined priorities and future directions.

1) Nomenclature. One name used by the entire scientific community is indeed necessary for the Carnian episode, in order to make the literature consistent, to ensure clarity among authors, and to make readers immediately aware of the subject. The published literature shows authors have used many different names for the Carnian Pluvial Episode. It has been called Raibl Event and Reingraben Turnover (Reingrabener Wende; e.g., Schlager and Scöllnberger, 1974; Hornung and Brendner, 2005), Carnian Pluvial Episode (e.g., Simms and Ruffell, 1989), Carnian Pluvial Event (e.g., Visscher et al., 1994; Roghi et al., 2004; Franz et al., 2014; Dal Corso et al., 2015), Carnian Wet Intermezzo (Kozur and Bachmann, 2010), Carnian Humid Episode (e.g., Ruffell et al., 2015; Sun et al., 2016), Carnian Pluvial Phase (e.g., Mueller et al., 2016; Shi et al., 2016), and Mid-Carnian Event (Ogg, 2015). The majority of these names emphasize one aspect of the CPE, i.e. the increase in precipitation. We now know that the CPE wasn't a constant and homogeneous period of higher precipitation. Palynological and sedimentological evidence shows distinct humid pulses interrupted by arid periods (e.g., Roghi et al., 2010; Stefani et al., 2010; Mueller et al., 2016). Moreover, the CPE is not only a time interval of increased humidity, but also a major and complex carbon-cycle perturbation (Dal Corso et al., 2012, 2015; Mueller et al., 2016a, 2016b; Sun et al., 2016; Miller et al., 2017), a time of global warming (e.g., Trotter et al., 2015; Sun et al., 2016), a widespread platform carbonate precipitation crisis and rise of the CCD (Schlager & Scöllnberger, 1974; Hornung et al., 2007a; Rigo et al., 2007; Dal Corso et al., 2012, 2015; Gattolin et al., 2015), a time of reduced oxygen availability in many marginal basins of the Tethys (Hornung & Brandner, 2005; Keim et al., 2006; Hornung et al., 2007a, 2007b; Wang et al., 2008; Rostasi et al., 2011; Soua, 2014; Dal Corso et al., 2015), an interval of increased resin production that yields the oldest significant amber deposits (Gianolla et al., 1998; Roghi et al., 2006), a time of extinctions (Simms & Ruffell, 1989; Benton 1991) but also a time of incredible evolutionary innovation (Benton, 1983, 1991; Preto et al., 2013), and possibly many other still un-described phenomena. Therefore, emphasizing only one aspect of the CPE, i.e. the increase in humidity, could be reductive. However, the main and the first described characteristic of the CPE that it is quickly and widespread recognisable in many geological settings (from continental to deep-water) and at different latitudes is a sedimentological change indicating increased humid conditions (coarse siliciclastic material, laminated shale, clay minerals, etc.). Hence, the use of “Pluvial” or “Humid” is justified. The term “event” can generate confusion. In stratigraphy, an event is assumed to be a short-lived and sudden change (sedimentological, lithological, palaeontological, or geochemical) that is recognisable in the stratigraphic record and used as a marker (e.g., Einsele et al., 1991). Events are thus typically instantaneous or in the order of few thousands of years. We agreed with Ruffell et al. (2015) that

the brief (approx. 41 Kyrs; Miller et al., 2017) negative carbon-isotope excursion at the onset of the CPE is an “event”. This is followed by a long interval (approx. 1.2 Myrs; Zhang et al., 2016; Miller et al., 2017) of climatic, geochemical, and biotic changes. For these reasons “Episode” or “Phase” should be preferred. The use of “Mid-Carnian Episode” has been discussed during the workshop and put forward as an option. However, no agreement could be reached, the major concern being the use of “middle Carnian”. In the recent literature the Carnian stage is subdivided in two substages, Lower (or Julian) and Upper (or Tuvalian) (Gradstein et al., 2012), hence, from a chronostratigraphic point of view “Mid-Carnian Episode (or Event)” would be misleading.

2) Reference sections. It is necessary to identify reference terrestrial, marginal marine, and deep-sea sections for interdisciplinary studies. Such reference sections should provide information on the effects of the CPE on continents (e.g., palynology, palaeobotany, and vertebrates palaeontology), shallow marine environments (e.g., sea-level changes, platform carbonate production), and oceans (e.g., redox conditions of the water column). Some sort of a “stratotype” and “golden spike” are needed to enable the unambiguous stratigraphic definition of the CPE.

3) Definition of a pre- and post-CPE “normal Carnian”. The early Carnian is described in the literature as a climatically arid interval suddenly interrupted by the CPE. The definition of the precursor climatic and oceanographic conditions, and their variability between different geological settings, is necessary to evaluate the extent and rate of the changes occurring during the CPE. Similarly, a deeper understanding of the precursor marine and terrestrial biological community structure is crucial to define the extinction and origination rates during the CPE.

4) The Structure of the Episode. Sedimentological and palynological records across the CPE in the Tethys realm show the episode is structured into at least 3–4 discrete humid pulses (e.g., Breda et al., 2009; Roghi et al., 2010). Such sedimentological changes are biostratigraphically constrained in the Dolomites and Northern Calcareous Alps (including Lunz) to the Julian1 – Julian2 boundary, within the Julian2, at the Julian–Tuvalian boundary, and ca. at the Tuvalian1 – Tuvalian2 boundary (e.g., Roghi et al., 2010). A continental carbon-isotope record in southwest England shows multiple carbon-cycle perturbations during the CPE (Miller et al., 2017). However, the lack of biostratigraphic constraints makes it difficult to precisely date these carbon-isotope excursions and to correlate them with the marine marginal sections where multiple climatic changes are documented. Carbon-isotope records across the CPE in different geological settings are thus crucial to understand the structure of the episode and to link carbon-cycle perturbations to environmental changes. Moreover, it is important to understand whether the CPE was preceded by any precursor event/episode. Indeed, current dating of the Wrangellia shows that the LIP activity started already at least at the Ladinian–Carnian boundary.

5) Causation. The exact temporal relationships between the emplacement of the Wrangellia LIP and the CPE need to be constrained. New radiometric ages of Wrangellia basalts are necessary to correlate the different phases of the LIP eruption with the CPE. The study of the sedimentary successions below, within and above the Wrangellia basaltic floods in different areas

is required to biostratigraphically constrain the LIP volcanism. This will allow to understand the mechanisms of the climate change and extinction in relation to the magnitude and rate of volcanic gas emissions, as in the case of other similar episodes (e.g., end-Triassic mass extinction and CAMP volcanism). The possible contribution of other known Carnian volcanic centres (in Greece, Turkey, and Russia; Sun et al., 2016) to the carbon-cycle perturbation and climate change, i.e. the age of these volcanic eruptions, extent, and timing, must be assessed.

6) *Sea-level changes.* Substantial mid-Carnian sea-level changes of 3rd-order and higher order are well recognised from many Tethyan and peri-Tethyan localities and resulted in, for example, karstification of Carnian platforms (Dolomites) and flooding of peri-Tethyan lowlands (CEB). The resulting stratal pattern architectures were translated into sequences (e. g. Gianolla et al., 1998; Gattolin et al., 2013). Preliminary correlations based on sequence-stratigraphic arguments suggest circum-Tethyan eustatic cycles and thus, have demonstrated the high potential of linking Tethyan and peri-Tethyan sea-level records (Franz et al., 2014). However, these correlations need to be further justified by improved stratigraphic control on reference sections employing bio-, chemo and magnetostratigraphy. Certainly the most challenging question will be the link of 10⁶-year scale cycles to other mid-Carnian environmental perturbations, such as glacioeustatic sea-level changes or the Wrangellia LIP.

7) *Timescale.* Standardized conodont taxonomy, and its calibration to ammonoid biostratigraphy, is necessary to correlate the CPE through different geological settings. More magnetostratigraphic records are required from well-calibrated (ammonoid and conodont) stratigraphic successions. The chemostratigraphic records need to be framed within a firm stratigraphic scheme of the Carnian. Integrated stratigraphy will enable a deeper understanding of the timing and duration of the phenomena (e.g., rate of carbon emissions) related to the CPE.

8) *Extinction and evolutionary innovations.* It is crucial to better estimate the extinction rates among marine and terrestrial taxa, compare them with Mesozoic baseline rates and mass extinctions, and to understand the timing of radiation of major important groups (e.g. dinosaurs, pelagic calcifiers, conifers) and its temporal link with the CPE. This will allow understanding whether extinction and radiation rates during the CPE actually stand out from the Phanerozoic background or not, and if there is any causal relationship between environmental change and evolution. Increasing precision in dating and improved knowledge of fossil records will also improve our understanding of the long-lasting impact of this major perturbation on the rebuilding of new ecosystems in the sea and on land.

9) *Analogy with modern and anthropogenically driven climate change.* A deeper knowledge of the temporal links between volcanism, climate change, and biotic turnover will permit to develop global biogeochemical models to understand the causal relationships and the long-term effects of the climate perturbation on the environments and biota. As other LIP-related episodes, the CPE could be an analogue for today climate change, marked by $p\text{CO}_2$ rise, global warming, and ocean acidification.

ACKNOWLEDGEMENTS

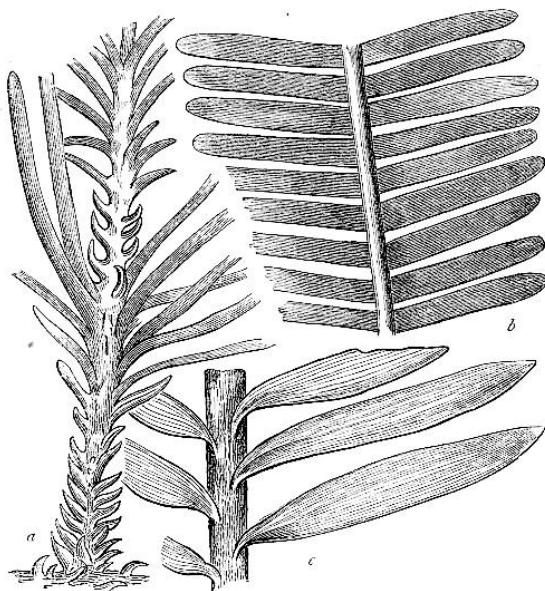
We thank the rector and all the staff of the Hanse-Wissenschaftskolleg (HWK) Institute for Advance Study in Delmenhorst for hosting this workshop and the financial support. In particular, we would like to thank Dr. Doris Meyerdierks and Marion Wachholz-Logemann for all the administrative and logistic assistance. JDC acknowledges the HWK for a Junior Fellowship (2016–2017), without which this workshop could not have taken place.

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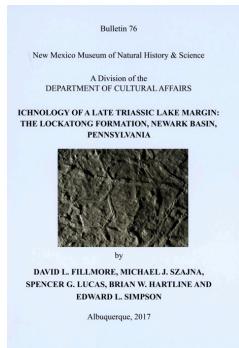
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Publication Announcements

Ichnology of a Late Triassic lake margin: the Lockatong Formation, Newark Basin, Pennsylvania by D.L. Fillmore, M.J. Szajna, S.G. Lucas, B.W. Hartline and E.L. Simpson. New Mexico Museum of Natural History & Science Bulletin, 76: 1-107. 2017

This 107-page volume presents complete documentation (including numerous photographs) of one of the most extensive invertebrate ichnossemblages known from the Newark Supergroup. If you are interested in ordering Bulletin 76, it costs \$20 and you can contact Holly Lowe, Store Manager for the NMMNH&S, at hlowe@naturalhistoryfoundation.org to place orders.

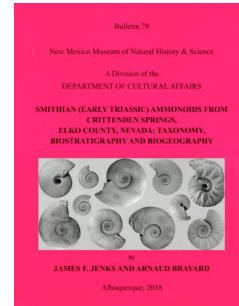


Abstract—The Late Triassic Lockatong Formation exposed in the Newark Basin of eastern Pennsylvania yielded a spectacularly diverse and abundant nonmarine ichnofossil assemblage, formed in a lacustrine-margin setting. The specimens described in this report, numbering more than 200, now conserved by the State Museum of Pennsylvania Invertebrate and Vertebrate Paleontology Collections, were recovered from a single construction site located approximately 8 km northeast of Souderston, Pennsylvania, referred to herein as the Silverdale Development Discovery Site (SDDS). The ichnofossils are from the Tumble Falls Member near the top of the Lockatong Formation. Eighteen invertebrate ichnogenera are described and illustrated together with three vertebrate footprint ichnotaxa (the vertebrate ichnofossils are described more fully in separate reports), and five *Undichna* ichnospecies. The invertebrate trace fossils are dominated by arthropod trackways that include *Acanthichnus*, *Bifurculipes*, *Cruziana*, *Diplichnites*, *Diplopodichnus*, *Kouphichnium*, and *Lithographus*; arthropod resting traces, *Rusophycus*; invertebrate feeding traces, *Selenichnites* and *Treptichnus*; grazing trails, *Cochlichnus*; relatively larger burrows, *Scyenia*; as well as six somewhat similar burrows-trails, *Gordia*, *Haplotichnus*, *Helminthoidichnites*, *Helminthopsis*, *Planolites*, and *Sphaerapus*. The vertebrate trace fossils described are assigned to *Atreipus*, *Gwyneddichnium*, *Rhynchosauroides*, and five ichnospecies of *Undichna*. Additionally, a new ichnospecies, *Diplichnites metzi*, is identified and described. Enigmatic sedimentary structures, including unique sandy spheres of algal origin, and round, stellate-shaped structures, are present. Invertebrate trace fossils of this collection best fit the *Mermia* Ichnofacies, and, to a lesser degree, the *Scyenia* Ichnofacies. Vertebrate trackways of this collection fall into the *Grallator* Ichnofacies. The large collection

of well-preserved invertebrate and vertebrate specimens, with a few sedimentary features, all illustrate the incredible biological diversity present along the Newark Basin lake shorelines of the Late Triassic.

Smithian (Early Triassic) ammonoids from Crittenden Springs, Elko County, Nevada: Taxonomy, biostratigraphy and biogeography by James F. Jenks and Arnaud Brayard. New Mexico Museum of Natural History & Science Bulletin, 78: 1-175. 2018.

This 175-page volume presents the results of decades of research at Crittenden Springs, one of the world's most prolific Early Triassic ammonoid localities. If you are interested in ordering Bulletin 78, it costs \$16 and you can contact Holly Lowe, Store Manager for the NMMNH&S, at hlowe@naturalhistoryfoundation.org to place orders.



Abstract—We present a comprehensive monographic treatment of all currently known Smithian (Early Triassic) ammonoid taxa from Crittenden Springs. Extensive collection efforts from numerous stratigraphically discontinuous, condensed outcrops over a period spanning four decades has yielded a total of 60 taxa. This activity has also resulted in the recognition of a new biostratigraphic succession unique to Crittenden Springs, consisting of 12 ammonoid intervals that normally occur within a typical ~1 m thick condensed outcrop. Ammonoids of early Smithian age are reported for the first time from this locality. Intraspecific variation of the more abundant taxa is documented and illustrated. Early and middle Smithian ammonoid biostratigraphy is shown to correlate reasonably well with the latest early and nearly the entire middle Smithian portion of the newly reported Utah and Nevada successions as well as most Tethyan and western Panthalassic localities. Late Smithian biostratigraphy correlates well with both the Utah and Nevada successions as well as all major worldwide localities. The latest late Smithian ammonoid fauna also contains well preserved, undoubtedly members of the *Glyptophiceras sinuatum* fauna, originally reported from the Tethyan realm. At least nine taxa from Crittenden Springs (e.g., *Preflorianites* cf. *P. radians*, *Mesohedenstroemia kwangsiensis* and *Wasatchites* cf. *W. distractus*), while common to several Tethyan localities, have not yet been reported from Utah, Nevada or other western USA

localities. Many of the newly described taxa further confirm the paleoequatorial nature of ammonoid faunas from Crittenden Springs as well as the low paleolatitude faunal exchange that occurred between opposite sides of the Panthalassic Ocean during Smithian time. One new family, the Crittendentidae is erected, whose composition includes *Crittendenites* n. gen. and *Wyomingites* Hyatt, 1900. Newly described taxa (three genera and six species) include a proptychitid, *Gambleites eichhorni* n. gen., n. sp., a galfettitid, *Montelloites stephensi* n. gen., n. sp., a crittendenitid, *Crittendenites jattioi* n. gen., n. sp., an arctoceratid,

Arctoceras rubyae n. sp., a prionitid, *Meekoceras bylundi* n. sp. and an aspenitid, *Aspenites weitschati* n. sp. Additionally, two new genera (*Condensoceras* n. gen. and *Elkoceras* n. gen.) are erected for previously described taxa, the xenoceltitid “*Xenoceltites*” *youngi* (Kummel and Steele) and family Incertae Sedis, “*Dieneroceras*” *spathi* (Kummel and Steele), respectively. Also included are seven newly reported taxa, e.g., *Proharpoceras carinatibusculatum*, *Meekoceras millardense*, *Meekoceras* cf. *M. olivieri*, *Kashmirites* cf. *K. guangxiense* and *Glyptophiceras* cf. *G. sinuatum*.



MAURIZIO GAETANI 1940 -2017

IN MEMORANDUM

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CIAO MAURIZIO

Last century, during up to 20 years we have shared the Subcommission on Triassic Stratigraphy (STS) adventures, the Himalayan Ladakh passion, the IGCP field meetings, the Tethys Program followed by the Peri-Tethys one and associated studies. In 1962, you started researches in Iran and 10 years later I went, reading your papers, also in this country, studying as you at Permian-Triassic sections in Elburz Mountains.

During summer 1977, immediately after the North India opening to foreigners, you went to Ladakh with Lia, your wife, for geological reconnaissance as separately I did as tourist with my wife and we discuss by letters of our new Himalayan experiences.

Our first meeting was at the 1979 Symposium you organized with Isabella Premoli Silva in memory of Riccardo Assereto and Julio Pisa in the famous Bergamo castle. A local newspaper wrote about this meeting the attendance of the “Elite culturale dell mondo”.

At that time, we both were appointed as STS active member. You ask me on organizing a common expedition in Lahaul and SE Ladakh Himalaya and you succeeded obtaining a grant from the Italian Research Ministry. I came during 1980 in your home in Segrate near Milano and in the spring of 1981, you went with your Milano team at our rented chalet in Swiss Prealps to finalize the preparation of the expedition. On August first 1991, we took a flight to Delhi, a bus to Manali and went to Darcha in Lahul. But to reach the Zangla nappe with his Triassic succession, we had, with horses and horsemen, to cross the Baralacha-La and the Phirtse-La passes up to the Kurgiak Valley. Due to health problem I was not able to participate to the sampling of the Jingshen PT



Figure 1 – Our camp in the Ichar Valley, S Ladakh, August 19, 1981



Figure 2 – Group photo of the participants in the Antalya Mountains, SW Turkey, Maurizio is in the middle, back.

sections with your team, Alda Nicora, Eduardo Garzanti and Andrea Tintori, but together, we could add and complete the main structural observations I started to collect with the Lausanne group in 1979. Some of our new results appeared in 1984 and we were among the first to describe in detail the nappe structure of the Tethys Himalaya.

With your PhD student Eduardo Garzanti and Georges Mascle teaching at Grenoble University, we were preparing during 1982, a second Ladakh expedition along the Spongtag klippe organized for 1983, as you were in charge of the 1984 expedition to be done with your Milano team to finish the stratigraphic studies started in 1981.

During these years of the eighty's, started a friendly spirit of competition on Himalayan studies between your strong and united Milano team, the French teams of Grenoble, Paris and Nancy and the Swiss teams from Lausanne and Zurich. This came with some successful collaboration, as you organized first with me and later with French colleagues and friends as Patrick Lefort. Your master was Ardito Desio, “il Padre” of Himalaya-Karakorum geologists and explorers. It is why, following your desire for a look at the other side of the Tethys Ocean, you chose, with a great ambition, to unravel the Karakoram story. Starting in 1986, during 22 years up to 2008, you were the kingpin of 10 expeditions between Chitral, Wakhan, Shimshal and Shaksgam areas surrounding the Karakorum Range. You admirably summarized this incredible successful survey in nowadays forbidden border regions, in your paper “Blank on the Geological Map” that came out two years ago in *Rendiconti Lincei*, 27-2, p. 181-195. The near forty published papers by all your team and a large geological map, testify the Karakorum happy ending story with a tremendous scientific contribution carried in great part by your team-leader soul.

As member of the IGCP project 203, you helped greatly to the organization of the Field conference on Permian and Permian-Triassic Boundary (PTB) of the South Alpine segment of the Western Tethys in Brescia, July 4-12, 1986 and you participated to the post-conference field workshop that Jean Marcoux and I organized in SW Turkey.

In 1987 you joined the field workshop of the IGC Program 109 on "Rare Events" with a conference in Islamabad on Dec. 8, and a workshop in the Nammal Gorge of the Salt-Ranges. This was a section that Jean Guex and I studied in 1975. As shown by the picture below taken in Nammal Gorge, you were in favor of a PTB level based on the first occurrence of the conodont *H. parvus*!

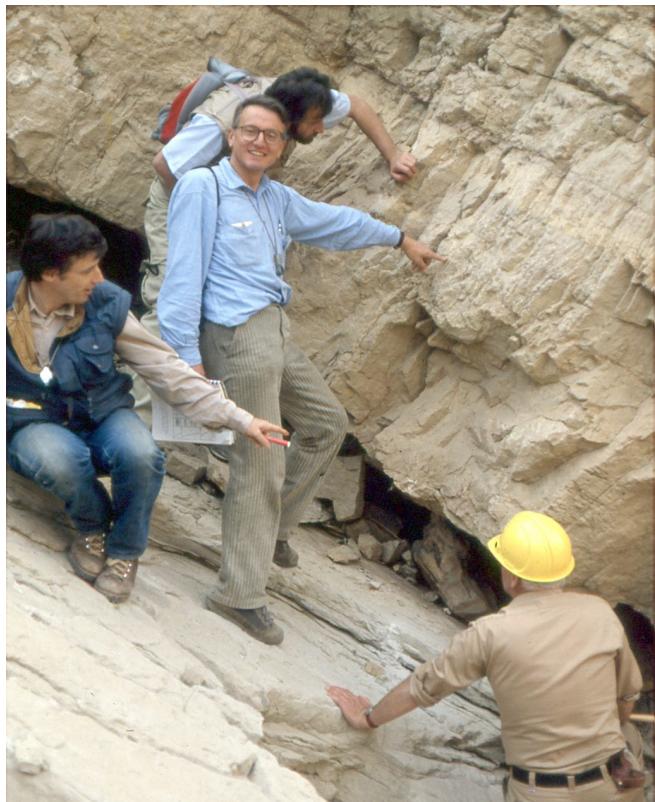


Figure 13– Maurizio showing his view on the Permian-Triassic Boundary (PTB) level. Sitting on the left I pointed the classical PTB and Tim Tozer, our master, is skeptic.

Following the Salt-Ranges workshop, you joined as friend and expert our small party with Jean Marcoux and Tim Tozer for a look at the Permian-Triassic Kashmir sections. Taking a flight in Lahore, we went to Srinagar through Delhi and rent rooms in a houseboat on Dal Lake. As temperatures fall down, each of us bought a fur's hat and we were proud to show it on the Houseboat balcony (picture below)! The days after, we sampled the Guryul Ravine and the Paghram sections. Six month later, all this area fell to terrorism, imposed curfew and during 25 years became closed for foreigners and scientists.

Between 1989 and 1990, we discussed together on the discovery of recycling fossils done by V. J. Gupta with his invention of fossiliferous localities in some azoic rocks of Himalaya. These fake data's in paleontology made you very



Figure 4 – On the houseboat balcony, Maurizio, Tim, Jean and I, Dec. 14, 1987.

angry, and you actively collaborated with John Talent and other colleagues to publish the detail of the Gupta's recycling fossils method (*Journal of the Geological Society of India*, 35(6), p. 569-585). Another serious alert was the work of J.B Waterhouse on the Lower Triassic Ammonoid of Nepal, an area you actively studied with your Milano team. It is why you published with your colleagues in *Albertiana* 15, 1995, a qualifying statement how to work correctly in paleontology and stratigraphy, that was apparently not the case of Waterhouse, as you wrote.

In 1999 began the Tethys project leaded by Jean Dercourt and Emmanuel Ricou, both from Paris VI Jussieu University, with a financial support of some interested Petroleum companies. Our friend Jean Marcoux was in charge of the Triassic paleogeographical and paleoenvironmental maps working group (Anisian and Norian), me of the Permian (Murgabian map) working group, and during the following 4 years, you helped us greatly, participating to numerous working meetings for publishing the first three maps and the explanatory notes. At the end of 1993, all these three maps were coming out in the Atlas Tethys, each with an expanded explanatory note.

Due to your strong diplomatic and scientific abilities, you get an opportunity to start, at an higher level, a six years project named Peri-Tethys Programme, that you carefully prepared with Jean Dercourt and co-leded with him. Responsible of 4 maps from Wordian to Norian, you finally were, with 8 colleagues, in the editorial charge of 24 paleogeographical



Figure 5 – Our first breakfast in the House-Boat, Maurizio, Tim, I and Jean, Dec. 14, 1987



Figure 6 –Maurizio on the left seems not convinced by my talk at the Augusto Gansser session during the Kyoto IGC, August 29, 1992

and paleoenvironmental maps with explanatory notes from Moscovian to Langhian that came successfully out in 2000. Your 2003 Foreword, in PPP (volume 196), resume very well the amazing accomplished task. Along a similar leader line, you opened in 2003 with Eric Barrier a new four years Middle -East Basins Evolution Programme (MEBE) with the same sponsors who helped greatly many active research teams with low institutional financial support. You followed with great attention the production of 15 palaeogeographical maps of the MEBE area, from Norian to Piacenzian and published in 2008.

Coming back to Subcommission on Triassic Stratigraphy (STS), it is on July 12, 1989, during the International Geological Congress (IGC) held in Washington, that you were elected as STS vice-chairman, just at the time I became chairman.

In 1991, with Jean Marcoux, you helped me and my colleague Jean Guex in the organization of a Symposium on Triassic stratigraphy held at Lausanne University, October 20-22 and for preparing the STS meeting with an important vote on Triassic stage name. On October 23, acting as vice-chairman and secretary, you went in charge of the Triassic stage boundary working group. You also participated to the editorial Committee of the Symposium Proceeding edited in 1994.

In 1992 you participated to the Kyoto IGC, August 22-31 and wrote a report on the 1992 STS activities, with a description of the Olenekian-Anisian, Anisian-Ladinian and Ladinian-Carnian potential boundary localities and sections.

You also announced a 1993 field meetings in Italy followed by Hungary to look at the Anisian-Ladinian boundary (ALB) proposals in both countries.

The report you published in *Albertiana* (Vol. 12, p. 5-9) on this 1993 ALB successful meeting was very detailed and significant.

At the next STS meeting held in Albrechtsberg near Vienna Sept. 10, 1994, you made the state of advancement of your stage boundary working group.

In 1995 you got an unanimous vote by the STS members to be chairman, and this election was confirmed by IUGS general



Figure 7 –Maurizio, future chairman and me, chairman in charge, at the STS meeting held in Albrechtsberg near Vienna Sept. 10, 1994

assembly during the Beijing IGC, Aug. 4-14, 1996.

Also in 1995 you accepted to be Editor in chief of the *Rivista Italiana di Paleontologia e Stratigrafia* belonging to the Milano University and you asked me to join your scientific Committee. During the twenty years of this responsibility you perfectly fulfilled, you asked me to do some paper review and to give my advise on some conflicting manuscripts.

Within the STS activities, one of your task was to get advancement on the Olenekian-Anisian boundary (OAB) studies, and, from 1989, you restudied in great detail with your German and Italian colleagues the sections of Chios Island (Greece) but, after 6 years, the main results were showing a gap in the sedimentary succession close to the expected boundary. You found similar problems on the OAB of the Kçira section that you were studying with your team in Albania. It is why you took a great interest in our Olenekian -Anisian researches in Romania undertaken within the Peri-Tethys project on the Triassic of the North Dobrogea. Especially the Desli-Caira section rich in ammonoids and conodontes edited in the Scientific Report of the Peri-Tethys Programme published in Lausanne (1997) kept your attention. From 1995 to 2000 we both corresponded by webmail on the opportunity to propose a GSSP at this Section. But after 5 years of endless argue with some colleagues, we had to postpone this proposal due to internal Romanian problems and the absence of a free GSSP access guaranteed for all scientists.

The GSSP proposal of the Anisian-Ladinian boundary (ALB) you initiated in 1993 with the excursion in Bagolino (Italy) and in Feldsôors (Balaton, Hungary) was more successful with a final meeting in 2002 at Veszprém, (Hungary) and a positive vote in 2003 by the STS members for the Bagolino section proposed by Peter Brack and colleagues, and finally ratified by the IUGS executive Committee in 2005. This was the first approved, GSSP within the Triassic System.

During the Rio de Janeiro IGC, August 6-17, 2000, you presented the main achievement of the Peri-Tethys Programme and with the Italian delegation you obtained a positive vote for the next IGC organization in Florence. Concerning the STS, Mike Orchard was elected as new chairman, and you became past-chairman.

Just before the 2004 Florence IGC, you had the honor to



Figure 8 –Maurizio, center, surrounded by friends, colleagues and participants of the 1987 Salt Range workshop

lead, with our friend Jean-Pierre Burg, with A. Zanchi and Q.M. Jan, an unique IGC Prestige Field Trip on “A geological transect from the Indian plate to the East Indu-Kush, Pakistan”. We were envious of you!

When you came back, we met us during the Congress, August 20-28, 2004, as you were in charge (chairperson) of 2 sessions, one the “Triassic in the Tethys realm” with a poster on the Triassic of the Karakorum Range and the other on the “Geology of Caspian and Aral seas regions” of the MEBE Programme.

In March 2007, just at the time you went into teaching retirement, your close colleagues organized a friendly party and invited me in Milano to your honor’s dinner and colloquium. I was deeply touched by this nice thought.

End of June 2008 you heard that our close friend Jean Marcoux just passed away. Affected by this sad news and being about to leave for your farewell Karakorum expedition you wrote me, as always in French: “Je parts demain au Karakorum pour dire adieu à ces magnifiques montagnes” and “Je penserai à notre ami Jean dans ces montagnes”. This sentence touched me a lot.

From this 2008 time up to last year we, as old friends, kept in touch, and, as you and me went back after forty to fifty years to our lovely Iran sections we had still a lot to discuss.

Your messages described also your Piano Rancio second home, your cross-country-skiing passion, your every year participation to the “Marcialonga di Fiemme” end of January and you told me about your travel to Finland with a 400km cross-country-skiing marathon, but “only” 300km for Lia as you wrote to me! You both, among your plenty of personal qualities, were really great

sportsman and women.

Our last meeting was in Perugia, at the International Congress on Paleozoic Stratigraphy of Gondwana, Perugia, April 14-16, 2016. With your happy mood you appear me and to my wife still young and elegant as forty years before, and we spent time to discuss on our recent researches. You asked me about the possible continuation of the Triassic succession you discovered on Socotra Island on the Oman side of the Gulf of Aden, and you were interested by the lower Triassic brachiopod accumulation we found in the Batain area of SE Oman. During 20 years, I told you: “please come join one of our field studies in Oman” and just end of 2015 you foresee an opportunity to come in 2017 but apparently it was no more possible. This was a dream for me to introduce you in this geological paradise. We miss it, and we still had more souvenirs and experiences to share, me, modestly, studying remote places of our whole wide world and you, with a such exceptional international career, taking large responsibilities at European wide research programs and at the same time taking care and giving encouragement at your close research team as you always did at your family level.

“Tout ce que tu as reçu, tu l’as distribué généreusement”

We will all miss you, Ciao Maurizio

Postscript: Maurizio’s comprehensive biography with the connected publication list will be published soon by his Milano close colleagues and friends.

