IGCP 630: Permian and Triassic integrated Stratigraphy and Climatic, Environmental and Biotic Extremes

THE PERMIAN-TRIASSIC TRANSITION IN SOUTHERN ARMENIA

October 8th - 14th, 2017

Workshop schedule:

October 8: Arrival in Yerevan, transfer to a hotel.

October 9: Conference Day 1, at the Round Hall of Presidium of the Armenian National Academy of Sciences, Yerevan.

October 10: Conference Day 2, at the Round Hall of Presidium of the Armenian National Academy of Sciences, Yerevan., and Visit of the Khor Virap monastery and the Matenadaran Scientific Research Institute of Ancient Manuscripts.

October 11: Field Trip, Day 1, Yerevan to Ogbin (166 km by bus). Visit to the Ogbin outcrop section. Accommodation in the Hotel Amrots in the city of Vayk.

October 12: Field Trip, Day 2, Vayk to Zangakatun, 50km. Visit to the Chanakhchi outcrop section. Return to Hotel Amrots.

October 13: Field Trip, Day 3, Vayk to Vedi (86km). Visit to the Vedi outcrop sections and visit of the Noravank monastery.
Return to Yerevan (67 km), Conference dinner in evening.

October 14: Samples packing for expedition, departure of the participants in the afternoon or in the night.

CONTENTS

CONFERENCE PROGRAM

Registration of participants will begin at 8:30 AM on the 9th of October at the Armenian National Academy of Sciences, Yerevan, 24 Marshal Baghramyan Avenue. Conference will start at 09:00 AM. Both Presidium and our Institute are very easy to locate on Baghramyan Avenue. **For details see the photo and the map below.**

9-10 OCTOBER, ROUND HALL OF PRESIDIUM OF THE NATIONAL ACADEMY OF SCIENCES OF REPUBLIC OF ARMENIA

OCTOBER 9

08:30-9:00 REGISTRATION

Introduction and Welcome address by **Director of IGS, Dr. Sci. Kh. Meliksetyan**

Presentation 1: **Deputy Director of IGS, Dr. Sci. L. Sahakyan**
Geology and geodynamic evolution of the territory of Armenia: new data and review.

Presentation 2: **Baud A., Sahakyan L.**
Introduction to the field workshop and the three visited sections.

Session I, **Chairperson: Prof. Zhong-Qiang Chen**

10:00-10:20 **Avagyan A.,** Sosson M., Sahakyan L., Vardanyan S., Sheremet Y., Martirosyan M. POST EOCENE DEFORMATIONS OF PALEOZOIC SUBSTRATUM IN THE SOUTH-EAST ARARAT DEPRESSION (ARMENIA).

10:20-10:40 **Baud A.,** Friesenbichler E., Richoz S., Krystyn L., Sahakyan L. INDUAN (EARLY TRIASSIC) GIANT SPONGE-MICROBIAL BUILD-UPS IN ARMENIA.

10:40-11:00 **Grigoryan A.,** Melik-Adamyan H. THE HISTORY OF RESEARCH OF PERMIAN-TRIASSIC DEPOSITS OF ARMENIAN HIGHLAND.

11:00-11:30 Coffee break

Session II, **Chairperson: Dr. Aymon Baud**

11:30-11:50 **Zhong-Qiang Chen.** MAJOR MICROBE-METAZOAN TRANSITIONS FROM THE PRECAMBRIAN TO PRESENT DAY: CHINESE RECORDS RESPONSE TO GLOBAL EVENTS.

11:50-12:10 **Hongfei Chen**, Chenyi Tu, Zhong-Qiang Chen. CRINOIDEA (ECHINODEMATA) EXTINCTION AND RECOVERY OVER THE PERMIAN-TRIASSIC TRANSITION: DATA FROM SOUTH CHINA AND GLOBAL PATTERNS.

12:10-12:30 **Yichun Zhang**, Kyi Pyar Aung. PERMIAN FUSULINES FROM EASTERN MYANMAR AND THEIR GEOLOGICAL IMPLICATIONS.

12:30-12:50 **Yuheng Fang**, Zhong-Qiang Chen, Adam Woods, Yuangeng Huang. PERMIAN–TRIASSIC BOUNDARY MICROBIALITES IN SOUTH CHINA: SEDIMENTOLOGIC AND GEOCHEMISTRY FEATURES AFTER THE END-PERMIAN BIOCRISIS.

12:50-13:50 Lunch break

Session III, Chairpesron: Prof. Dr. Shuzhong Shen

13:50 -14:10 **Shu-Zhong Shen,** Jahandar Ramezani, Jun Chen, Chang-Qun Cao, Douglas H. Erwin, Hua Zhang, Lei Xiang, Shane D. Schoepfer, Charles M. Henderson, Quan-FengZheng, Samuel A. Bowring, Yue Wang, Xian-Hua Li, Xiang-Dong Wang, Dong-Xun Yuan, Yi-Chun Zhang, Lin Mu, Jun Wang, Ya-Sheng Wu. A SUDDEN END-PERMIAN MASS EXTINCTION IN SOUTH CHINA.

14:10-14:30 **Foster W.J.,** Lehrmann D., Yu M., and Martindale R.C. THE COMMUNITY COMPOSITION AND TEMPORAL DYNAMICS OF THE GREAT BANK OF GUIZHOU MICROBIAL REEF, EARLY TRIASSIC.

14:30-14:50 Kolar-Jurkovšek T., Jurkovšek B., Nestell G.P., **Aljinović D.** REINTERPRETATION OF THE BIOSTRATIGRAPHY AND SEDIMENTOLOGY OF THE UPPER PERMIAN AND LOWER TRIASSIC STRATA OF THE MASORE SECTION, WESTERN SLOVENIA.

14:50-15:10 **Korngreen D.,** Orlov-Labkovsky O., Zilberman T. THE ESTUARINE ENVIRONMENTS: NEW INSIGHTS FROM COMBINING ISOTOPIC, SEDIMENTARY AND BIOSTRATIGRAPHY CONSTRAINS ON THE TROPICAL MIDDLE – LATE PERMIAN TO EARLY TRIASSIC MARGINAL MARINE STRIP OF GONDWANA SUPERCONTINENT.

15:10-15:40 Coffee break

Session IV, Chairpesron: Prof. Dr. Guang Shi

15:40-16:00 **Peryt Tadeusz Marek,** Raczyński Paweł, Peryt Danuta, Chłódek Krzysztof, Jasionowski Marek. WUCHIAPINGIAN ZECHSTEIN LIMESTONE REEFS IN WESTERN POLAND.

16:00-16:20 **Alexander S. Biakov,** Micha Horacek, Igor L. Vedernikov and Inessa V. Brynko. DEEP-WATER UPPER PERMIAN AND PERMIAN-TRIASSIC BOUNDARY SEDIMENTS IN THE NORTH-EAST ASIA (BALYGYCHAN BASIN, KOLYMA-OMOLON REGION): NEW $\delta^{13}C_{org}$, $\delta^{15}N$, PALAEONTOLOGICAL AND GEOCHRONOLOGICAL DATA.

16:20-16:40 **Smirčić D.,** Aljinović D., Hrvatović H., Barudžija U., Kolar-Jurkovšek T., Jurkovšek B. THE GEOTECTONIC EVOLUTION OF THE DINARIDIC PART OF WESTERN TETHYS FROM THE EARLY PERMIAN TO THE LATE TRIASSIC.

Discussion and IGCP 630 information (Past and next meetings, future projects)

OCTOBER 10

Session IV, Chairperson: William Foster

09:00-09:20 **Guang R. Shi.** GLOBAL CHANGES, EARLY WARNING SIGNALS AND THE END-PERMIAN MASS EXTINCTION.

09:20-09:40 **Forel Marie-Béatrice,** Crasquin Sylvie. OSTRACODS AS STRATIGRAPHICAL INDICES OF THE LATE PERMIAN–EARLY TRIASSIC POST-EXTINCTION INTERVAL.

09:40-10:00 **Grigoryan A.,** Avagyan N., Grigoryan G. BIOSTRATIGRAPHY OF TRIASSIC SEDIMENTS OF ARMENIA.

10:00-11:00 POSTER SESSION, Chairperson: Dr. Lilit Sahakyan

10:00-10:10 **Raczyński Paweł,** Sremac Jasenka, Jasionowski Marek, Peryt Tadeusz Marek, Peryt Danuta. BIOTA OF PERMIAN REEFS IN THE ZECHSTEIN BASIN (POLAND, GERMANY AND LITHUANIA) AND WESTERN TETHYS (CROATIA AND SLOVENIA).

10:10-10:20 **SerobyanVahram**, Grigoryan Araik, Cronier Catherine, Denise Brice, Danelian Taniel. BRACHIPODS IN UPPER DEVONIAN – LOWER CARBONIFEROUS SEDIMENTARY SEQUENCES OF SEVAKAVAN SECTION.

10:20-10:30 **Orlov-Labkovsky, O., Korngreen, D.** SPATIAL VARIATION IN FORAMINIFERA DISTRIBUTION AND OCCURRENCE IN RESPONSE TO CHANGES IN THE SEDIMENTARY ENVIRONMENTS AND GLOBAL CHANGES; THE TROPICAL MIDDLE – LATE PERMIAN TO EARLY TRIASSIC MARGINAL MARINE STRIP OF GONDWANA SUPERCONTINENT.

10:30-10:40 **Grigoryan Gevorg,** Vachard Daniel, Grigoryan Arayik, Zambetakis-Lekkas Alexandra & Danelian Taniel. LATE PERMIAN MICROPALEONTOLOGY (FORAMINIFERA), BIOSTRATIGRAPHY AND PALAEOENVIRONMENTS IN ARMENIA AND GREECE.

10:40-10:50 **Grigoryan A.,** Avagyan N. THE UPPER TRIASSIC CONODONTS IN EXOTIC BLOCKS OF SEVAN-HAKARI OPHIOLITE ZONE OF THE LESSER CAUCASUS.

Discussion

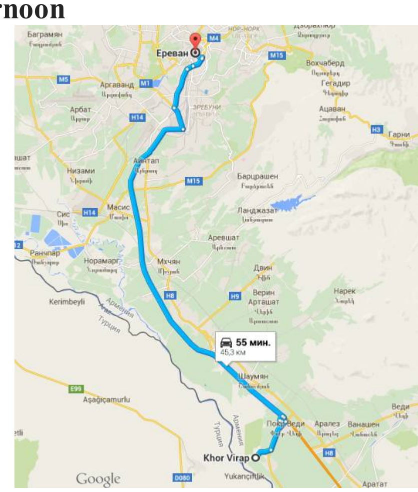
11:00-11:30 Coffee break

11h30-13h30 **Visit Matenadaran museum**

Matenadaran - Scientific Research Institute of Ancient Manuscripts after Mesrop Mashtots is a repository of ancient manuscripts, research institute and museum in Yerevan. It holds one of the world's richest depositories of medieval manuscripts and books which span a broad range of subjects, including history, philosophy, medicine, literature, art history and cosmography in Armenian and many other languages.

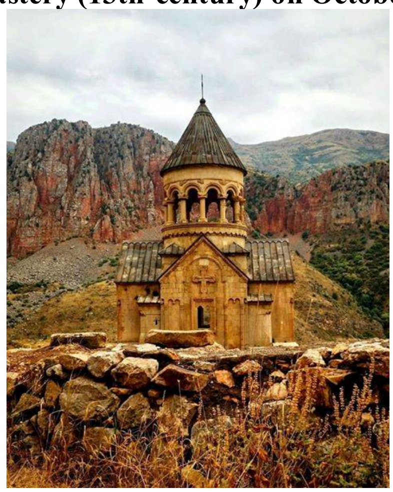
13:30-14:30 Lunch break

14:30 Visit Khor Virap monastery on October 10, afternoon



It is located in the Ararat plain in Armenia, near the closed border with Turkey. The Ararat Mountain is making an amazing landscape. The taller peak reaches 5.165m, whereas the small one is just 3.900m high; they are separated from each other by the 11.3km distance. The Khor Virap Monastery is a shrine and a pilgrimage site important to the Armenian Christianity. The church complex is built atop the pit (= virap in Armenian), where St. Gregory the Illuminator was cruelly imprisoned, some time at AD 288 by the heathen Armenian King Trdat III. St. Gregory suffered his imprisonment in that pit for 14 years until upon miraculously curing the king of a loathsome disease, the king freed him and converted himself and Armenia to Christianity. In 301, Armenia was the first country in the world to be declared a Christian nation.

2- Noravank Armenian monastery (13th-century) on October 13, morning.



Noravank means “new monastery” in English. The church, completed in 1339, is said to be the masterpiece of the great medieval Armenian architect Momik. Two extremely narrow steps form a cantilever lead up to the main hall of the church. The fine carved relief of Christ overly the doorway, flanked by St. Peter and St. Paul. Above the ground floor, directly below the cantilevered stairs, there is a carved relief of the Holy Virgin with Jesus set on her lap and a pair of angels.

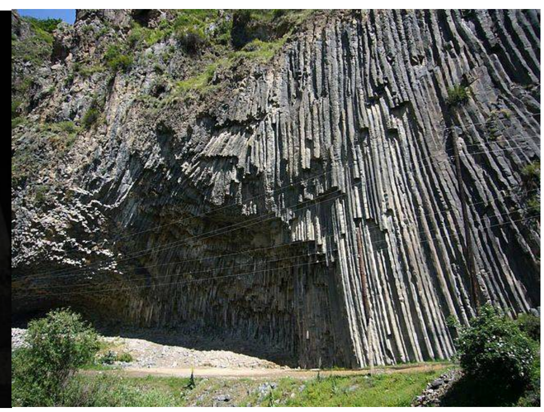
SPECIAL PROGRAM FOR ACCOMPANYING PARTICIPANTS

OCTOBER 9

09:00 from Institute of Geological Sciences, the Armenian National Academy of Sciences, 24 Marshal Baghramian Ave.

Visit Garni Fortress and the 1st century AD Classical Hellenistic Temple of Garni. It is located at 28 km away from Yerevan. Then the car will take a route to the spectacular gorge of the Azat River, which is located at a short distance from the temple and see spectacular columnar joints lava flow and Garni active fault. After the lunch we will visit to the 4th-13th Century AD Geghard Monastery and view of Vokhchaberd volcanoclastic suite of Upper-Miocene-Pliocene Age. Geghard (in Armenian meaning "spear") is a medieval monastery in Kotayk province of the Republic of Armenia, being partially carved out of the adjacent mountain, surrounded by cliffs. The monastery complex was founded in the 4th century by Gregory the Illuminator at the site of a sacred spring inside a cave.

Garni Hellenistic temple



Geghard Monastery

Garni columnar lava flow, dated 127 Ka

OCTOBER 10

09:00 from Institute of Geological Sciences, the Armenian National Academy of Sciences, 24 Marshal Baghramian Ave.
On this day our excursions will be carried out in Vagharshapat town, where we will visit Etchmiadzin Cathedral (est. 4th Century AD) - Center of the Armenian Apostolic Church and Hripsime 7th Century AD church. The accompanying participants will join the IGCP conference group for visit Matenadaran museum and Khor Virap monastery.

Mother See *of* Holy Echmiatsin

Hripsime church (7th Century AD)

OCTOBER 11 to 13

The accompanying participants will join the IGCP conference group to visit the localities of Ogbin, Zangakatun and Vedi.

ABSTRACTS

POST EOCENE DEFORMATIONS OF PALEOZOIC SUBSTRATUM IN THE SOUTH-EAST ARARAT DEPRESSION (ARMENIA)

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The studies of foothill, intermountain depressions of the Ararat basin south- eastern part allow proposing modern geologic structural models of evolution corresponding to tectonic, geodynamic contemporaneous concepts. The investigation has show that the studied area of the Ararat depression is not controlled by extensive structure as normal fault and grabens. The Paleozoic basement outcrop in Sari Pap and KhorVirap sites are not related to horst structures, they are controlled by contractionary tectonics which has clear post Upper Eocene and Oligo-Miocene, Neotectonic activity. The thrust and reverse stress regime of the study area was dominant during long period from collision initiation, influencing farther tectonics, complicated by strike-slip faulting. The secondary normal faults, superimposed gravitational slopes processes and selective erosion complicate moreover the overall structure pattern. These processes continue up today.

INDUAN (EARLY TRIASSIC) GIANT SPONGE-MICROBIAL BUILD-UPS IN ARMENIA

Aymon Baud[1], Evelyn Friesenbichler[2], Sylvain Richoz[3], Leopold Krystyn[4], Lilit Sahakyan[5]
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The basal Triassic units of central Armenia offers the opportunity to study a new sponge-microbial community development in the aftermath of the end-Permian mass extinction. The sponge-microbial build-ups outcrop well in the Chanakhchi section (previous Sovetachen or Zangakatun). They are spaced from 5 to 20 m. and surrounded by thin-bedded platy lime mudstone in a deep ramp environment between the fair weather wave base and the storm wave base (1). The basal part consists of a succession of centimeter- to decimeter-scale branching columnar stromatolite within lime mud rich in fibers of putative keratose sponges. Calcium carbonate oversaturated sea-water caused a very early diagenetic replacement of the former organic tissue by calcite mono-crystals, which are often surrounded by calcium carbonate needles or fans (original aragonite). The following sponge-microbial growth phase consists of numerous superposed thrombolitic domes with specific internal structures reaching a total height of up to 12 m and a top head diameter of 8 m. An observed asymmetrical growth of the build-ups indicates a steady bottom current condition which also contributes, with strong storms, to the concomitant distal deposition of thin bedded bioclastic lime-mudstones and -wackestones containing ostracods, foraminifers, gastropods, bivalves, sponge fibers as well as ammonoids, and to embedding the build-ups. The thrombolites forms dark patches on the outcropingbioherm and, at least five texture types are recorded in the microstructures, comprising spherulites, coalescent hemispheric acicular calcite crystal intergrowths similar to sea-floor carbonate cements, and calcified sponge tissue network within lime mud, within thrombolites or within spar spheroids (former sponge bodies?). Although, if the microbialites from South China and South Turkey flourished only during the lower Griesbachian, the Armenian build-ups lasted the whole Griesbachian and extended up to the basal Dienerian, from *parvus* to *kummeli*conodont zones (2), that is, at least, twice long (about 700'000 years) as it is China and Turkey . To resume, the Chanakhchi basal Triassic sponge- microbial build-ups are of a new type and of a long duration, not yet known during this time interval.

(1) Friesenbichler, E., Richoz S., Baud, A. Krystyn, L., Sahakyan, L., Vardanyan, S., Peckmann, J., Reitner, J. &Heindel, K. (submitted): Sponge-microbialites from the lowermost Triassic Chanakhchi section in southern Armenia: Microfacies and carbon stable isotopes.
(2) Zakharov, Y.D., Biakov, A.S., Baud, A. and Kozur, H. (2005) Significance of Caucasian Sections for Working out Carbon-Isotope Standard for Upper Permian and Lower Triassic (Induan) and Their Correlation with the Permian of North-Eastern Russia. J. China University of Geosciences, 16 (2), 141-151.

DEEP-WATER UPPER PERMIAN AND PERMIAN-TRIASSIC BOUNDARY SEDIMENTS IN THE NORTH-EAST ASIA (BALYGYCHAN BASIN, KOLYMA-OMOLON REGION): NEW $\delta^{13}C_{org}$, $\delta^{15}N$, PALAEONTOLOGICAL AND GEOCHRONOLOGICAL DATA

Biakov A.S.[1,2], Horacek M.[3,4], Vedernikov I.L.[1] and Brynko I.V.[1]

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Upper Permian and Lower Triassic deposits in the Balygychan basin (Kolyma-Omolon region, North-East Asia) are include the Ovod, Pautovaya and GherbaFms which accumulated in deep-water environments of continental slope (Biakov, 2004). Recently we obtained the first detailed $\delta^{13}C_{org}$record of this deposits (Biakov et al., 2017). Here we too presente new data on $\delta^{15}N$ record and new SHRIMP date from the lower part of the Pautuvaya Fm.

Pre-*Otoceras* part of the Changhsingian stage (PautovayaFm) are characterized here by relatively high values of $\delta^{13}C_{org}$. (between –23 and –25 ‰), decreasing to distinct event-level (base of the GherbaFm) to –27 ‰. This level supposedly corresponds to the base of *Otoceras*layers and is associated with the extinction of typical Permian high latitudinal Boreal fauna (*Inoceramus*-like bivalves *Intomodesma* genus and gastropods *Straparolus* sp.), and the complete disappearance of bioturbation. Also earlier the Changhsingian bivalve *Claraioides*aff. *primitives* (Yin) was discovered here (Biakov, 2001). Previously, we recorded the signs of anoxia at this level (Biakov & Vedernikov, 2007). Obviously, this level corresponds to the so-called "Arctic extinction event" marked by T. Algeo and others in the Canadian Arctic (Algeo et al., 2012).

Based on the correlation of the $\delta 13C_{org}$ record of our section and the recently obtained analogous record of the $\delta 13C_{org}$ from the Setorym Section, Southern Verkhoyansk Region (Zakharov et al., 2014; 2015), where an approximate position of this boundary is outlined, we can trace the approximate position of the PTB at 20 m above the base of the Gherba Fm. In the lower part of the GherbaFm values of $\delta^{13}C_{org}$ constitute about –27 ‰, gradually decreasing up the section to –29.9 ‰, where the first finds of ammonoid*Tompophiceras* were discovered (about 80 m from the event level). The new data show a good agreement with a number of other sections of the Boreal and TethyanSuperrealm, especially in the Buchanan Lake section in Arctic Canada (Grasby et al., 2015), the Festningen section on Spitsbergen (Grasby& Beauchamp, 2009), the WadiShahha section on the Arabian Peninsula (Clarkson et al., 2013) and published sections in the Dolomites (Horacek et al., 2010).

We also discovered the ash bed in the lower part of the Pautovaya Fm, from which the zircons were separated and dated by U-Pb SHRIMP method. The isotope age is 255±2 Ma.

Taking into account the position of the dated sample, we can also assume the position of the Wuchiapingian-Changhsingian boundary in the studied section in the middle part of the Pautovaya Fm. For the first time we also obtained the $\delta^{15}N$ record, which reveals a distinct trend of a decrease in its values from 7–8‰ in the Late Wuchiapingian-Early Changhsingian (lower part of the Pautovaya Fm) to 4–5‰ in the Late Changxing and further its decrease to 3‰ in the Early Induan (lower part of the Gherba Fm). On the whole, rather high values of $\delta^{15}N$ are explained, apparently, by the deep-water conditions of sedimentation.

This study was supported by the Russian Foundation for Basic Research, project No 17-05-00109, and Austrian National Grant for the IGCP 572 project.

OSTRACODS AS STRATIGRAPHICAL INDICES OF THE LATE PERMIAN–EARLY TRIASSIC POST-EXTINCTION INTERVAL

Forel Marie-Béatrice[1], Crasquin Sylvie[1]

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Ostracods (Crustacea) have been important components of marine throughout the Phanerozoic, from shallow shelves to deep basins. These essentially benthic micro-organisms have been deeply affected by the Permian–Triassic boundary event, with about 70% of the species going extinct (Crasquin & Forel, 2014). Microbial mats thriving in the post-extinction environments served as oases for abundant ostracods of the Bairdiidae family, fueling their exceptional Triassic recovery and radiation (e.g. Forel *et al.*, 2013). Conversely, members of the order Palaeocopida disappeared from the stratigraphical record close to the Permian–Triassic boundary event, with only residual occurrences up to the Carnian (Late Triassic; Forel *et al.*, in press). Species of the genus *Hollinella* are often present just after the end-Palaeozoic mass extinction event, in latest Permian and earliest Triassic beds. They are among the last representatives of Palaeocopida, the emblematic Palaeozoic straight dorsal border ostracods. We report abundant *Hollinella* assemblages developed on the southern margin of the South China Craton. In South China, a monospecific assemblage of *Hollinellapanxiensis* Wang, 1978 proliferated in the lowermost Kayitou Formation of the at the Mide section, as a result from a short proliferation event during unstable conditions (Bercovici *et al.*, 2015; Forel& Yu, work in progress). These hollinellids-dominated assemblages appear to be characteristics of post-extinction marginal marine successions in South China (Forel& Yu, work in progress). In Vietnam, abundant *Hollinella (H.) lungcamensis* thrived in the post-extinction open marine environments of the Lungcam section (Crasquin *et al.*, 2017). We propose that these species of the genus *Hollinella* are stratigraphical markers of the post-extinction interval in transitional and marine waters of the South China craton under the influence of important terrigenous influx.

Bercovici A., Cui Y., Forel M.-B., Yu J. X., Vajda V. 2015. Terrestrial paleoenvironment characterization across the Permian–Triassic boundary in South China. *Journal of Asian Earth Sciences*, 98, 225–246.

Crasquin S., Forel, M.-B. 2014. Ostracods (Crustacea) through Permian–Triassic events. *Earth Science Reviews*, 137, 52–64.

Crasquin S., Forel M.-B., Yuan A., Nestell G., Nestell M. 2017. Species of *Hollinella* (Palaeocopida, Ostracoda, Crustacea) as stratigraphical indices of the Late Permian-Early Triassic post–extinction interval. *Journal of Systematic Paleontology*, dx.doi.org/10.1080/14772019.2017.1283648.

Forel M.-B., Crasquin S., Kershaw S., Collin P.-Y. 2013. In the aftermath of the end-Permian extinction: the microbialite refuge. *Terra Nova*, 25, 137–143.

Forel M.-B., Tekin U.K., Okuyucu C., Bedid Y. Tuncer A., Crasquin S. in press. Discovery of a long-term refuge for ostracods (Crustacea) after the end-Permian extinction: a unique Carnian (Late Triassic) fauna from Southern Turkey. *Journal of Systematic Paleontology*.

THE COMMUNITY COMPOSITION AND TEMPORAL DYNAMICS OF THE GREAT BANK OF GUIZHOU MICROBIAL REEF, EARLY TRIASSIC

Foster W.J. [1], Lehrmann D. [2], Yu M.[3], and Martindale R.C. [1,4]

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The Permian-Triassic transition is a key interval for the evolution of modern marine ecosystems. The timing of the key radiations and changes in ecosystem structure are poorly understood, but the immediate extinction aftermath is becoming increasingly recognized as a key interval for the diversification of many marine animals. To investigate the diversification of the benthos and changes in ecological parameters during this critical interval, we undertook the highest resolution study to date of the Basal Early Triassic Microbial (BETM) unit by investigating 83 paleoecological samples from the ‘Great Bank of Guizhou’. Here we recognize 54 benthic invertebrate species from 4373 individuals, including one new bivalve, and three new gastropod species. This takes the diversity of the Great Bank of Guizhou basal microbial unit to 91 invertebrate species. 71% of the genera are Permian holdovers, whilst only 18% of the species are Permian holdovers. This new data, records no temporal trends in the richness, composition, or body size of the benthos during the BETM. The BETM benthic community is both ecologically and taxonomically diverse, recording articulate brachiopods, lingulids, crinoids, echinoids, bivalves, gastropods, microconchids, foraminifera, and ostracods. The small body sizes of the benthic community, and the large lophophoral cavity in the lingulids suggests that these animals lived in a highly stressed environment. We propose that the BETM contains a survival fauna in an interval that represents persistent environmental stress from the late Permian climate event, associated with deoxygenation, high SSTs, and elevated primary productivity.

THE HISTORY OF RESEARCH OF PERMIAN - TRIASSIC DEPOSITS OF ARMENIAN HIGHLAND

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The initial stage of the paleontological study of the Permian-Triassic transition, as well as of the Paleozoic and Mesozoic deposits of the Armenian plateau is connected with the name of the outstanding German naturalist, the founder of the geological study of the Armenian Highlands, Academician Herman Abich, who deserves the credit for the discovery of the world-famous Late Permian fauna of the Julfa Gorge.

Several generations of scientists have studied Permian Triassic deposits. It can be divided into three main stages. The first stage (1844-1920): Permian and Triassic deposits were studied by F. Frech and G. Athaber, A. Stoyanov, P. Bonnet, K.O. Rostovtsev, N. Yakovlev, V.I. Meller. They have given the first faunistic justification for the age of Permian-Triassic sediments. The beginning of the study of the Triassic deposits was laid by E. von Mojsisovics (1879).

The second stage (1920-1990): covers the Soviet period of systematic works in all areas of geology. Permian-Triassic sediments of Transcaucasia were studied by K.N. Paffenholz (1948), A.D. Miklukho-Maclay (1947), R.A. Arakelyan (1951, 1964), A.M. Sadykov (1953, 1954), Sh.A. Azizbekov (1965, 1972), and in the 70's and 80's K. Roostovtsev, N.R. Azaryan, I.S. Barskov and N.V. Korolyova, M.V. Pyatakova, E.Ya. Leven, H. Kozur, G.V. Kotlyar, Y.D. Zakharov, A.G. Grigoryan, A.S. Alekseev and others.

The aforementioned researchers gave the first faunistic justification for the age of the Permian and Triassic deposits of the Transcaucasus, the boundaries of their distribution were specified. The first schemes of stratigraphic separation and the new Midian and Dorashamian regional stages were proposed. There were significant disagreements between the researchers, connected with stratigraphic position of Upper Permian and Lower Triassic boundaries, which was moved from the base of the Julfian Stage of Upper Permian up to the Claraia layers of the Lower Triassic.

The third, modern stage (the beginning of the XX1 century): nowadays, Permian Triassic sediments of Armenia attract the attention of scientists from foreign countries, linked on modern problems.

THE UPPER TRIASSIC CONODONTS IN EXOTIC BLOCKS OF SEVAN-HAKARI OPHIOLITE ZONE OF THE LESSER CAUCASUS

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Upper Triassic Conodonts from exotic limestone blocks in massive and pillow lavas of basaltic andesites of Sevan-Hakari ophiolite zone (the old Sotk pass) were found (Grigoryan, 2005). Olistoliths in the upper flow of the river Shamkhor (Azerbaijan) are revealed as well. Conodont complex in these olistoliths presented by *Epigondolella bidentata, Parvigondolella sp., Ep. sp., primitive Misikella sp.* which are close to the complex described in Sotk *Epigondolella abneptis, Ep. postera, Clarcina naviculla*. Due to the study of conodonts it became clear that in Sevan ophiolite zone Upper Triassic limestones occur more widely. The olistoliths from both sections have identical sedimentary composition and according to the conodonts the same age boundary (lower- Middle Norian stage).

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LATE PERMIAN MICROPALEONTOLOGY (FORAMINIFERA), BIOSTRATIGRAPHY AND PALAEOENVIRONMENTS IN ARMENIA AND GREECE

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The Late Permian is studied in Armenia and Greece, based on the fossil record, for biostratigraphic and palaeoenvironmental purposes. This direct investigation is also supported by numerous bibliographic data in South China, Iran, Turkey, Afghanistan and Uzbekistan.

In Chios Island (Greece), three field sections include microfossiles of both stages of the Late Permian: Wuchiapingian and Changsingian. In this area, located in NW Chios, the Middle Permian was known; but this is the first characterization of the Late Permian. The Wuchiapingian of Chios is composed of rudstone extremely rich in gymnocodiacean algae. Rare small foraminifers confirm this age (especially *Robuloides*). The Changhsingian shows very interesting microfacies with inozoan, richtofeniids, tubiphytids and smaller foraminifers. If the richtofeniid reefs were already described by two or three articles, their assignment to the Changhsingian is made here for the first time. This stage is characterized by an assemblage of smaller foraminifers ("*Angelina*", *Frondina*, *Labioglobivalvulina*, etc.) and rare fusulinids of the genera *Reichelina* and *Shindella*.

In Armenia, the Wuchiapingian age limestones of the Khachik Formation are very rich in small fusulinids (i.e. *Codonofusiella*), as well as many gymnocodiaceans. The Nodosariata confirm the age. The Changsingian (or Dorashamian in Armenia) records facies that are too deep for foraminifers, but the transitional beds from the Wuchiapingian platform to Changsingian paleoslope contain rare Nodosariata (*Polarisella* and *Nodosinelloides*). Furthermore, the Changhsingian of Armenia is very precisely dated and zoned by ammonoids and conodonts.

Based on our microfacies observations, the palaeoenvironments reflected by the studied sequences are reconstructed in a generalized Upper Permian carbonate platform model (from shore to basin). Finally, the studied sequences allow us follow the evolution of palaeonevironments through the Late Permian.

BIOSTRATIGRAPHY OF TRIASSIC SEDIMENTS OF ARMENIA

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Triassic sediments in the territory of Armenia in contrast to the sediments in the territory of Nakhijevan Autonomous Republic have limited development and only in anticlinal structures of Prearaksian subzone (about 1200m) are known. The sequence is represented by Permian-Lower Triassic carbonatic and Upper Triassic regressive coal-mollas formations (500-700m). Lower Triassic is represented by the sediments of Karabaghlar suit (algal, fucoidal, oolitic and dolomite limestones) and Upper Triassic by series of Jermanis (coals, sandstones, argillites, dolomite and organogenic limestones). Induan and Olenekian in Lower Triassic, and Carnian and Norian stages in Upper Triassic are highlighted (Grigoryan, 1990, 2003). Formerly, the presence of only Lower Triassic (Induan stage) and Upper Triassic palaentologicaly was justified, but the «dumb stratum» (pelitomorph, partially dolomite limestone and argillites) are highlighted conditionally according to stratigraphic position, which after according conodont zonal subdivision scheme is referred to Lower Triassic Olenekian stage. A new scheme of detailed stratigraphic subdivision of Lower Triassic deposits compiled based on new microfauna (conodonts) data. Eight conodont zones and three subzones were defined. The scheme is correlating with other same age sections of the world. It is proved that the upper part of south- eastern section of Jermanis belongs to the Norian stage of Upper Triassic, and the north-western part sediments that were considered as Upper Triassic are entitled to the uppermost part of Olenekian stage of Lower Triassic. So, recent studies don't confirm the existence of Middle Triassic in Transcaucasia.

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GLOBAL CHANGES, EARLY WARNING SIGNALS AND THE END-PERMIAN MASS EXTINCTION

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In modern ecology, an increasing emphasis is being placed on the identification and characterization of critical early warning signals (CEWS) in the lead up to catastrophic ecological regime shifts. As a result, an emerging list of CEWS indicators have been proposed, including (but not limited to): ecosystem-wide body size reduction, increased ecosystem-wide abundance reduction and mass mortality, compositional change and increased rate of community replacement, increasingly more frequent and chaotic changes in at least some chemical signals of the environment (e.g., those indicating redox conditions), above-background evolution and taxon turnover rates, critical slowing down(or loss) of some community-wide as well as organism-level ecological and life-history functions (e.g., metabolism, energetics, reproduction, species interactions) coupled by increase of system-wide variability; increased shell malformation, dissolution and/or mineral polymorphism, increased distributional range fragmentation and reduction, increased number of species migrating to higher latitudes and deeper waters, etc. However, many of these proposed CEWS indicators are yet to be tested with the fossil record, especially with respect to mass extinctions. In this paper, I will use the end-Permian mass extinction (EPME) as an example to demonstrate the validity of at least some of the proposed CEWS indicators as possible precursors of catastrophic ecological regime shifts.

Most of previous studies tend to link the EPME to global warming following eruptions of the Siberian Traps volcanism. But, a key question remains: was the Siberian volcanism merely a trigger and accelerator of an ecosystem already doomed to collapse? In other words, would there have been a mass extinction at the Permian-Triassic boundary had the Siberian Traps volcanism not taken place? In this paper I will review recently published evidence in support of key Late Palaeozoic global environmental changes and large scale biotic responses, followed by advocating a synergistic model suggesting that the EPME was an event that had been precipitated by a number of prior global change processes over several millions of years that, on approaching the Permian-Triassic boundary, conspired and accelerated creating a potentially inevitable catastrophic situation in which the global ecosystem was already severely stressed to the brink of collapse. In this context, the widely reported Siberian Traps continental volcanism cannot be regarded as the ultimate and single culprit of the end-Permian mass extinction but merely an accelerator of a process that was already well underway leading towards an inevitable global catastrophe. This scenario naturally leads to an interesting hypothesis that still needs to be tested: that the end-Permian mass extinction represents the final outcome of an earth-bound long-term system decline already heading towards a collapse, a process that was only to be accelerated and exacerbated by the Siberian Traps volcanism. Using one mass-extinction example of deep-time fossil records, this study validates at least some of the proposed ecological indicators to serve as useful critical early warning signals prior to major ecological regime shifts and even mass extinctions.

CRINOIDEA (ECHINODEMATA) EXTINCTION AND RECOVERY OVER THE PERMIAN-TRIASSIC TRANSITION: DATA FROM SOUTH CHINA AND GLOBAL PATTERNS

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This paper rebuilds the extinction and recovery of Crinoidea over the Permian-Triassic transition and summarizes its global patterns by collecting fossil crinoids in Guizhou, South China and analyzing global fossil data of crinoids during this period. Perfect Early-Middle Triassic fossiliferous strata of marine facies is exposed in Qingyan section, Guizhou Province, which is considered as an important area to study the biotic recovery in the aftermath of Permian-Triassic mass extinction. Based on the crinoid fossils collected from the Leidapo Member, Qiangyan Formation, combined with field records from Mingtang Section, Bianyang County, I identified 7 species within 7 genera (within 5 different families) in total. They are *Encrinus* cf. *Liliiformis*, *Qingyanocrinuskueichounensis*, T*yrolecrinuswugangi*, *Holocrinusdoreckae*, *Bangtoupocrinuskokeni*, *Silesiacrinusparvus*, *"Isocrinus" apetalus*, respectively. The morphological changes and size variations of stem column of this group before and after the biotic crisis were described and measured, respectively. The transformation of geographic distributions of crinoids were also analysed, on the basis of the fossil materials we collected , the data sourced from the Palaobiology Database and previous references in terms of the Permian crinoids.

This study suggests that the diameter of crinoid stem column decreased dramatically and the geographic distributions reduced sharply in the aftermath of Permian-Triassic mass extinction. The body size bagan to initially rebound in the Spathian and the geographic ranges expanded as well within the same interval, which show that this group started to recovery in the Spathian, temporally comparable or a bit earlier than other fossil taxa. There is noteworthy that the rebound of this group initially rooted in tropic areas and then gradually expanded to high-latitude zones. Additionally, we discovered two characters within crinoids that originated in the aftermath of the 'Great Dying': the latera of the stem column within *Bangtoupocrinuskokeni* exhibits tubercles, *Qingyanocrinuskueichounensis*bears numerous cirri within only one column. This would represent the new characters asscociated with the adaption and radiation among crinoids, driven by the increase of predatory pressure in the aftermath of the biotic crisis.

Key words： crinoids; Permian-Triassic boundary; mass extinction; recovery; Qingyan, Guizhou Province

REINTERPRETATION OF THE BIOSTRATIGRAPHY AND SEDIMENTOLOGY OF THE UPPER PERMIAN AND LOWER TRIASSIC STRATA OF THE MASORE SECTION, WESTERN SLOVENIA

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Upper Permian and lowermost Triassic strata of the Masore section in western Slovenia have been restudied by means of bio- and lithostratigraphy. The section is mainly characterized by a carbonate succession of the Bellerophon Formation deposited in a shallow ramp environment that was located in the western part of the Palaeo-Tethys. Four types of microfacies have been differentiated in the Bellerophon Formation and microfacies indicate deposition on the well inhabited inner ramp and the reworking of primary biomicrites in the vicinity of small biostromes. Deposition of the bioclast-rich Bellerophon Formation abruptly ceased and was overlain by fossil-poor microbial deposits of the Permian-Triassic boundary (PTB) transition marked by laminated microbialites – stromatolites. The microbial facies was deposited in the mid-part of an unrimmed ramp around a fair-weather wave break.

The conodont elements recovered enabled the recognition of the *Hindeoduspraeparvus* Zone (Late Changhsingian) in the Bellerophon Formation. Gondolellids are documented in the PTB transitional interval with microbial microfacies, whereas the *Isarcicellaisarcica* Zone (Early Griesbachian) is recognized in the tectonically separated Werfen Formation just above the microbial deposit of the section. The conodont faunas are characterized by dominant *Hindeodus-Isarcicella* populations indicating restricted marine environments. The PTB transitional interval beds are marked also by the presence of *Clarkina* suggesting a good communication with the open sea, possibly in a deeper part of an extensive ramp. The recovery of gondolellid elements from the PTB interval of Slovenia has significant global correlation potential.

Foraminifers from the Upper Permian Bellerophon Formation are abundant, diverse, and consist of species characteristic for the Upper Permian, of many regions of the Palaeo-Tethys. Foraminifers from the PTB transitional interval are very scarce and represented by the agglutinated species *Ammodiscuskalhori* and *Hyperamminadeformis,* with rare representatives of the Late Permian calcareous genera *Geinitzina*, *Tristix* and *Globivalvulina,* probably holdover taxa trying to survive in a stressful environment after the mass extinction of calcareous foraminifers.

THE ESTUARINE ENVIRONMENTS: NEW INSIGHTS FROM COMBINING ISOTOPIC, SEDIMENTARY AND BIOSTRATIGRAPHY CONSTRAINS ON THE TROPICAL MIDDLE – LATE PERMIAN TO EARLY TRIASSIC MARGINAL MARINE STRIP OF GONDWANA SUPERCONTINENT

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It is well established that the biology and the geochemistry of oceans have been significantly affected by their estuarine belts, reflecting the relations under terrestrial transported nutrients and C_{org}, CO_2 saturation exchange, and water bodies mixing, all leading to unique biological and geochemical signatures. However, the extent affect and involvement of the eutrophic estuarine belts in the Permian – Triassic studies, attracted less attention than the oligotrophic environments basically due to biostratigraphy correlation constrains.

This work describes a circumtropical Middle and Late Permian- Early Triassic eutrophic estuarine/marine belt from Gondwana margins (David 1, Pleshet 1, and Avdat 1 boreholes; 10's to 100's Km apart, Levant basin, southern extension of the Palmyrides rifting), by combining together $\delta^{13}C_{carb}$, $\delta^{13}C_{org}\delta^{18}O_{carb}$, carbonate content and foraminifera occurrence. Correlation with global events of the period was based on $\delta^{13}C_{carb}$ negative excursions and unique foraminifera distribution. A prominent negative shift of $\delta^{13}C_{carb}$ and $\delta^{18}O_{carb}$ values at the late Guadalupian is indicating a global warming phase, produced maximum terrestrial sediments influxes. A major intense cooling event ("the Kamura event") ended the Guadalupian period, accompanied by significant increase in the carbonate content (up to 80%). The carbonate content profile reflects frequent expansions and contractions of the ITCZ along the period (humidity/aridization respectively in the hinterland) indicating high frequent climate change. At the Kamura event peak, the Guadalupian – Lopingian Boundary occurrence is recognized by the maximum positive increase of the $\delta^{13}C_{carb}$ values, and undoubtedly was associated with a trend of deepening and differential subsidence related to the Palmyrides rifted phase. The following two prominent negative $\delta^{13}C_{carb}$ peaksare attributed to the Wuchiapingian-Changhsingian transition and to the Late Permian Event (LPE), precursor the PTB (Korngreen and Zilberman, 2017). The isotopicprofiles of $\delta^{13}C_{org}$ and$\delta^{13}C_{carb}$ exhibit a change to stratified water column from the LPE to the Early Triassic, in a marginal marine strip, ~400 km wide, as enlighten by the change into mirror trends of the $\delta^{13}C_{org}$ profiles, the enhanced differences of $\delta^{13}C_{carb}$ profiles between proximal/distal settings, and by the $\delta^{18}O_{carb}$ values indicating essential involvement of meteoric water leading to ^{18}O-depleted water.

This work is suggesting that the estuarine belt may be at least additional potential contributor to the negative shift mechanism of the global $\delta^{13}C_{carb}$ excursions, and further research on these zones is required.

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SPATIAL VARIATION IN FORAMINIFERA DISTRIBUTION AND OCCURRENCE IN RESPONSE TO CHANGES IN THE SEDIMENTARY ENVIRONMENTS AND GLOBAL CHANGES; THE TROPICAL MIDDLE – LATE PERMIAN TO EARLY TRIASSIC MARGINAL MARINE STRIP OF GONDWANA SUPERCONTINENT

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Carbonate platforms form in meso-oligo-trophic ecosystems that allow algae-symbiotic organisms to become dominant, augmenting the total carbonate precipitation; therefore, although their limited representativeness of the worldwide-life they become very attractive for scientific research.

However, proximal marginal marine environments attached to supercontinents are under eutrophic conditions, developing stressed conditions to the symbiotic organisms and oppressing the carbonate precipitation.

This work describes the occurrence pattern of foraminifera during the M-L Permian, PTB and Early Triassic events in Gondwana margins facing the western NeoTethys seaway (David 1and Pleshet 1 boreholes, Levant basin), represents circum tropical marginal marine environment with constant terrestrial siliciclastic contribution (ranging 10% - 90%) exhibits a sequence of environmental changes from positive to inverse estuarine environments associated with global climate changes and correlated with global C-cycle perturbation based on stable isotope-stratigraphy (Korngreen and Zilberman, 2017; see also Korngreen et al., this meeting).

Declining of all foraminifera classes characterized events of increase siliciclastic influxes coupled with global warming trend and C-cycle perturbation, i.e. during the Middle-Upper Guadalupian events, during the Wuchiapingian-Changhsingian transition, the Late Permian, the PTB and the Early Triassic events. In sever global warming trends, the declining of foraminifera variety turned to barren intervals in the proximal locations during the middle Guadalupian, lattermost Permian through the PTB.

Outstanding global cooling trend (6°C?) was identified at the upper part of the Guadalupian (equivalent to the “Kamura Event”), increasing the carbonate content (up to 90%) and the variety of foraminifera. The Fusulinoida exhibit dominance of Schubertellida, flowering here in the relative shallower and apparently cooler setting; the Ozawainellida occurs in small species number and characterizes the assemblages with the deepening trend. Noteworthy, the paleotextularids (esp. *Paraglobuvalvulinamira*) displayed much adaptation to the intermediate eutrophic environments (up to 40% siliciclasts).

In general, Milioloida variety tended to increase during global cooling periods and Lagenoida increased during global warming trends. In times of Fusulinoida flowering, both noticeably decreased. The relatively high variety of the fusulinids kept through the Gouadalupian – Lopingian boundary, gradually declined afterward similar to the Tethys and the peri-Gondwana provinces, disappeared at the Late Permian Event (LPE) in proximal setting, survived the LPE at deep location, but all disappears before the PTB. The first to recover after the PTB were the Milioloida alone in proximal setting, and associated with Lagenoida and Ammodiscoidea in the relatively distal location.

WUCHIAPINGIAN ZECHSTEIN LIMESTONE REEFS IN WESTERN POLAND

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The Zechstein Limestone (Wuchiapingian) reefs of the Brandenburg-Wolsztyn-Pogorzela High (western Poland) originated following the sudden inundation of the Late Permian intra-continental topographic depression in northwestern and Central Europe by seawater around 258 Ma. Microencruster communities dominated by sessile foraminifers played an important role in the colonization of new niches. Botryoidal aragonitic cementation played a very important role in the first phase of reef formation. This phase was dominated by bryozoans and terminated suddenly; one possible reason was that a relative change of sea level – first a fall and then a rise – disturbed the upwelling circulation. Consequently, bioclastic deposition predominated for a relatively long time until the second phase of bryozoan reef development occurred, but the latter was not accompanied by dubious early cementation. Subsequently, microbial reefs developed and abound in the upper part of the Zechstein Limestone sections. The general shallowing-upward nature of deposition in the reef area resulted in reef-flat conditions with ubiquitous, microbial deposits, in the central parts of the reefs. Then, the reef-flat started to prograde and eventually the entire reefs area became the site of very shallow, subaqueous deposition.

Microbialites, laminar and nodose encrustations, were important in the growth and cohesion of the Zechstein Limestone reefs. In many cases, the real nature of those encrustations is difficult to ascertain. These laminated encrustations show great similarity to *Archaeolithoporella* that is one of the most important Permian reef-building organisms. The Permian shelf margin carbonate buildups of the Guadalupe Mountains in west Texas and southeastern New Mexico are the best-known examples of the microbial-dominated reef and its slope and a highly productive microbial boundstone factory extends there from the platform break down the slope to nearly 300 m (or more) depth; in the case of the Wolsztyn High, the depth of the lower slope was between 100 m and 200 m as indicated by seismic sections. The estimated rate of progradation was 400 m/My. This value is slightly lower than progradation rates counted for the Capitan reef margin, but relief of the slope was considerably lower in the Zechstein case than in the Capitan margin.

Many reefs show features that reflect the tectonic instability, such as formation of neptunian dykes, fracturing and brecciation. Particular blocks constituting the High could show varied subsidence, which manifested itself during deposition of the lower Zechstein strata. In a more shallow setting, the assumed varied subsidence resulted, for example, in the origin of the carbonate breccia complex. Possibly, the generally deeper location of some reefs at the onset of reef formation resulted in the lack of botryoidal aragonitic cementation.

BIOTA OF PERMIAN REEFS IN THE ZECHSTEIN BASIN (POLAND, GERMANY AND LITHUANIA) AND WESTERN TETHYS (CROATIA AND SLOVENIA)

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The Permian reef biotas are very distinctive communities of organisms at the end of the Paleozoic. Their taxonomic diversity is very large. They carry a lot of information about life in the Late Palaeozoic seas shortly before the great extinction. In spite of the relatively short distance between the basins of the Zechstein and the Western Tethys, the groups of organisms occurring in them differ substantially. In the Zechstein basin, the reefs fastly developed during the deposition of Zechstein Limestone (Ca1), in the Wuchapingian times (Peryt et al, 2012). In the Croatian and Slovenian Tethys the reefs developed mainly in the Middle Permian, but survived to the end of the Palaeozoic (Sremac et al, 2016).The Zechstein reefs are primarily made of the remains ofbryozoans, and in the upper part of microbialites. Algae other than cyanobacteria are rare. These reefs form one of the longest reef systems in the world (along the edge of the shelf platform) and a series of isolated reefs inside the basin. The thickness of reef limestones sometimes exceeds 100m. They A number of biofacies, characterized by different types of bryozoans (stenolemnates, mostly fenestelids and acanthocladids) and brachiopods (mostly strophomenids and terebratulids), can be distinguished. The bryozoans and brachiopods are accompanied by molluscs and echinoderms. The remains of rich organism communities are building the lower and middle parts of the reef, upper parts are dominated by thetaxonomically poor communities of mollusks occurring in microbial mats. In Croatia and Slovenia the Permian reefs were formed over a longer period of time. These were mainly reefs forming on carbonate shelf platforms. Large reef bodies are uncovered in Slovenia (the middle Permian around Bled), smaller in Croatia (e.g. the central Velebit). The main reef builders are sponges, which are accompanied by algae, brachiopods, bryozoans and molluscs. The bryozoans are less frequent; the brachiopods communities also clearly differ from the Zechstein assemblages. Higher parts of the reefs are dominated by microbial mats. In both basins the dominant reef communities are organisms that are characteristic for restriction zones. The factors limiting the development of other groups of organisms were different. In the Zechstein basin, the bottom was settled after a violent transgression that carried cool waters far south to the tropics. Short sedimentation time of the Zechstein Limestone (Ca1) did not allowed for the adaptation of more taxa. At the equatorial areas of the Tethys basin, the high water temperature was a factor influencing the restoration, which eliminated a large number of potential reef builders. In both cases the domination of microbialites in the upper part of the profile was associated with a decrease in sea level during regression. The associated salinity increase was an additional factor impoverishing the palaeontological record.

THE LATE DEVONIAN BRACHIOPODS OF ARMENIA REVISITED: PRELIMINARY RESULTS FROM THE SEVAKAVAN SECTION

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Armenia offers exceptional outcrops of Upper Devonian sequences, which are particularly abundant in brachiopods. They have the potential to provide valuable insights in the understanding of Devonian mass extinction events. The Upper Devonian sedimentary rocks of Armenia accumulated on a shallow water platform that was located at the northern margin of Gondwana; they are shallow marine deposits of mixed carbonate/terrigenous origin. The Upper Devonian to Lower Carboniferous biostratigraphy of Armenia was previously studied by Abramyan (1957, 1964) and Arakelyan (1964). In the present study, we focus on an Upper Devonian sequence that crops out at the Sevakavan section in order to understand the biodiversity of brachiopods in their modern taxonomic framework; the Sevakavan section has potential to reveal the brachiopod biotic response during the Hangenberg mass extinction event. 157 brachiopod specimens were collected recently from the Sevakavan section; they belong to 2 classes, 5 orders, 8 families, 11 genera and 19 species. Some of the identified species were discovered for the first time in the Sevakavan section. These brachiopods may be assigned to two biozones of the regional biozonation of Rzhonsnitskaya & Mamedov (2000): the *Paurogastroderhynchus nalivkini* and *Spinocarinifera nigra Sphenospira julii* biozones. The former biozone is characterized by the presence of the index species *Paurogastroderhynchus nalivkini* (Abrahamyan), while the latter biozone is based on the occurrence of the brachiopod assemblage *Spinocarinifera niger* (Gosselet), *Sphenospira julii* (Dehee), *Athyris lamellosa* (L'Eveilla), *Camarotoechia pleurodron* (Phillips), *Camarotoechia panderi* (Semenov &Meller), *Camarotoechia delicatacostata* (Abrahamyan), *Athyris sulcifera* var. *intermedia* (Nalivkini), *Aulacella interlineate* (Sowerby), *Gruntathyris innae* (Gretchishnikova) and *Athyris gurdoni* (Reed). All these brachiopods mentioned above are characteristic of the Late Famennian.

A SUDDEN END-PERMIAN MASS EXTINCTION IN SOUTH CHINA

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Previous studies of the end-Permian mass extinction have established that it was geologically rapid, but condensed sections have made it difficult to establish the exact timing of the extinction relative to fluctuations in the ocean carbon cycle, oxygen levels, and temperature. Integrated high-precision U-Pb geochronology, biostratigraphy, and chemostratigraphy from a highly expanded section at Penglaitan, Guangxi, South China reveal a sudden end-Permian mass extinction that occurred at 251.939 ± 0.031 Ma, which is temporally coincident with the extinction recorded in Bed 25 of Meishan. Despite the significantly expanded nature of the section and extensive collecting of more than ten major marine fossil groups, there is no evidence of biotic diversity decline prior to the extinction interval and no Permian-type species survive the extinction at this location. Fossil range data suggest a nearly instantaneous extinction at the top of an interval limited to 31±31 kyr. The extinction was preceded by and/or accompanied by fluctuations in $\delta^{13}C_{carb}$ and $\delta^{13}C_{org}$ of 2-3‰, and 3-5ºC in seawater temperature. A larger, more rapid seawater temperature rise of 6-8 ºC immediately followed the extinction level at Penglaitan. The extinction is marked by a thick pyroclastic flow unit accumulated during a massive volcanic eruption event and is correlative with an ash layer (Bed 25) in the deeper water setting at Meishan, where some Permian-type organisms survived the extinction. Our study reveals that the survivability of Permian taxa after the major pulse is highly variable and dependent upon the severity of

environmental perturbation in different sedimentary settings. The sudden extinction may fit an ecological surprise model in which the onset of Siberian Traps and South China intensive volcanism *ca* 420 kyr before the extinction may have diminished the ecological resilience of communities and reducing the ecological function with little change in diversity. However, once the environmental stress reached a limit, a single environmental disturbance may have triggered the sudden collapse of global ecosystems disturbance may have triggered the sudden collapse of global ecosystems.

THE GEOTECTONIC EVOLUTION OF THE DINARIDIC PART OF WESTERN TETHYS FROM THE EARLY PERMIAN TO THE LATE TRIASSIC

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Investigating the Middle Triassic volcanic and volcaniclastic rocks in the External Dinarides (Croatia and Bosnia and Herzegovina) an undeveloped rift system has been determined. This rift system was formed as a back-arc extension in the north-western edge of Palaeotethys Ocean (Stampfli & Borel, 2002; Schmidt et al., 2008).Geochemical data (whole rock REE and trace element composition and EMP analysis on pyroxene and feldspar crystals and crystaloclasts of different volcanic and volcaniclastic facies) indicate calc-alkaline magma composition, characteristic for subduction zones and contamination by the crustal material. Therefore we interpret the development of Middle Triassic rift in the Dinarides as a back-arc rift area that was strongly influenced by the subduction of the Palaeotethys toward north that started in Early Permian and lasted throughout the whole Triassic. The geotectonic history of this part of Tethys is described as follows:

In the Upper Permian and Early Triassic the Dinarides were located in the western Palaeotethys. According to the palinspastic reconstructions (Haas et al., 1995; Scotese, 2002; Stampfli&Borel, 2002; Schmidt et al., 2008; Stampfli et al., 2013) this Palaeotethyan area represented a shallow bay resembling a vast epicontinental sea, in the Dinarides, interpreted as a broad epeiric ramp (Aljinović et al., 2015). In the southern part of this ocean rifting started in the Permian between the Cimmerian block and the southwest coast of Pangea. This rift system (Neotethys) advanced to the north and finally formed the Tethyan Ocean in the Jurassic.

From afore mentioned palaeogeographic reconstructions it is notable that the subduction of Palaeotethys persisted throughout the Triassic. This subduction process could have triggered the magma formation in the Middle Triassic. The former subduction, which caused the formation of Pangea could have also left the imprint on the Middle Triassic magma composition (Crisci et al., 1984). Palinspastic reconstructions place the area of the External Dinarides, and surrounding areas in the vicinity of earlier Gondwana and Laurasia suture line, having the similar direction asthe newly formed Tethyan rift. The subduction of the Gondwana crustal material and its partial melting had great influence on the Middle Triassic magma in the western Tethys. Along with the primary rifting there were additional extensional/rift systems in the continental part of Pangea.There were three recorded back-arc rift zones in the Middle Triassic: Meliata and Meliac Oceans, and the rift system directed across the Dinaridic and Alpine area. The area of the External Dinarides was bordered by the opening of the Tethyan Ocean from the southwest and opening of the Meliata and Maliac Oceans in the north. The External Dinaridic aborted rift did not evolve since these two compressive movements forced its closure.

PERMIAN FUSULINES FROM EASTERN MYANMAR AND THEIR GEOLOGICAL IMPLICATIONS

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The palaeogeographic evolution of the Qinghai-Tibet plateau during the Late Paleozoic has been a focus of detabes in recent decades. Especially for the Lhasa Block, latest several studies, including geochemistry, sedimentology and paleontology, have indicated that the Lhasa Block was attached to the Western Australia rather than the Indian Plate before its rifting from Gondwanan margin (Zhu et al., 2011, 2013; Zhang et al., 2013; Liao et al., 2015). Then, a significant question is raised with respect to the relationship between the Lhasa Block and the Sibumasu Block.

In order to unravel the relationship between the Sibumasu block and the Tibetan blocks, a fieldwork was undertaken in the Shan State of eastern Myanmar, which is a main part of the Sibumasu Block.

In the Hopang area of northeast Myanmar, abundant *Cancellina*species were found in the limestone. The associating genera include *Pseudofusulina*, *Parafusulina, Nankinella*and *Toriyamaia.* The dominance of *Cancellina* and absence of both *Misellina* and *Neoschwagerina* indicate a Kubergandian (Late Kungurian) age. The Middle Permian (Wordian) fusulines in several areas in the Thitsipin Limestone Formation are dominated by abundant *Eopolydiexodina* species.

The *Cancellina* fauna were also documented from the South Qiangtang Block (Zhang et al., 2012) and Southeast Pamir (Leven, 1967). But they have never been reported from the Lhasa Block. Insteadly, the Lhasa Block were dominated by a relatively cool water environment during the Late Kungurian as evidenced by cool-water brachiopod and solitary corals (Zhang et al., 2013; Yuan et al., 2016). The different faunal palaeobiogeography between the Sibumasu, South Qiangtang Block and the Lhasa Block may suggest that the Bangong-Nujiang Ocean may have opened before Late Kungurian.

This conclusion is also supported by the Middle Permian fusulines. *Eopolydiexodina* was widely reported from the western Thailand, eastern Myanmar, Baoshan Block, South Qiangtang Block (Ueno, 2003; Cheng et al., 2005). But, this genus has never been reported from the Lhasa Block. Interestingly, another *Nankinella-Chusenella*fusuline assemblage was documented from several areas in the Lhasa Block such as Tsochen, Xainza and Bashor areas, as well as northern Tengchong Block (Zhu, 1982; Huang et al., 2007; Zhang et al., 2010, 2017, in review). However, this assemblage was not reported from the South Qiangtang, Baoshan and Sibumasu blocks. The different Middle Permian fusuline assemblage between the South Qiangtang-Baoshan-Sibumasu blocks and Lhasa-Tengchong blocks also suggest the presence of Bangong-Nujiang Ocean during the Middle Permian.

KEYWORDS: Myanmar, Tibet, Sibumasu Block, Permian, paleogeography

ACKNOWLEDGMENT

This research work is jointly funded by Strategic priority Research Program (B) of the Chinese Academy of Sciences (XDB18000000, XDB03010102), National Science Foundation of China (41472029, 41420104003, 41290260), China Geological Survey (1212011121257, DD20160015), and Youth Innovation Promotion Association CAS for ZYC (2016282).

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PERMIAN–TRIASSIC BOUNDARY MICROBIALITESIN SOUTH CHINA: SEDIMENTOLOGICAND GEOCHEMISTRYFEATURES AFTER THE END-PERMIAN BIOCRISIS

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Unusual sedimentary deposits such as stromatolites, thrombolites, dendrolites, and giant ooidsare widely distributed in platform facies of Permian–Triassic boundary (PTB) beds worldwide. However, the genesis of these PTB microbialites and the oceanographic conditions linking them to the PTB mass extinction still remain enigmatic despite intense study. Here, we present a new example of astromatolite-dendrolite-thrombolite-giant ooid association from the PTB beds of the Yudongzi section in the northwestern Yangtze Platform, South China. The Yudongzi microbialites rest on an irregular contact with underlying Permian bioclastic limestone and are comprised of lower bedded stromatolite, digitatedendrolite, upper bedded stromatolite, and thrombolite units. Abundant microproblematica are found in the microbialites and are thought to represent calcimicrobe structures and are tentatively identified as *Gakhumella*. Each *Gakhumella* individual has densely arranged segments forming a columnar- to fan-shaped micro-structure. The microbial structure was first documented occurrence of *Gakhumella* within PTB limestones. Other microbial structures are *Renalcis*, coccoid-like spheroids, bacterial clump-like spheroids (BCLS), and peloids. The PTB microbialites are capped by shelly grainstone and a massive giant oolite, implying that the demise of the Yudongzi microbialites may be due to destruction by strong wave currents in a high energy setting. Some ooids are coated unevenly by micritic laminae (or envelopes) indicating the possibility of a microbe-related origin.
We also present geochemical data and test the size of pyrite framboids, focusing on microbialites. Our geochemical analysis shows that Ce/Ce* ratios of microbial carbonate range from 0.6 to 1, suggesting suboxic to anoxic seawaters on the carbonate platform. Detailed study of size distributions of 2972 pyrite framboids found in 31 horizons in Yudongzi section, were also performed to evaluate the paleo-redox condition of the shallow-marine environment. Mean diameters of pyrite framboids from microbialites are 5.5-9.4, indicating dysoxic water columns.

Keywords: Permian–Triassic boundary microbialites, *Gakhumella*, *Renalcis*, REE, Pyrite framboids, Yudongzi section, South China

MAJOR MICROBE-METAZOAN TRANSITIONS FROM THE PRECAMBRIAN TO PRESENT DAY: CHINESE RECORDS RESPONSE TO GLOBAL EVENTS

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Growing evidence shows that biotic activities are involved in most, if not all, sedimentation processes from the ancient geological past to the present day. As reflected in recent publications, organism-induced sedimentation (also termed Biosedimentology) has attracted increasing interest from global geologists. This study focuses on organism (including microbial) involvement in sedimentation throughout Earth's history from the Proterozoic to the present-day with an emphasis on well-preserved examples from China. Both metazoan-induced carbonate and microbial carbonate are the most important proxies revealing oceanic geochemical conditions and biological process during the physic sedimentation. They are one of most common sedimentary rocks in the geological records and occur alternatingly in the deep-time sedimentary successions. These two types of sedimentary rocks therefore are important target materials in revealing the relationships among organism, environment and climate regime. Biosedimentary records show that sedimentary system and ecosystem have undergone at least five major microbe-metazoan transitions (MMTs) from the Precambrian to present. The first MMT witnessed the rise of complex multicellar organisms in the microbial mat-dominated ecosystems in late Ediacaran, the last period of the Precambrian. Microbial participation is crucial in the establishment of metazoan-dominated ecosystem and in the preservation of late Ediacaran animal embryos. Since the early Cambrian explosion, the sea floors of shallow seas changed from matgrounds to highly bioturbated substrates through the early to middle stages of the Cambrian. Microbial and metazoan reefs are exceptional, and their alternate occurrences characterize the Cambrian MMT. The rest three MMTs are linked with three major biotic extinction and environmental stresses, and occurred in the aftermaths of the Ordovician-Silurian (O-S), Frasinia-Famennian (F-F), and Permian-Triassic (P-Tr). The MMTs seem to be more profound from the Silurian to Triassic. In contrast, both 16 the Triassic-Jurassic and Cretaceous-Paleogene (C-Pg) mass extinctions did not resultin the deposition of typical MMTs in their aftermaths. This brief review concerns biological processes in physical sedimentation throughout the geological past to the present day and their possible consequences and controls. It emphasizes three aspects: (1) microbially mediated and microbially induced sedimentary records (i.e., microbial mats, microbialites, oolites, oncolites), (2) metazoan build-ups (i.e., reefs, bioherms, and carbonate platforms), and (3) (bio) geochemical signals of extreme environment and climate changes during the critical transitions. Ultimately, we hope that these biosedimentologic records advance global knowledge on biotic involvement in sedimentation during critical life and environmental turning transitions, and will provide strategies to help manage the current global extreme events and subsequent restoration of marine ecosystems.

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Notes