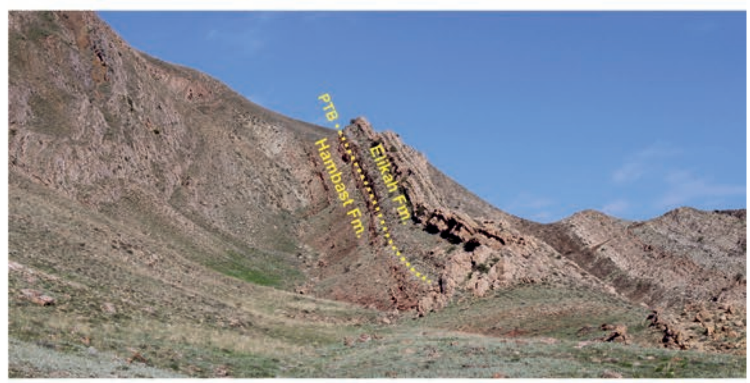
Permophiles

International Commission on Stratigraphy



Newsletter of the Subcommission on Permian Stratigraphy

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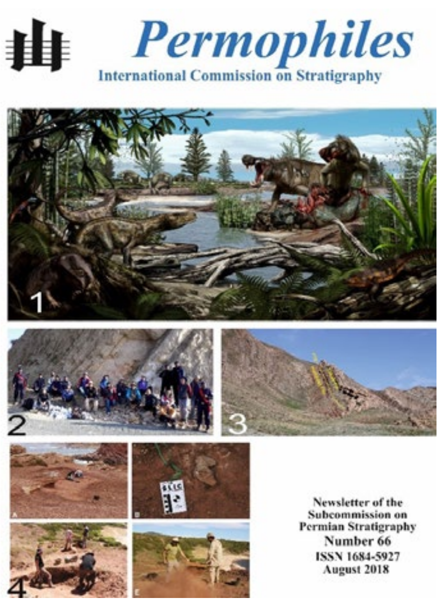

Fig. 1. The reconstructed Lopingian lush equatorial ecosystem at the Bletterbach site. Artwork by Davide Bonadonna. Bernardi et al., this issue.
Fig. 2. Participants to a joint field excursion was organized by the Department of Earth Sciences, COMSATS Institute of Information Technology, Abbottabad, Pakistan, the Nanjing Institute of Geology and Palaeontology, and the Institute of Tibetan Plateau Research of the Chinese Academy of Sciences during March, 2018. Courtesy S. Shen.
Fig. 3. Hambast and Elikah formations at the Zal section and the putative Permian-Triassic boundary. Gennari et al., this issue.
Fig. 4. Recovery and preliminary analysis of the sphenacodontid material from Nurra area, NW Sardinia. Romano et al., this issue.

Notes from the SPS Secretary

Lucia Angiolini

Introduction and thanks

This issue was prepared during an exceptionally hot summer - exceptional at least for Europe - via email, as Shuzhong Shen and I did not have the opportunity to meet *de visu*. We delayed its publication in order to include the abstracts of the 8th International Brachiopod Congress, 11- 14 September 2018, Milano, Italy, which form the supplement to this issue, as was the case for the last International Brachiopod Congress held in China in 2015. One hundred-forty brachiopodologists from all over the world will attend the congress (from Canada, New Zealand, China, Japan, USA, Argentina, Iran, Armenia, Israel, Russia, France, Italy, Poland, Hungary, Sweden, Spain, Germany, Denmark, Austria, Slovakia, Czech Republic, United Kingdom, and Belgium), for which 3 plenary talks, 11 keynotes, 65 oral presentations and 47 poster presentations are scheduled.

This delay had the advantage in allowing more contributions for this issue, and my warm thanks go to Charles Henderson, Geoffrey Warrington, Marco Romano and co-authors, Michael Stephenson, Spencer Lucas, Massimo Bernardi and co-authors, and Valerio Gennari and co-authors.

I would like to thank Claudio Garbelli for his assistance in also editing this issue of Permophiles.

Finally, I would like to keep drawing your attention to the new SPS webpage that Shuzhong Shen has provided at http://permian.stratigraphy.org/, where you can find information about Permophiles, what's going on in the Permian Subcommission, an updated version of the list with addresses of the SPS corresponding members, and the updated Permian timescale.

Previous and forthcoming SPS Meetings

A forthcoming SPS meeting is scheduled during the 8th International Brachiopod Congress, held in Milano, Italy from 11 to 14 September 2018. A second SPS business meeting will be organized during Strati 2019, 3th International Congress on Stratigraphy, Milano, 2-5 July 2019.

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This issue starts with the IUGS ratification of the Global Stratotype Section and Point (GSSP) for the base-Sakmarian Stage (Lower Permian) released on 22 July 2018.

It continues with the fourth harangue of Charles Henderson who deals with time and resolution, enhancing the importance of deep time, of its outstanding and incomparable record which should be analyzed with the highest possible resolution. Charles also voices the possibility that stratigraphic resolution down to thousands and maybe even hundreds of years in the Permian may not be a dream.

The next contribution is by Geoffrey Warrington who is completing a revised edition of 'A correlation of Permian rocks in the British Isles', started by the late Denys Smith. In this report, Geoffrey discusses some interesting aspects of the revision, including recent advances on the palynological study of the British Permian succession and the magnetostratigraphy of the upper part of the Exeter Group and the Aylesbeare Mudstone Group, which allowed identification of the Illawara Superchron.

Marco Romano and co-authors present a very detail report of the state of the art of their important research on the Lower to Middle Permian continental deposits of NW Sardinia. Once thought to contain only rare fossils, their very detailed work and several field campaigns have revealed a very interesting vertebrate association with a very large animal, *Alierasaurus ronchii,* and a representative of Sphenacodontidae, as well as several ichnofossils.

Michael Stephenson, who along with Charles Henderson and Spencer Lucas, is one of the most prolific contributors to Permophiles issues, discusses the age of lower part of the glacigene Al Khlata Formation, Oman, focusing on the problematic occurrence of the Visean taxon *Indotriradites daemonii* alongside monosaccate pollen, which are known to appear first in the early Namurian/Serpukhovian.

The report by Spencer Lucas introduces a new subject to Permian readers, dealing with the review of the distribution and biostratigraphy of Permian charophytes, fresh and brackish water green algae. The author shows that, even though charophyte biostratigraphy is at a very early stage of development, their Permian record seems to be promising and it allows the establishment of several biotic events in the Early and Late Permian.

Massimo Bernardi and co-authors present a report of an excursion that visited Permian-Triassic outcrops in the Dolomites, organized for the XVIII Congress of the Italian Paleontological Society, at Trento, NE Italy, June 6–8, 2018, in which I had the pleasure to participate. The field trip visited the Upper Permian succession of the Bletterbach gorge and a new PTB section recently discovered near Tramin/Termeno in the Adige valley.

In the next report, Valerio Gennari and co-authors, report about fieldwork performed by the Italian-Iranian working group in the Permian-Triassic successions of Zal and Ajabshir (NW Iran) and Abadeh (Central Iran), which is of outstanding importance for calibrating the Middle Permian, the Late Permian and the PTB in the Tethyan Realm. The authors underscore the importance of small benthic foraminiferal assemblages as biostratigraphic indices.

Finally and very sadly, two obituaries commemorate eminent experts on Carboniferous, Permian and Triassic stratigraphy and palaeontology, Maurizio Gaetani and John Roberts, who passed away at the end of 2017 and in 2018.

Future issues of Permophiles

The next issue of Permophiles will be the 67th issue.

Contributions from Permian workers are very important to move Permian studies forward and to improve correlation and the resolution of the Permian Timescale, so I kindly invite our colleagues in the Permian community to contribute papers, reports, comments and communications.

The deadline for submission to **Issue 67** is **31th December, 2018**. Manuscripts and figures can be submitted via email address (lucia.angiolini@unimi.it) as attachments.

To format the manuscripts, please follow the TEMPLATE that you can find on the new SPS webpage at http://permian.stratigraphy.org/ under Publications.

We welcome your contributions, your letters, comments, answers and advices to improve our communication as we move forward.

Notes from the SPS Chair

Shuzhong Shen

First of all, I am pleased to announce that the Sakmarian-base GSSP has been formally ratified by ICS with 100% approval and by IUGS on July 21, 2018. Congratulations to our Russian colleagues! Thanks to the Sakmarian-base Working Group for their long-term hard work. This is the first GSSP established in Russia and it has been 13 years since the last Permian GSSP (Wuchiapingian Stage) was approved. The base of the Sakmarian Stage is defined by the FAD of the conodont *Mesogondolella monstra* at 55.4 mab in Bed 26/3 of the Usolka section in southern Urals, Russia.

We still have the Artinskian- and Kungurian-base GSSPs to be defined in the Permian System. We hope the next major work for SPS is to move the Artinskian- and Kungurian-base GSSPs forward as soon as possible. Meanwhile, new problems for other ratified old GSSPs have emerged. The most serious problem is that the FAD of the conodont *Jinogondolella aserrata* at the Getaway Ledge section, Texas cannot be confirmed after tens of samples were collected and processed.

We are deeply saddened to hear that two distinguished Permian colleagues passed away recently. Profs. Maurizio Gaetani and John Roberts, both made remarkable contributions to numerous Permian issues and brachiopod faunas. In deepest sympathy, we express our heartfelt condolence to their families (see two obituaries of Profs. Gaetani and Roberts in this issue).

Some new progress on Permian stratigraphy and timescale has been made recently. A comprehensive publication on the Permian System has been published in the Special Publications series of the Geological Society of London, edited by Spencer Lucas and Shuzhong Shen (http://sp.lyellcollection.org/content/450/1). This volume reviews the state of the art of the Permian timescale, biostratigraphy based on different biotas, and provides the international timescale of the Permian System. Meanwhile, a review paper on Permian integrative stratigraphy and the timescale of China is online already too (https://link.springer.com/article/10.1007/s11430-017-9228-4). This paper summarizes the Permian stratigraphy and timescale of China and also provides a correlation with the international timescale. A volume on the timescale of China from Ediacaran to Quaternary will be available soon, together with the Permian timescale.

A joint field excursion was organized by the Department of Earth Sciences, COMSATS Institute of Information Technology, Abbottabad, Pakistan, the Nanjing Institute of Geology and Palaeontology, and the Institute of Tibetan Plateau Research of the Chinese Academy of Sciences during March, 2018. This excursion mainly investigated the Precambrian/Cambrian, Permian/Triassic and Paleocene/Eocene boundary sequences in Pakistan. I would thank Prof. Ishtiaq A.K Jadoon, Dr. Muhammad Qasim and other Pakistan colleagues for their hospitality and careful safety protection, and sincere thanks also go to Prof. Ding Lin of Institute of the Tibetan Plateau Research for his guidance during the field work (see picture on the cover).

Many thanks to Lucia Angiolini, Gaia Crippa and Claudio Garbelli for their hard work in compiling the whole volume of abstracts of the 8th International Brachiopod Congress which will be held in Milano in September, 2018. Thanks to all contributors of this issue of Permophiles. We hope we can get more contributions from you. Your comments and opinions are very important for the Permian community to move Permian issues forward.

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July 21, 2018

Prof. Philipp Gibbard
Secretary-General, International Commission on Stratigraphy of the IUGS

Dear Prof. Gibbard.

I am pleased to inform you that the IUGS Executive Committee has voted unanimously to ratify the GSSP proposal for the base of the Sakmarian Stage (Permian) as approved by the International Commission on Stratigraphy and forwarded to the IUGS EC on 30 June 2018.

Congratulations to the International Commission on Stratigraphy. Also please send congratulations from the IUGS EC to Dr. Shu-Zhong Shen, Chair of the International Subcommission on Permian Stratigraphy, and to Dr. Valery V. Chernykh, lead author on the ratified GSSP proposal.

Sincerely,

Stanley C. Finney
Secretary General of IUGS

International Union of Geological Sciences

REPORTS

Henderson's Harangue #4

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Introduction

As an attempt to stimulate debate or perhaps simply because something smells fishy, I deliver my fourth harangue. In Italian, it would be "L' arringa di Henderson" (the double "r" is important).

I just came back from a roadtrip where I was investigating a Permian-Triassic succession in the Cache Creek Group of south-central British Columbia with a team of students and former students. It was hot (36C) and the smoke of many forest fires in southern British Columbia lingered in the air, filling our nostrils and irritating our eyes. We persevered and as good geologists, we got the job done and collected many samples. These smoky hot summers are becoming the norm recently and many regard this as a signal of climate change. How many summers does it take before we know for sure that this is really climate change rather than a short-term weather pattern? Quaternary geologists, climatologists, and biologists are studying these patterns and considering the effects on life. They have the benefit of studying in near-time or current time and measure resolution at the millennial to decadal scale. I thought more about this as I enjoyed a nice smoky and peaty Islay scotch one evening after collecting some Upper Permian rocks.

Deep Time versus Near Time Resolution

Deep-time researchers do not have such resolution at their disposal, but it is getting a whole lot better. Climate change researchers do not feel that the resolution in deep time is sufficient to answer complex climate questions and therefore there is little collaboration among these groups. However, in addition to increasing levels of resolution, deep time researchers enjoy the fact that the climate experiment they study has run its full course – we can see the good times, the extinction, and the recovery. The greatest extinction in Earth's history occurred very close to the end of the Permian and it is all about climate change. According to the most recent geochronologic data (Burgess et al., 2014) this event occurred between 251.941 Ma +/- .037 Myr and 251.880 Ma +/- .031 Myr – an interval of 60 +/- 48 Kyrs. That is very precise for a deep time event occurring nearly 252 million years ago. However, we don't have to say "about 252 Myrs ago" now, and we most certainly don't have to say "approximately 250 million years ago" as was the case in a paper I recently rejected during a review. Such a date is closer to the Induan-Olenekian boundary (see below). There has been a concerted effort by many to produce the volumes edited by Felix Gradstein and others in the Geological Time Scale (2004, 2012 and 2020 in progress). As geoscientists, we need to use these volumes and we need to find ways to resolve outstanding correlation and definition issues. If we want to join the climate-wagon (anthropogenic versus natural post-ice age warming or a combination), or at least to contribute with comparisons to help determine the long-term effects of climate change, then we need to use every bit of resolution we can in excellent sections that are sampled at incredible detail.

It is very likely that the end-Permian mass extinction (EPME) was diachronous at some level. Just as arctic regions today are warming more quickly than equatorial regions, it is possible that effects were greater at some locations before others during the Late Permian. Having worked extensively on Permian-Triassic successions in arctic and western Canada, I can attest to the fact that most biodiversity was lost well before the EPME as recognized in the Tethys. If we had studied this extinction in the Canadian Arctic first, we might call it the MPME or mid-Permian mass extinction. There were only a couple of conodont species, a few trace makers and demosponges left to witness the EPME in the Sverdrup Basin – and even then, there is evidence that the EPME signature preceded the same in the Tethys (see Algeo et al., 2012), but maybe only by a short time interval. The recovery from the EPME seems also to be quite diachronous from region to region and in different environments. The critical question to understand the dynamics of this recovery comes down to timing – finding sufficient resolution in the rock record. Diversity and organism size profiles seem to increase soon after the PTB (251.902 Ma +/- .023 Myrs) in some settings, near the Induan-Olenekian boundary in some regions, and much later in other areas. The IOB is poorly dated, but may have an age of 250 Ma – only 1.941 Myrs after the EPME and 1.902 Myrs after the PTB. So please editors, don't send me anymore papers to review that say the extinction occurred nearly 250 million years ago. We have to do better to be serious geoscientists.

How much better can we get? Integrating research on geochemical signatures, magnetic reversals, biostratigraphic events, geochronologic analyses, sequence stratigraphy, and cyclostratigraphy may reveal an answer. The latter discipline has great potential. Neogene workers have been astronomically tuning the excellent successions around the Mediterranean for many years now.

The cyclothems of the Late Pennsylvanian and Early Permian appear to demonstrate a consistent 405 Kyr long eccentricity signal. A student of mine (Chen Shen) recently "tuned" the Early Triassic of northeastern British Columbia, recognizing 100 Kyr short eccentricity, 33 Kyr obliquity, and 20 Kyr precession signals. He used XRF-elemental data that was collected every centimetre of a continuous 390 metre thick core of the Montney Formation for his analysis. He was able to show many obliquity cycles in key intervals of the Montney, which will prove of value for correlation regionally and possibly globally, given that they likely represent intervals at obliquity modulation maxima. Correlation of 33 Kyr cycles seems like very good resolution for the Early Triassic, but these trends were analyzed from data collected every centimetre; on average, every centimetre in this core represents about 125 years. We can't correlate these centimetres of shaly siltstone, but can we be so bold as to consider the possibilities.

Epilogue

To come closer to realize those possibilities we will need more PTMs (people, time and money). Maybe the next harangue could be about the inadequate funding model provided to geologists.

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On aspects of the Permian in the British Isles

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Introduction

Preparation of a revised edition of 'A correlation of Permian rocks in the British Isles' (Smith et al., 1974. Geological Society, London, Special Report No. 5) was begun by its senior author, Denys Smith, who contributed so much to our knowledge of the Zechstein succession in eastern and northeastern England (McLean, 2008). Denys had drafted revisions of some parts of the report before illness delayed and eventually prevented him from completing the work as he would have wished; he died in 2007. The writer was privileged to be asked to complete this revision. This has involved incorporating new information into the parts Denys had drafted, writing some missing sections, preparing new correlation diagrams and compiling an updated and expanded biobliography.

Aspects of the revision

During the course of the revision summaries of some of the work undertaken, including reviews of the chronology of the Permian in Devon, south-west England (Warrington, 2005, 2018a; Warrington and Scrivener, 2007) and the British contribution to the Global Devonian, Carboniferous and Permian Correlation Project (Warrington et al., 2007, 2012), have been published.

A review of the palaeontology of Permian successions in the British Isles and contiguous offshore areas forms part of the revision and has resulted in modification of some earlier age attributions. This review includes palynological records which the writer is also compiling for a proposed Micropalaeontological Society Special Publication ('Spores and Pollen of Great Britain'). He made presentations on this topic at a Micropalaeontological Society meeting (2012) and the joint 50th Annual Meeting of AASP – The Palynological Society, with CIMP and the Micropalaeontological Society Palynology Group (2017), held at the British Geological Survey, Nottingham. Summaries of this work appeared, with relevant bibliographies, in the CIMP (Commission Internationale de la Microflore du Paléozoique) newsletter (Warrington, 2015, 2018b). The writer has carried out a palynological study of the Permian succession in the Hilton Borehole at Hilton Beck in the Vale of Eden, Cumbria (Warrington, 2008), and contributed on palynological and other aspects of the Permian for the British Geological Survey memoir for the Nottingham district (Howard et al., 2009). He is currently assisting Martha Gibson, a PhD student at Sheffield University, who is working on the palynology of the Zechstein succession in eastern England (CIMP Newsletter no. 86, p. 10; no. 87, p. 9).

An important advance in the understanding of the Permian succession in south-west England follows the publication of the full results of a study of the magnetostratigraphy of the upper part of the Exeter Group and the succeeding Aylesbeare Mudstone Group (Hounslow et al., 2017). Only a summary of the Aylesbeare Mudstone results had been available previously (Hounslow et al., 1998). This has built upon earlier work on the Exeter Group carried out mainly by Cornwell (1967), the 'Cornwall' in Hounslow et al. (2017). The new study has identified the end of the Kiaman Superchron at a level near the top of the Exeter Group and has aided interpretation of the chronology of the Aylesbeare Mudstone which lacks biostratigraphical or other age control. The work formed part of a project suggested by the writer and commissioned by the British Geological Survey with the objective of locating the Permian – Triassic boundary in an unfossiliferous succession between beds in the upper Exeter Group, with palynological evidence of a Permian age, and ones in the Sherwood Sandstone Group, above the Aylesbeare Mudstone, with mid-Triassic magnetostratigraphical and biostratigraphical evidence of age (Hounslow and McIntosh, 2003; Barton et al., 2011). The Aylesbeare Mudstone Group had been regarded as Permian, Late Permian to Early Triassic or Triassic in age by different workers. Warrington and Scrivener (1990, fig. 2), for example, illustrated it in the Triassic but indicated uncertainty and stated that the system boundary was 'undefined'. With the availability of the summary of the magnetostratigraphy of the group (Hounslow et al., 1998) it became apparent that the Aylebeare Mudstone is Permian in age and the latest Permian and earliest Triassic are absent. This was discussed in a review of the chronology of the Permian and Triassic of Devon (Warrington, 2005) and illustrated by Warrington et al. (2012, fig. 3). Hounslow et al. (2017) also reached this conclusion but did not refer to those contributions and only discussed that by Warrington and Scrivener (1990) which they had superseded.

Warrington (2018a) has reviewed the isotopic dating and the biostratigraphical and magnetostratigraphical information now available from the Devon succession. The Exe Breccia, at the top of the Exeter Group, is the earliest unit with the magnetostratigraphical characteristics of the Illawara Superchron. This marks the end of the Kiaman Superchron, at *c.* 267 Ma (Hounslow et al., 2017) and provides confirmation of the minimum age of the miospore occurrences in the upper part of that group which had been regarded as Mid-Permian (Roadian(?) or early Wordian) (Warrington, 2018a). It also places an upper limit on the age of formations in the Exeter Group below the Exe Breccia. These span *c.* 32 myrs, though with a major gap between the lower part of the group which contains dated (Sakmarian to Artinskian) volcanic rocks, and the upper part for which palynology indicates a maximum age of early mid-Permian; the Kungurian may be unrepresented (Warrington 2018a, fig. 1). The Aylesbeare Mudstone is succeeded unconformably by the Chester Formation, formerly the Budleigh Salterton

Pebble Beds (Ambrose et al., 2014). Warrington et al. (2012, fig. 3) concluded that this hiatus extends from the late Lopingian into the Early Triassic and that the Permian-Triassic boundary is not represented in the rock succession. Hounslow et al. (2017, fig. 11) and Hounslow and Balabanov (2018, fig. 7) have illustrated a comparable situation, with a Capitanian to Wuchiapingian age assigned to the Aylesbeare Mudstone and the system boundary, between the Changhsingian and the Induan stages, not represented in the rock succession seen at outcrop.

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Permian tetrapod localities in the Nurra region (NW Sardinia, Italy): The State of the Art

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Introduction

The Nurra area in NW Sardinia is quite well known for the outcropping of a thick succession of more than 600 m of post-Variscan continental deposits (Fig. 1), with several dedicated studies and contribution already starting from the first half of the twentieth century (e.g. Lotti, 1931; Oosterbaan, 1936; Pecorini, 1962; Vardabasso, 1966; Gasperi and Gelmini, 1980). An intensive

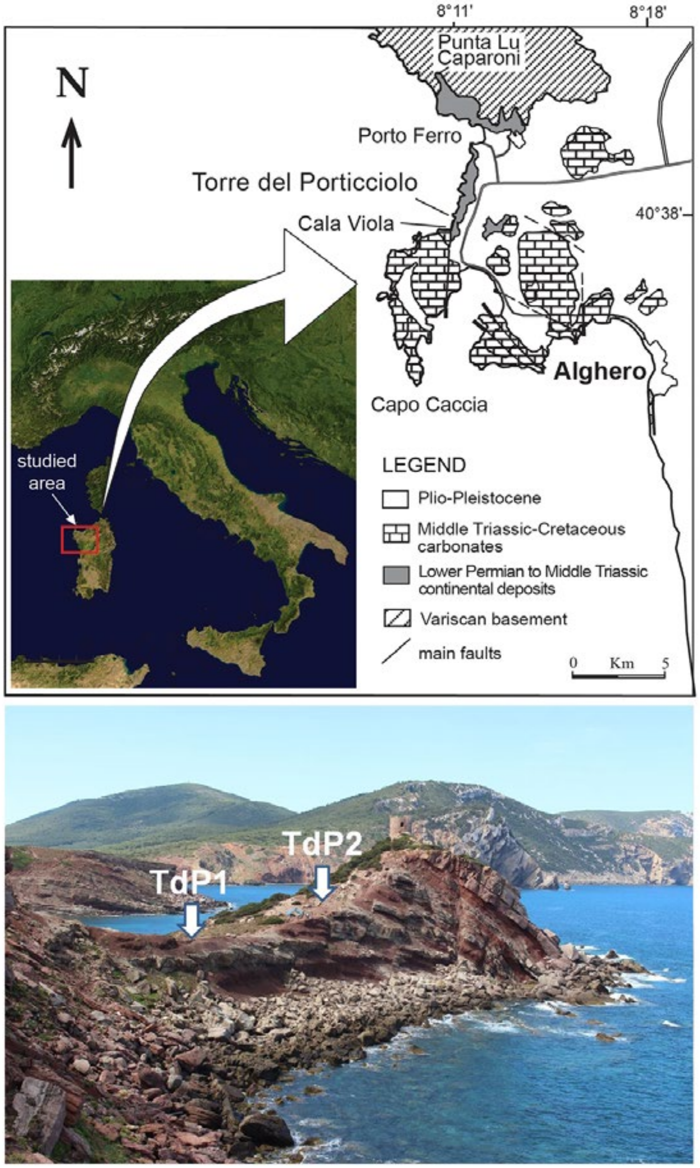

Fig.1. Simplified geological setting of the Nurra area, modified from Romano et al. (2018, fig. 1) (top); location of the two productive sites for osteological material TdP1 and TdP2 (bottom).

research program in the last 20 years has led to a better understanding and definition of the sedimentology and stratigraphy of the area, with the 600-m-thick Permian and Triassic continental succession subdivided in the following six formations (from base to top): Punta Lu Caparon., Pedru Siligu, Porto Ferro, and Cala del Vino formations for the Permian, and the Conglomerato del Porticciolo and Arenarie di Cala Viola for the Triassic (Gasperi and Gelmini, 1980; Cassinis et al., 2002a, 2003). The careful sedimentological analysis of the Permian-Triassic succession of the Nurra area allowed lithostratigraphic correlation with the deposits outcropping around Toulon in Provence (Cassinis et al., 2002a, 2003; Durand, 2006, 2008), with the Cala del Vino Fm. showing quite superimposable lithofacies and fluvial architecture to the one characterizing the Saint-Mandrier Fm. (Durand, 2008).

Despite intensive study of the area especially in the last twenty years, the fossiliferous content of the outcropping deposits in the Nurra is historically rare, and for a long time was essentially represented by macrofloral and microfloral remains from the basal portion of the Punta Lu Caparoni Fm (Gasperi and Gelmini, 1980; Pecorini, 1962; Ronchi et al., 1998) providing a middle Autunian age, and in the upper portion of Arenarie di Cala Viola, indicating an Early Triassic age (Pecorini, 1962). This situation changed dramatically and unexpectedly when, in 2008, a student from the University of Pavia found accidentally eight articulated vertebrae, still partially embedded in the red Permian sediments of the Cala del Vino Formation, outcropping in the Torre del Porticciolo promontory (Fig. 2). Since that day, more than fifteen field works have been conducted in the area, headed by a team of the Department of Earth Sciences of Sapienza of Rome in collaboration with the University of Pavia, to collect a truly unique material for both Italian and European Permian panorama. Overall, about eighty bones were recovered, both complete and fragmentary, all referable to the post-cranial skeleton of a very huge animal (Fig. 2). The preparation and study of the material allowed the description and formalization of a new taxon of the Family Caseidae, *Alierasaurus ronchii* (Romano and Nicosia, 2014) from 'Aliera' or 'Alighera', the old traditional name of the city of Alghero in Sardinia, and Ronchi in honor of Prof. Ausonio Ronchi from Pavia who reported us the new discovery.

In 2015, during a field work to collect additional material referable to the huge caseids, a second productive site (Torre del Porticciolo 2, TdP2) was discovered about hundred metres from the original *Alierasaurus* site (TdP1) (Fig. 1, bottom). Field works conducted in the new site in 2016 and 2017 led to the recovery of several bones and bone fragments both still embedded in the original deposits, and isolated elements in the deposit deriving from the erosion of the productive sedimentary body (see Romano et al., 2018) (Fig. 3). Despite a system of normal alpine fault displacing the meandering river deposits, the productive sedimentary bodies of TdP1 and TdP2 can be referred essentially to the same stratigraphic level (see Romano, 2018, fig. 4). A detailed taphonomic analysis allowed to refer all the recovered material to the same and single individual; in addition, a preliminary study of the most diagnostic elements among the already prepared bones allowed to refer the new specimen to a member of the Sphenacodontidae (Romano et al., 2018). Sphenacodontids are a crucial clade of highly predaceous non-therapsids synapsids (traditionally known as "pelycosaurs"), essentially known from the Permian beds outcropping extensively in the south-western United States. The new finding represents the first record of the group in Italy, throwing new light on the occurrence and dispersal of the clade in the European continent.

In the summer of 2017, during the excavation of skeletal remains at TdP2 locality, palaeontological survey was conducted along the sedimentary succession outcropping towards SSW and a reddish sandstone slab bearing an isolated tetrapod track was found as loose material. The prospecting was then focused in the area of the discovery and yielded two joined slabs preserving two couples of footprints (Fig. 4), coming from a very close horizon to the bone-bearing ones (TdP3), about one kilometre from TdP1 and TdP2 localities.

The new material constitutes the first ichnological evidence from the Permian of Sardinia and provides a more comprehensive

Fig. 2. Recovery of post cranial material referred to the giant caseid *Alierasaurus ronchii* from the siteTdP1. In top left, the first eight articulated caudal vertebrae found in 2008.

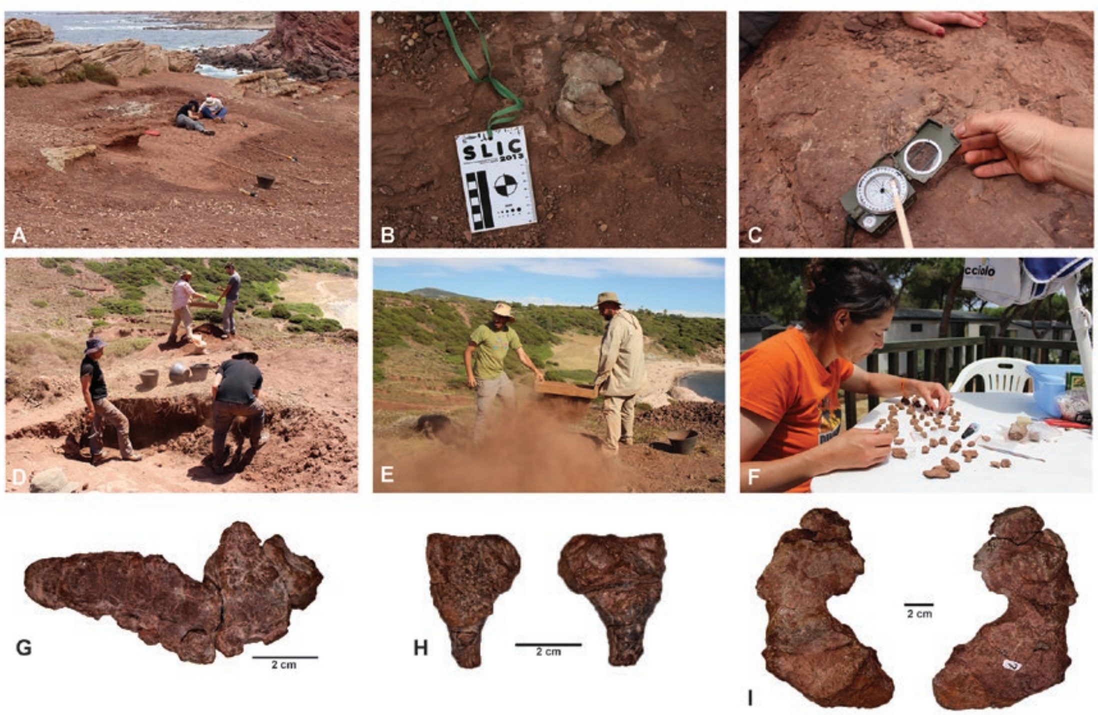

Fig. 3. Recovery and preliminary analysis of the sphenacodontid material from the site TdP2. A) Initial cleaning of an outcrop surface of about 40 square meters; B) a partial left portion of the pelvis in its original disposition within the productive sedimentary body; C) Before being extracted from the sediment, all the original orientations of each individual bone in the sediment were measured and recorded; D) digging and analysis of the debris deposited at the base of the productive sedimentary body; E) about seven cubic meters of debris were excavated and sifted in detail, using a sieve with 0.5 cm meshes which led to the recovery of several small bones and fragments; F) many of the recovered fragments were compatible and, after a long process of puzzling, it was possible to reconstruct even larger and diagnostic elements; G) Partial right maxilla MUST NS 166/8 in lateral view; H) isolated anterior tooth MUST NS 166/9 in lateral (left) and medial (right) view; I) portion of the left pelvis MUST NS 166/7 in lateral (left) and medial (right) view. MUST NS = Museum of Paleontology, University of Rome, Rome, Italy, New Series.

understanding of the faunal composition of the Cala del Vino Fm. As a matter of facts, the Torre del Porticciolo site turned out to be one of the few, rare, sites in Europe where both body fossils and ichnofossils are jointly preserved, enhancing our knowledge about the Permian faunal diversity and ecosystem structure in this area of Pangea.

***Alierasaurus ronchii*: the giant of "pelycosaurs"**

The first accounts on the new large caseid from Sardinia was provided by Ronchi et al. (2008) and Ronchi et al (2011). Ronchi et al. (2011) describe in detail the geology and taphonomy of the first site at Torre del Porticciolo area (TdP1), showing how all the material collected can be referred to the same individual. The taphonomic analysis highlighted a series of complex biostratinomic processes (see Ronchi et al, 2011) including: i) a first energetic transport phase, from the place of death to a second place, which caused the breaking of some long bones when the collagen was still present; ii) a phase of decay with ablation of the fragile haemal arches (broken during the energetic first transport); iii) a flooding episode (a flash-flood) who took in charge the bone material and buried them along with fine grained sediment, leading to the final deposit in a in a third place; this last event would explain why the bones are found scattered at various depths in the productive body.

Ronchi et al. (2011) in addition figure and briefly describe some vertebral, ribs and pedal material of the new caeseid, stressing the great affinities with the large North American caseids. The authors preliminary refer the new specimen to as ?*Cotylorhynchus* sp. Stovall, 1937. Ronchi et al. (2011) also discuss the stratigraphic occurrence of both North American and European caseids; using the North American Land Vertebrate faunochrons proposed by Lucas (2006), the authors suggest a late Kungurian–Roadian age for the upper part of the Cala del Vino Formation, and discuss the implication for the litostratigraphic correlation with the Permian-Triassic succession outcropping in Provence.

Romano and Nicosia (2014) provide the first detailed description of the new material with the formalization of the new caseid *Alierasaurus ronchii*. The author stress how great part of the preserved post-cranial material, especially conformation in ribs and foot elements are fully compatible with the known anatomy of large north American caseids, in particular with that characterizing the genus *Cotylorhynchus*. However, *Alierasaurus* shows apomorphic character, especially in the autopodial elements, supporting the erection of a new genus and species of Caseidae. Romano and Nicosia (2014) discuss the huge size of the new taxon comparable only to the giant North American species *Cotylorhynchus hancocki*, more than six meters in total length. The author in addition stress how the conformation of preserved large ribs allow to infer a very large "barrel-shaped" rib cage, indicating an high-fibers herbivorous diet (see Hotton et al., 1997; Sues and Reisz, 1998).

Romano et al. (2017) describe further postcranial material referable to *Alierasaurus*, collected during several field works in PdP1 site, and from the same sedimentary body in which the holotype was found. The new material confirms the attribution of all the collected bones to the same individual, based on the same kind of preservation and on the lack of double ore repeated elements. New diagnostic material includes caudal neural spine showing a broad bifid distal termination, a synapomorphy characterizing the more derived caseids. Even if the collected material is quite limited, and no diagnostic skull material was available, a phylogenetic analysis including the fragmentary Sardinian taxon was conducted using a recent cladistics analysis of Caseidae performed by Romano and Nicosia (2015). *Alierasaurus* posits in sister group relationship with the North American genus *Cotylorhynchus*, and result autapomorphic with the monophyletic Caseidae in the gen-

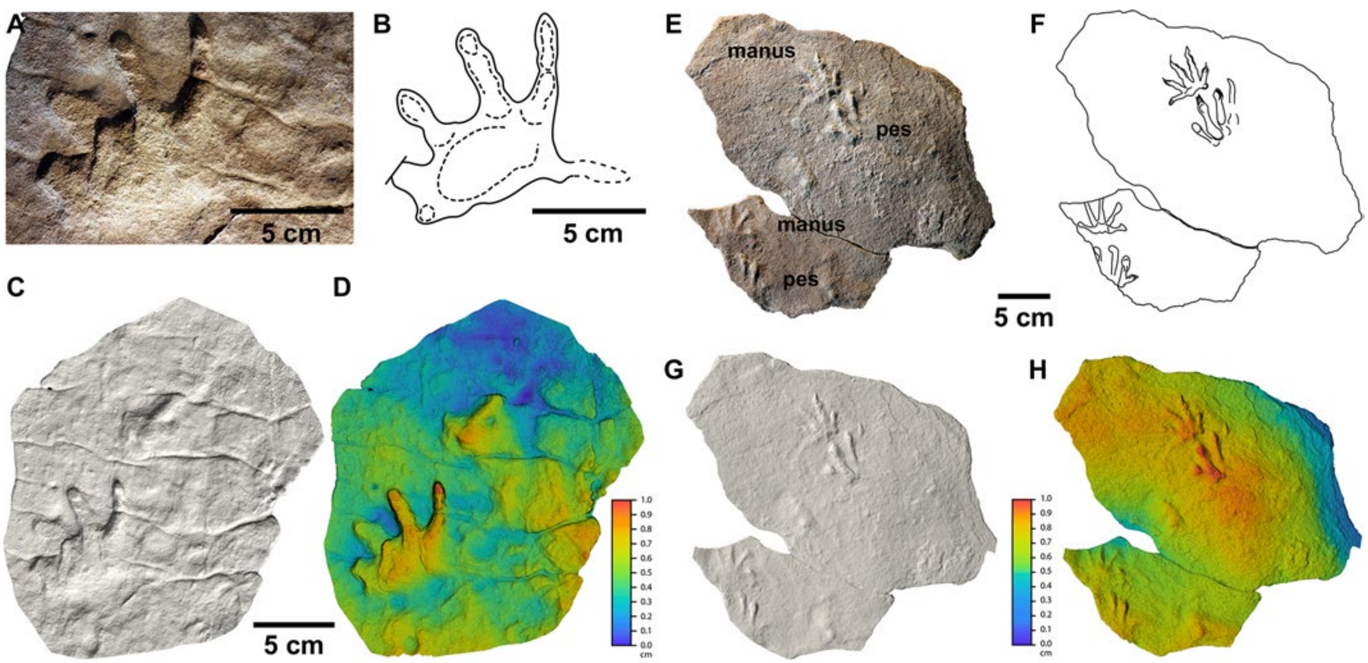

Fig. 4. Ichnological material from TdP3 site. A, isolated pes track found as loose material; B, interpretative drawing of the footprint; C, solid three-dimensional model; D, colour topographic profile with contour lines. E, manus-pes sets of smaller dimension; F, interpretative drawing of the footprints; G, solid three-dimensional model; H, colour topographic profile with contour lines.

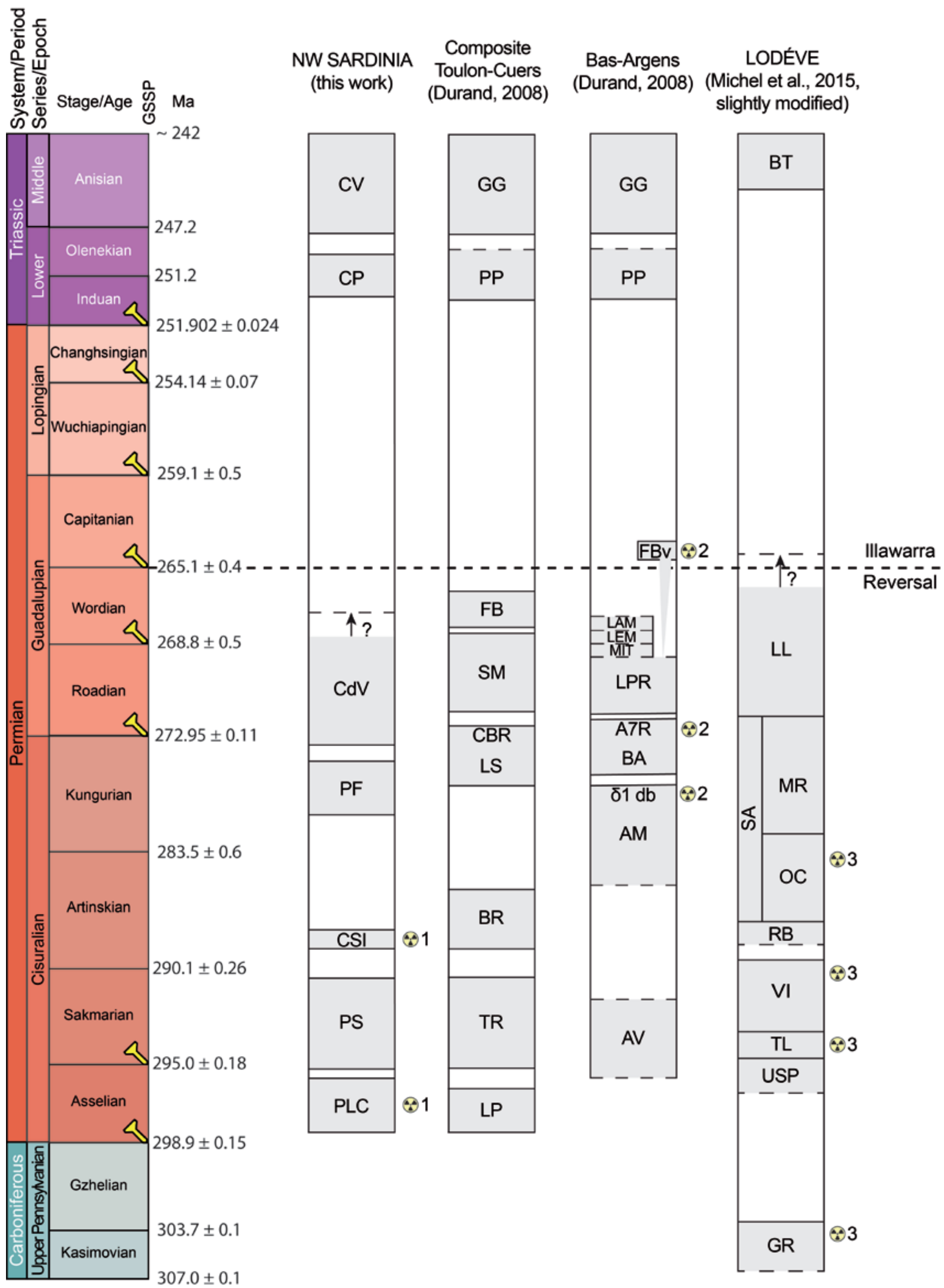

Fig. 5. Continental successions from Nurra (NW Sardinia) and French basins. Radiometric data available from: 1 - Gaggero et al. (2017); 2 – Zheng et al. (1992); 3 – Michel et al. (2015). Dashed blue lines superimposed to the ICC v2017/02 indicate the base of the Roadian and the Roadian-Wordian boundary according to Davydov et al. (2018). Lithostratigraphic units: A7R - A7 Rhyolite; AM - Ambon Fm.; AV - L'Avellan Fm.; BA - Bayonne Fm.; BR - Bron Fm.; BT - 'Buntsandstein'; CBR - Calcaires du Bau Rouge Mb.; CdV - Cala del Vino Fm.; CP - Conglomerato del Porticciolo; CSI - Casa Satta Ignimbrite; CV - Cala Viola Sandstone; δ1 db - δ1 doleritic basalt; FB - Fabregas Fm.; FBv - Fluorite-Barite vain with adularia; GG - Gres de Gonfaron; GR - Graissessac Fm.; LAM - La Motte Fm; LEM - Le Muy Fm.; LL - La Lieude Fm.; LP - Les Pellegrins Fm.; LPR - Les Pradineaux Fm.; LS - Les Salettes Fm.; MIT - Le Mitan Fm.; MR - Merifons Mb.; OC - Octon Mb.; PF - Porto Ferro Fm.; PLC - Punta Lu Caparoni Fm.; PP - Poudingue du Portissol; PS - Pedru Siligu Fm; RB - Rabejac Fm.; SA - Salagou Fm; SM - Saint-Mandrier Fm.; TL - Tuilieres-Loiras Fm.; TR - Transy Fm.; USP - Usclas-St. Privat Fm.; VI - Viala Fm.

eral construction of MT-IV and proximal phalanx IV-I.

The new collected material, especially a very big dorsal rib, confirms the extremely huge size of the Sardinian caseids, and a first *in vivo* restoration was provided in collaboration with the Italian artist Emiliano Troco (Romano et al., 2017, fig. 11). On the base of the possible reconstruction and comparison with published material or stored at museum collection, *Alierasaurus* resulted as one of the larger "pelycosaurs" ever found, with an estimated length that could reach seven meters, thus also bigger than the giant Nord American species *Cotylorhynchus hancocki* (Romano et al. 2017). The authors also discuss the huge body size reached by some members of caseids, and the ecological and general physiological advantage of large body size, not simply in relation to a specialized herbivorous lifestyle.

The first sphenacodontids of Italy

Field works activities in the new site (TdP2) were carried out in two principal phases (see Romano et al., 2018). A first phase consisted in the cleaning of an outcrop surface of about 40 square meters (Fig. 3A), followed by a careful excavation of the sediment in place; the process led to the recovery of about 30 bones, with both complete and fragmentary elements. Before being extracted from the sediment, all the original orientations of each individual bone were measured and recorded (Fig. 3C). A second phase consisted in the digging and analysis of the debris deposited at the base of the productive sedimentary body. In total, about seven cubic meters of debris were excavated and sifted in detail, using a sieve with 0.5 cm meshes (Fig. 3D-E). Many of the recovered fragments were compatible and, after a long process of puzzling (Fig. 3F), it was possible to reconstruct even larger and diagnostic elements such as a right maxillary, a portion of a left pelvis and a femur (Romano et al., 2018). The careful study of the various taphonomic evidence initially represented a very big puzzle, since some of these evidences seemed in open contradiction for the reconstruction of a single and unitary process. In particular, the evidence suggests the following elements: i) a very short ablation time, considering that long bones, ribs and autopodial elements, which are usually the first to be disarticulated, are preserved in the same place and some still in articulation (such as metapodials and phalanges); this indicates that some sort of ligaments, or soft tissues, had to be present at the time of burial. This element is also indicated by vertebral centra slightly deformed when the collagen was still to be present in the bones; ii) a relatively short time of sub-aerial exposure, and an early burial, indicated by the absence of superficial flaking or cracking (due to the bones weathering; rank "0" in the classic weathering scale of Behrensmeyer, 1978), lack of spiral fractures, and lack of biological reworking of bones, with no traces of scavenging or other type of bio-erosion. The essentially fragmentary state of the bones indicates a condition of fracture and general breakage of the material affecting more than 80% of the recovered bones. Both the bones recovered still embedded within sediment, and those coming from the debris, show straight and clean fractures, orthogonal to the long axis; these elements indicate fractures occurred in total absence of collagen, when the material was already diagenized.

The set of evidences were interpreted by Romano et al. (2018) according to the following multiphasic taphonomic process: i) the animal died very close to the flooding zone, without any transport of the body (no bones broken when the collagen was still present, as differently found for the large caseid in the first site); ii) the body, partly disarticulated partly still in articulation, was taken in charge and buried by a flooding after a short period of subaerial exposure, which prevented the bones to be scattered, to undergo weathering or to be reworked by scavengers; iii) in the buried skeleton some bones were deformed by the weight of the sediments when the collagen was still present, and the entire skeleton underwent processes of early diagenesis; iv) subsequently, the body was exhumed and transported by a very energetic current during another flooding event, which led to the formation of a crevasse-splay. The bone remains, and the embedding sediments, were transported by a high-density flow for a very short distance, and then re-deposited a second time in proximity of the main channel. To this stage are referred all the observable fractures in the already diagenized bones, found broken within the sedimentary deposits (see Romano et al., 2018, fig. 7).

Romano et al. (2018) also provide a brief description of some informative bones among the already prepared material. One of the most diagnostic element is a portion of the right maxilla, with 10 preserved teeth still in place, showing only the proximal portion of the crown preserved (Fig. 3G). In more basal "pelycosaurs", such as Eothyrididae, Caseidae and Edaphosauridae, the ventral margin of the maxilla is essentially straight; differently in the more derived clades the margin is slightly to consistently convex (Romer and Price, 1940; Reisz, 1986). In particular, the rather convex lower margin, that characterizes the maxilla in the new specimen, results a typical feature of the carnivorous group Sphenacodontidae. Furthermore, the most anterior portion of the ventral margin of the maxilla curves sharply upward, forming a peculiar notch in the bone profile. This structure is fully reminiscent of the so-called "maxillary step", a typical and exclusive feature of sphenacodontids within non-therapsid synapsids, to accommodate the anterior larger marginal teeth. The preserved basal portion of the teeth is strongly labio-lingually compressed, another typical feature of sphenacodontids, and the number of preserved marginal teeth in the maxilla are compatible with the classical count in the well-known genera *Dimetrodon* and *Sphenacodon*. On the base of such diagnostic characters of the maxilla, Romano et al. (2018) preliminary referred the new specimen to an indeterminate sphenacodontid.

The first Permian tetrapod footprints from Sardinia

The ichnological material from TdP3 locality, consisting of a single isolated pes track (Fig. 4A-D) and two complete manus-pes sets (Fig. 4E-H) all preserved as convex hyporeliefs, was described and discussed by Citton et al. (2018). The isolated track is impressed on a medium-grained, reddish sandstone slab, while the two sets are preserved on a grey-reddish, fine- to medium-grained and poorly cemented sandstone. On the whole, the footprints are wider than long. Pes tracks are tetradactyl to pentadactyl, with digit length increasing from digit I to digit IV; digit III and IV are comparable in size, while digit V is longer than digit I and comparable to digit II. Digit traces have slightly pointed digit tips and are straight, even if the central ones (i.e. digit II, III and IV) can be slightly medially bended at their tips.

In some cases, digit tips appear rounded, most likely as a result of a powerful kick-off phase and of a deeper entrance of digits into the sediments during trampling. Digital bases I-IV are associated with sub-circular traces, on the whole arranged in an arched way, which were most likely left by the metatarsal-phalangeal joints of the trackmaker autopod. Manus tracks are pentadactyl showing digit traces increasing in length from digit I to IV, with digit V longer than digit I. Digit are straight and, as observed in the hind prints, are characterized by pointed distal tips. A distinctive character of both fore and hind prints is the subparallel orientation of digit I with respect to the footprint proximal margin. Glenoacetabular distance, obtained from the manus-pes sets, indicated a trunk length of about 19 centimetres and suggested a trackmaker of about 50 centimetres in total body length. The isolated pes track, larger than the other footprints, most likely indicated a trackmaker one metre in total body length.

Citton et al. (2018) identified several characters shared with footprints collected from the uppermost portion of the Permian succession in the Lodève Basin (i.e., La Lieude Fm.) and referred by Gand et al. (2000) to as *Merifontichnus thalerius.* The variability observed in some track features(e.g. digit I orientation, morphology of digit tips and orientation with respect to the midline) was deemed consistent with the internal variability of the ichnotaxon, as illustrated by Gand et al. (2000) based on the type material, and finally enabled the authors to refer the ichnological material from TdP3 locality to as *Merifontichnus*, excluding at the same time other Late Palaeozoic ichnotaxa (see Citton et al., 2018). Moreover, previous ichnotaxonomic attributions to *Merifontichnus* of footprints from Northern Italy were rejected (see Citton et al., 2018) and the material from TdP3 locality turned out to be the first reliable report of the ichnogenus from Italy.

Concluding remarks and future directions

Known for over a century for the spectacular outcropping of Permian-Triassic deposits and for the almost total absence of fossil remains, the area of Nurra in the last decade of field work turned out to be otherwise of primary importance for the study of late Palaeozoic tetrapods in the European context. In fact, whereas the large part of non-therapsid synapsids is known from the highly productive site in North American, European basal synapsids are historically rare, with very few sites in western, northern, and central Europe (see a complete list in Romano et al., 2018). Considering the very poor European record fossil for basal synapsids, the new findings from the island of Sardinian are crucial to shed new light on the group evolution and dispersal outside of North America.

The finding and description of the first caseid from Italy, *Alierasaurus ronchii*, provides the first biochronological constrains for the age of the Cala del Vino Formation. In particular, the finding indicated the presence of a large hiatus between the Cala del Vino Fm. and the Triassic Conglomerato del Porticciolo, with a gap of about 20 million years. In addition *Alierasaurus* prove to be the largest "pelycosaurs" described to date, throwing new light on increasing body size within herbivorous non-therapisd synapsids.

The new finding from the second site (TdP2) represent the second basal synapsid from Sardinia and the first sphenacodontid from Italy. As briefly reported above, the great part of the sphenacodontid material comes from North America, with just five sphenacodontid taxa described from Europe, represented by *Neosaurus* from Moissey, France (see Leidy, 1854; Fritsch, 1889; Nopcsa, 1923; Fröbisch et al., 2011; Sphenacodontidae indeterminate in Falconnet, 2015), *Dimetrodon teutonis* from Thuringia, Germany (Berman et al., 2001; Berman et al., 2004), *Macromerion* from Kounová, Czech Republic (very poor material), *Cryptovenator hirschbergeri* from the Rhineland Palatinate, Germany (Fröbisch et al., 2011), and *Sphenacodon* (previously "*Oxyodon*" *brittanicus*, see von Huene, 1908; Paton, 1974) from England. In addition Falconnet (2015) reported three further specimens from Lodève Basin (France), referred to Sphenacodontidae indeterminate. The new specimen from Sardinia thus represent the ninth occurrence of the clade in the European continent. In addition, considering the late Kungurian–Roadian inferred age for the Cala del Vino Formation, the Sardinian specimen would represents the youngest sphenacodontids in Europe, throwing new light on the occurrence of the clade.

In Sardinia, calibration of Upper Palaeozoic continental deposits was based on tetrapod footprints, skeletal and plant remains, and radiometric ages in the Nurra region obtained from rhyolitic ignimbrites (see Citton et al., 2018 and references therein). A lithostratigraphic correlation between Permian and Triassic succession of Nurra region and southern Provence was already proposed by Cassinis et al. (2002a, 2003) and Durand (2006, 2008), which correlated the Cala del Vino Fm. to the Saint Mandrier Fm. of the Toulon-Cuers Basin (Fig. 5). The lower portion of this last unit was also correlated to the Les Pradineaux Fm. of the Estérel Basin in Provence (Durand, 2006, 2008). This unit was tentatively referred to the Wordian based on the available ichnoassemblage (Gand et al., 1995), palynological and palaeobotanical evidences (Visscher, 1968; Toutin Morin et al., 1994), as well as for an ostracod association (Lethiers et al., 1993). However, the Les Pradineaux Fm. lies above the A7 Rhyolite, dated Roadian (272.5 Ma; Zheng et al., 1992) and is cutted by a fluorite-barite vein with adularia dated about 264 Ma (Zheng et al., 1992) (Fig. 5). In the Lodéve Basin (Hérault, SW France), tetrapod tracks were reported from different lithostratigraphic units, comprising the Salagou Fm. and the La Lieude Fm, from which *Merifontichnus* was erected. These units were referred by Roscher and Schneider (2006) respectively to an age between the Kungurian and the Wuchiapingian (i.e. Salagou Fm.) and to the Wuchiapingian p.p. - Changhsingian p.p. (i.e. La Lieude Fm); however, the chronostratigraphy of the succession was recently revised by Michel et al. (2015), who ascribed the topmost part of the Salagou Fm. in the Roadian and the uppermost portion of the La Lieude Fm. around the Capitanian base (Fig. 5). This age is in agreement with the ichnoassociation of the La Lieude Fm., which was referred to the 'tapinocephalid stage' corresponding to the North American Roadian and Wordian (Cassinis et al., 2002b). According to this chronostratigraphic framework and the proposed age for the Cala del Vino Fm., the new ichnological material allows anticipating the occurrence of *Merifontichnus* to the early Guadalupian (Roadian).

The palaeontological record from the Nurra region, besides providing highly significant and punctual information, converted the Torre del Porticciolo site in a strikingly significant palaeontological site for the Permian of Europe, due the co-occurrence of skeletal and ichnological remains. The other remarkable example of a productive and diversified fossiliferous site is the Bromacker quarry locality in the Thuringian Forest (Germany), the most productive locality for terrestrial vertebrates in the Lower Permian of Europe. Here, a notable vertebrate assemblage preserved in different levels of the Tambach Fm. (Tambach Basin) was unearthed since the last century (Eberth et al., 2000). At Bromacker, 12 tetrapod taxa were identified and described, among which amniotes (bolosaurid parareptile, sphenacodontid, eureptiles, varanopid synapsid, and caseids) and anamniotes (amphibamid, ostodolepidid microsaur, seymouriamorphs, diadectomorphs, and trematopids) (Berman et al., 2014). In addition, the Bromacker locality is well-known for preserving a rich and very well detailed ichnofauna, referable at least to five ichnogenera, namely *Ichniotherium*, *Dimetropus*, *Amphisauropus*, *Varanopus* and *Tambachichnium* (Pohlig, 1885; Pabst, 1895, 1908; Haubold, 1971, 1973, 1998; Voigt and Haubold, 2000; Voigt, 2005; Voigt et al., 2007; Romano and Citton, 2015; Romano et al., 2016; Buchwitz and Voigt, 2018). In the case of Bromacker locality, the combined ichno and body fossil record offered the unique opportunity to find a strong match between bones and tracks, as highlighted by Voigt et al. (2007) for the two diadectids *Diadectes absitus* and *Orobates pabsti* and the two ichnospecies *Ichniotherium cottae* and *Ichniotherium sphaerodactylum*. Later, Romano et al. (2016) corroborated the attributions and showed that once established a track-trackmaker correspondence, footprints can be used to improve and correct assumptions made only on the basis of skeletal remains.

As Bromacker, the Torre del Porticciolo site represents a sumptuous reservoir of data, conveying information difficult to achieve together if the preservational requirements of the two type of record are considered, and improving our understanding of the ancient ecosystems and the palaeoecological relationships between different clades. Currently, the record of the Nurra region is providing a more complete understanding, and different integrated representations, of the faunal composition. While the skeletal remains indicated a medium to large sphenacodontid and a giant herbivorous caseid, footprints added also a small animal, probably to be sought among synapsid therapsids, as a further constituent of the terrestrial palaeofauna. On the whole, the new evidence indicates for the time being a fauna with tetrapods ranging from 50 cm up to more than seven meters in length.

Next steps in the research will include a detailed description and illustration of the new material from TdP2 site, which will probably lead to the formalization of a new taxon within sphenacodontids, on the basis of some autapomorphies characterizing especially the ilium in the pelvis, and the general structure of the femur. New field work and prospections will be conducted in the Cala del Vino and Cala Viola areas, searching for new osteological and ichnological material, to further enhance our understanding

Fig. 6. Excavation Team, Torre del Porticciolo, September 2015. From left to right: back, Marco Romano, Davide Bonadonna and Andrea Pirondini; center, Paolo Citton, Umberto Nicosia, Eva Sacchi and Simone Maganuco; front, Anna Giamborino and Teresa Coppola.

of the faunal diversity of this area of Pangea during the latest Early Permian to early Middle Permian time interval. The field works will be carried out also thanks to the great support of the Associazione Paleontologica e Paleoartistica Italiana (A.P.P.I.), that, in recent years, has financed part of the excavations as well as helping consistently in the field operations (Fig. 6).

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On the age of the deepest part of the glacigene Al Khlata Formation in the Mukhaizna Field, Oman, based on palynology

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The glacigene Al Khlata Formation has been the subject of palynological study for almost half a century, mainly because it bears hydrocarbons in the subsurface of interior Oman. The Al Khlata Formation comprises clastic lithologies that range from conglomerates through diamictite, gravels, pebbly sandstones, siltstones to silty shales (Levell et al., 1988).

A study of the Mukhaizna Field in south-central Oman distinguished five biozones in the Al Khlata Formation working downhole mainly with cuttings samples but also with small amounts of core and sidewall core (Stephenson et al., 2008). The top of the highest, Biozone A, is marked by the first downhole increase of *Microbaculispora tentula* and *Cycadopites cymbatus* and is associated with high gamma-ray readings indicating the Rahab Member of the Al Khlata Formation. The top of Biozone B is distinguished by the first downhole appearance (FDA) of, amongst others, common cavate-zonate spores. It is associated with shaley diamictites and more distal lacustrine mudstones with considerable lateral variability. The top of Biozone C is marked by the FDA of *Anapiculatisporites concinnus* but also

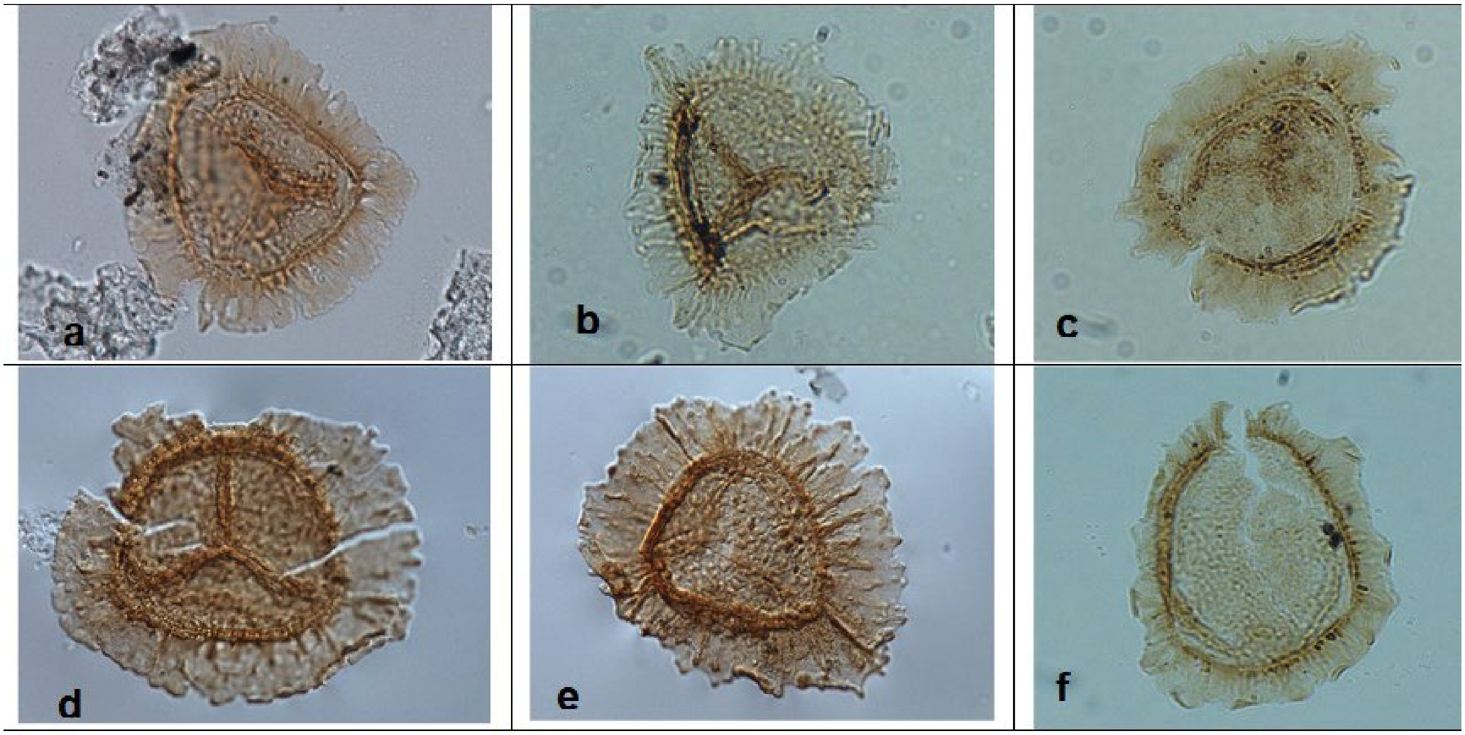

Plate 1 *Indotriradites daemonii* Loboziak, Melo, Playford and Streel, 1999 from the Al Khlata Formation in the Mukhaizna Field. Location given by England Finder; BGS MPK collection number; diameters given individually in microns **(a)** E40, MPK 13569, 57 µm; **(b)** L37, MPK 13570, 58 µm; **(c)** U24/4, MPK 13571, 60 µm; **(d)** G23/3, MPK 13572, 58 µm; **(e)** T15/1, MPK 13573, 72 µm; **(f)** W23/4, MPK 13574, proximal face missing, 65 µm.

contains persistent occurrences of *Ahrensisporites cristatus*, *Spelaeotriletes triangulus* and *Deusilites tentus*. It is associated with thick sequences of shaley diamictites that occur throughout the Mukhaizna field with relatively little lateral variability, suggesting very long-lived, large, proglacial or subglacial lakes. A lower subdivision of Biozone C, termed Sub-Biozone C1 is distinguished by very high percentages of cavate-zonate spores.

The most problematic (and deepest) of the biozones, Biozone D, is characterised by very low diversity assemblages dominated by monosaccate pollen and *Punctatisporites*. It also represents rocks of much greater lateral variability in thickness and character (as shown by log character) than rocks assigned to the younger biozones. Stephenson et al. (2008, fig. 3) also showed that a marked palynological discontinuity appears to occur at the Biozone C/D boundary in the sense of an abrupt change in quantitative compositions of assemblages. Subsequent unpublished work has suggested that depocentres in Biozone D times, gained from correlations across the field, were quite independent of those of Biozones A to C.

In view of its problematic character and low palynological diversity, Biozone D core and sidewall samples were processed in larger-than-usual amounts, and extra palynological slides were prepared to ascertain the range of rare taxa, concentrating particularly on those confined to Biozone D. Stephenson et al (2008) noted one taxon – a species of *Indotriradites*– that occurred in very low numbers, but consistently, in core and sidewall core samples from Biozone D. This taxon has also been recovered from cored sequences of equivalent age to Biozone D in other well sections in Oman (Stephenson, unpublished data). Stephenson et al (2008) collected a population of specimens large enough to name the species *Indotriradites fibrosus*. However Playford (2015) recently correctly recognised that *Indotriradites fibrosus*, as described by Stephenson et al. (2008), is unmistakably a junior synonym of *I. daemonii* Loboziak, Melo, Playford and Streel, 1999.

According to Loboziak et al. (1999) and Melo & Playford (2012), *I. daemonii* has been recorded from Visean strata of North Africa, the Middle East and Brazil. The taxon is believed to be confined to the mid Visean 'Mag' Range Zone in Brazil (Playford, pers. comm., 2018).

This range, however, seems inconsistent with the presence in Biozone D of monosaccate pollen in quite high numbers (Stephenson et al., 2008). According to many authors monosaccate pollen first occur in the early Namurian in NW Europe (e.g. Owens et al., 2004); in the Rhadames Basin, Libya (Clayton, 1995); in eastern Canada (Utting, 1987); and in Asia (Ouyang, 1996). This apparently synchronous first appearance has prompted the use of monosaccate pollen by many palynologists as a marker for the basal Namurian worldwide (e.g. Jones and Truswell, 1992; Stephenson et al., 2017).

This evidence could suggest either that (1) *I. daemonii* ranges higher in Oman than elsewhere, (2) that the Oman specimens are reworked, or (3) that monosaccate pollen occur earlier in Oman. The weight of evidence suggests that the third option is unlikely. Option two is a possibility but other indisputably Visean taxa appear not be present, and the preservation of *I. daemonii* in assemblages is relatively good. It also seems unlikely that only specimens of *I. daemonii* would be reworked from the Visean into younger rocks.

Clearly more work needs to be done to establish the character of assemblages in the deepest glacigene rocks in Oman but an age that might indicate a significant time separation between Biozone D and younger biozones would be consistent with the Biozone D sequence's rather distinct character – which suggests a separate (older?) depositional system.

Nevertheless studies like that of Stephenson et al. (2008) reveal that rare taxa may have an important role in dating problematic rocks and that processing of large amounts of material and preparation of extra slides may be necessary to recover rare taxa. The study also shows that clear descriptions and illustrations of taxa allow other palynologists the opportunity to contribute to dating, through the establishment of synonymy.

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Permian Charophytes: Distribution and Biostratigraphy

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Introduction

Charophytes are fresh and brackish water green algae with a fossil record that extends back to the Silurian. Calcification occurred in most charophytes, and the group is particularly well known from fossils of the calcified female fructification, the gyrogonite. Indeed, the taxonomy of fossil charophytes is based almost entirely on features of the gyrogonite, as have interpretations of the phylogeny and evolution of the group.

Charophyte fossils have a broad geographic distribution across Permian Pangea (Fig. 1). Biostratigraphic schemes have been developed using Permian charophytes in Russia and China. Here, I review the distribution and evaluate the biostratigraphy of Permian charophytes, a synopsis of a longer treatment that is in press elsewhere (Lucas, 2018).

Taxonomy

A useful biostratigraphy relies on the unambiguous recognition of operational taxonomic units (OTU's) to establish correlation. Identical OTU's are assumed to indicate identical ages, a statement that I have termed the "index-fossil hypothesis." Here, the OTU is the genus because most Permian charophyte species are unique to one locality, which suggests to me that they are endemic ecophenotypes not useful in biostratigraphy. Furthermore, taphonomic differences between charophyte assemblages and oversplitting of species-level taxonomy has also contributed to the apparent endemism of many Permian charophyte species.

The genus-level taxonomy used here follows Feist et al. (2005), though not all agree on the taxonomy compiled by those workers. For the Permian, I thus recognize eight valid charophyte genera and their synonyms used for some Permian species: (1) *Auerbachichara* Kiselevsky (= *Shaikiniella* Kiselevsky); (2) *Clavatorites* Horn af Rantzien (= *Cuneatochara* Saidakovsky); (3) *Gemmichara* Wang; (4) *Leonardosia* Sommer (= *Leonidiella* Kiselevsky; = *Luichara* Kiselevsky; = *Paracuneatochara* Wang); (5) *Palaeochara* Bell; (6) *Porochara* Mädler (=*Aclistochara* Peck, in part; = *Euaclistochara* Wang, Huang & Wang); (7) *Stellatochara* Horn af Rantzien (= *Maslovichara* Saidakovsky); and (8) *Stomochara* Grambast (= *Catillochara* Peck & Eyer; =*Horniella* Shaikin; = *Altochara* Saidakovsky).

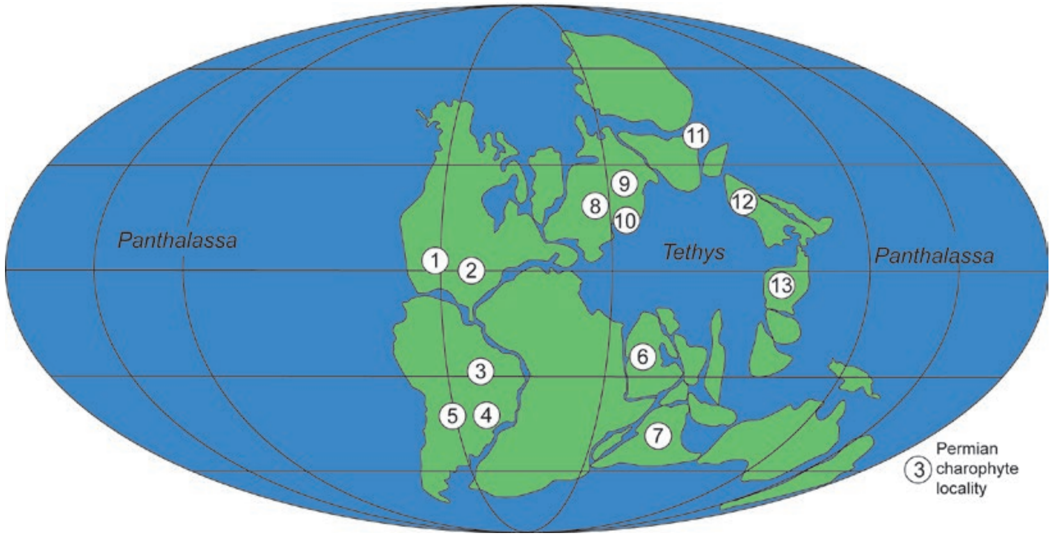

Fig. 1. Permian charophyte distribution. Localities are: 1 = Kansas-Oklahoma, USA; 2 = Ohio, USA; 3 = São Paulo State, Brazil; 4 = Paraná State, Brazil; 5 = Paraguay; 6 = Saudi Arabia; 7 = India; 8 =Ukraine and Germany; 9 = Russia; 10 = western Kazakhstan; 11 = Xinjiang, China; 12 = northern China; 13= southern China.

Permian Charophyte Distribution

Permian charophytes are known primarily from the Ukraine, Russia, western Kazakhstan and China, and most records are of Middle-Late Permian age (Fig. 2):

1-2. North America--Peck and Eyer (1963) noted occurrences of charophytes in Early Permian strata (Council Grove Group) of Kansas (also see Peck, 1934; Lane, 1958) and in the Lower Permian Dunkard Group of Ohio. They assigned all of these records to *Catillochara moreyi* (Peck), which has been reassigned to the genus *Stomochara* (Feist et al., 2005). Lucas and Johnson (2016) described a large sample of *Palaeochara* from the Kungurian (Leonardian) Wellington Formation of Oklahoma.

3-5. South America--Sommer (1954) named the common Permian charophyte genus *Leonardosia* for material from the Permian Teresina Formation in Paraná State, Brazil (also see Herbst, 1981). Faria et al. (2013; also see Christiana de Souza et al., 2012; Ricardi-Branco et al., 2016) described abundant *Leonardosia* from the Teresina Formation. Additional material of *Leonardosia* has been reported from the Permian of São Paulo State, Brazil (Corumbatá Formation) by Ragonha and Soares (1974), Zamporilli et al. (1997) and Faria and Ricardi-Branco (2009). These workers assign the Brazilian records of *Leonardosia* a tentative early Guadalupian age. Herbst (1981) reported *Leonardosia* from Permian strata in Paraguay considered to be correlative to the Brazilian Teresina Formation.

6. Saudi Arabia--Hill and El-Khayal (1983) reported *Palaeonitella* (a form genus for extinct vegetative remains of charophytes) from the Midhnab Member of the Khuff Formation of central Saudi Arabia, which they regarded as of Late Permian age. Vaslet et al. (2005) assigned this record a Changhsingian age based on foraminiferal biostratigraphy.

7. India--De (2003) reported two species of *Leonardosia* (as *Paracuneatochara*) from the Talchir basin near Mumbay in India. These are from the upper part of the Middle Barakar Formation, assigned a late Early Permian age based on macrofossil plant biostratigraphy and palynostratigraphy (Goswani and Singh, 2013).

8. Germany--*Stomochara* is very common in Upper Pennsylvanian (Gzhelian) limestones in the German Saale basin (Gebhardt and Schneider, 1985; Schneider et al., 2005). From Permian deposits in Germany (originally called Carboniferous), *Palaeochara* has been reported as mass occurrences in lacustrine shales that straddle the Gzhelian/Asselian boundary (Kozur et al., 1982). Though charophyte gyrogonites and vegetative parts (thalli) are known from thin sections of micritic limestones (algal-gastropod-ostracod limestones) found in several Early Permian German basins, the charophytes remain to be studied and identified (J. Schneider, pers. commun., 2017).

8-10. Ukraine, Russia, Kazakhstan--Saidakovsky (1966) described Permian charophytes from Tatarian strata in the Donetz basin of the Ukraine that he assigned to *Stellatochara* (as "*Maslovichara*") and *Porochara*. Saidakovsky (1989) described new species of *Stomochara* (some as *Horniella*) from the Permian of Russia. These are primarily from boreholes in the Vyatka-Kama basin near Kazan. Saidakovsky (1989) also reassigned *Stomochara gracilis* Esaulova and Saidakovsky, 1985, from Kazanian strata in the Kama River region to *Leonardosia*.

Kiselevsky (1993c) described species of *Leonardosia* (as *Acutochara,* and the new genera *Leonidiella* and *Luichara*), *Clavatorites* (as *Cuneatochara*) and *Stomochara* (some as *Horniella*) from Kazanian-Tatarian strata of western Kazakstan and the Kirov and Orenburg regions of Russia. Kiselevsky (1998) reviewed earlier work (Kiselevsky, 1980, 1993a, b, c, d; Esaulova and Saidakovsky, 1985; Esaulova and Kiselevsky, 1993) on the Middle-Late Permian (Ufimian-Kazanian-Tatarian) charophyte assemblages of the Kazan region and plotted the stratigraphic ranges of the genera *Clavatorites* ("*Cuneatochara*"), *Leonardosia* ("*Luichara*"), *Stellatochara* and *Stomochara* (including "*Horniella")* (Fig. 2). Note that Arefiev et al. (2015) recently listed several records of Permian charophytes from the East European platform, but without taxonomic identifications.

11-13. China--Wang (1984) named two new genera of charophytes, *Gemmichara* and *Paracuneatochara* (= *Leonardosia*),

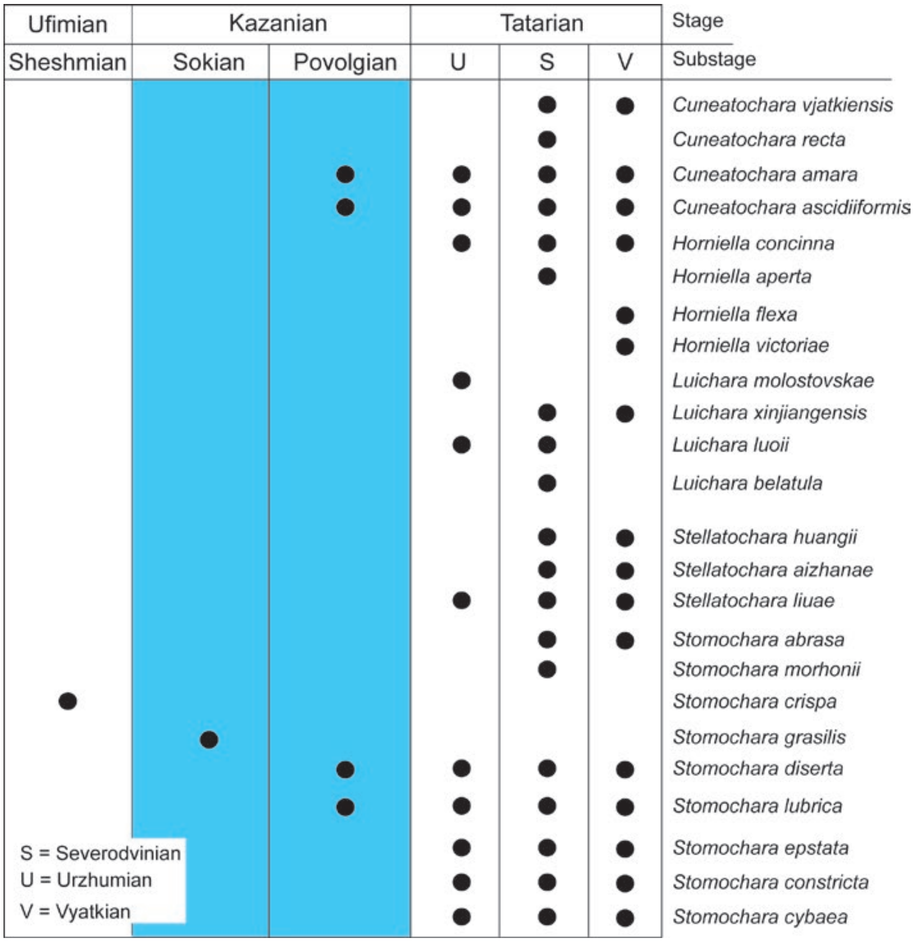

Fig. 2. Biostratigraphy of Permian charophyte species in the Vyatka-Kama basin near Kazan, Russia (after Kiselevsky, 1998). Note that *Cuneatochara* is here considered a synonym of *Clavatorites*; *Horniella* is a synonmy of *Stomochara*; and *Luichara* is a synonym of *Leonardosia*.

from the Late Permian Sunlan Formation in Gansu and the Hongla Formation in Liaoning. *Gemmichara* is particularly significant, as it is the stratigraphically highest genus of the "Trochiliscales" (see below).

Lu and Luo (1984) reported *Leonardosia* (as "*Paracuneatochara*") from the Late Permian Xiaolongkou Formation in Xinjiang. They noted the presence of similar charophytes in the Hongla Formation of Liaoning and the Sunan Formation of Gansu.

Wang and Wang (1986) reported *Gemmichara* and *Leonardosia* (as "*Paracuneatochara*") from Early-Middle Permian strata in eastern China (Henan, Anhui and Jiangsu provinces). The *Gemmichara* is from the Upper Shihotze Formation, whereas the *Leonardosia* is from the Lower and the Upper Shihotze Formation. Wang et al. (2003), based on floral and magnetostratigraphic data, considered the Lower Shihotze Formation to be Makouan (early-middle Guadalupian), and the Upper Shihotze Formation to be Lengwuan (late Guadalupian).

Luo (1987) reported *Stomochara* and *Porochara* from Late Permian strata in the western Tarim basin of China. Lu and Luo (1990) reported a single gyrogonite of *Leonardosia* from the Kangkelin Formation in the Tarim basin of Xinjiang, which they regarded as an earliest Permian (Zisongian) record. Lu and Zhang (1990) reported *Leonardosia* from the Late Permian, lower part of the Guodikeng Formation in Xinjiang.

Permian Charophyte Biostratigraphy

Kiselevsky (1998) presented a biostratigraphy based primarily on borehole records of charophytes from the Kazan region of southern Russia (Fig. 2). This biostratigraphy distinguishes most of the horizons of the Russian Middle-Late Permian regional stages (Ufimian, Kazanian, Tatarian) by presence/absence of one or more charophyte species (Fig. 2). However, this is a very local biostratigraphy (almost all of the species are endemic) of no proven value to correlation outside of southern Russia.

In China, Lu et al. (2000; also see Wang et al., 2003) recognized a succession of five Permian charophyte assemblages (the two youngest of which are approximately coeval) in China: (1) *Leonardosia* sp. assemblage from the Early Permian Kangkelin Formation of Xinjiang; (2) *Leonardosia yongchengensis* assemblage from the middle and upper part of the Lower Shihotze Formation; (3) *Gemmichara pingdingshanensis*-*Leonardosia*? sp. assemblage from the Upper Shihotze Formation, to which they assigned a Wuchiapingian age; (4) *Leonardosia jinxiensis*-*L. jimsarensis*-*Gemmichara sinensis* assemblage from the lower

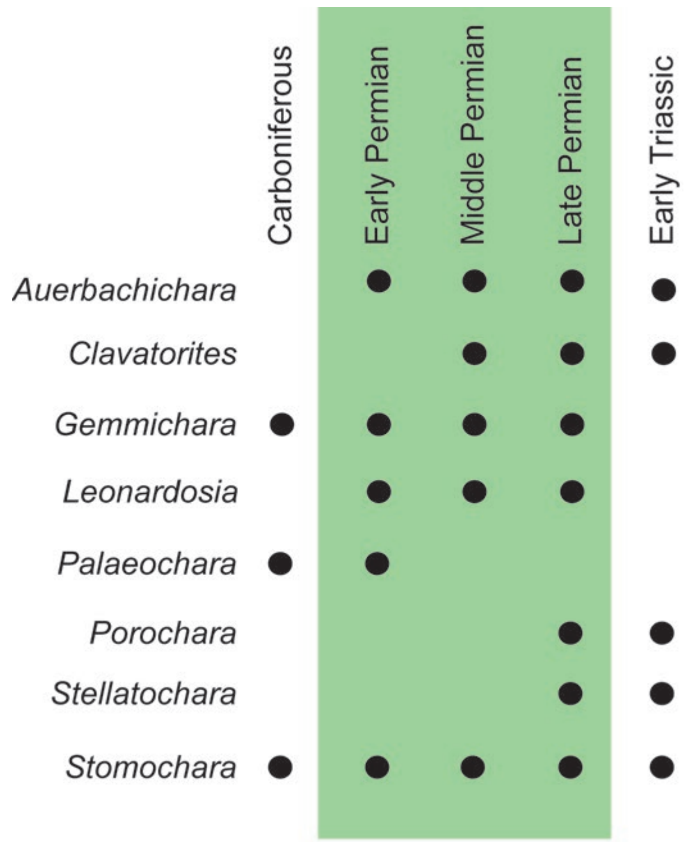

Fig. 3. Stratigraphic distribution of Permian charophyte genera by series.

Guodikeng Formation in Xinjiang, lower part of the Hongla Formation in Liaoning and the Sunan Formation in Gansu, to which they assigned a Changhsingian age; and the coeval (5) *Stomochara kunlunshanensis-Porochara moyuensis* assemblage from the Duwa Formation in Xinjiang, also assigned a Changhsingian age. The *Leonardosia jinxiensis-L. jimsarensis-Gemmichara sinensis* assemblage provides some basis for correlation across northern China, from Xinjiang to Liaoning. However, the biostratigraphic utility of most of this succession remains to be proven.

If we examine the stratigraphic distribution of Permian charophyte genera at the series level (Fig. 3), a few possible biostratigraphic datums can be identified: (1) *Leonardosia* is characteristic of Permian strata, though it has one Early Triassic record; (2) the HO (highest occurrence) of *Gemmichara* is Late Permian, and the HO of *Palaeochara* is Early Permian; and (3) the LO (lowest occurrence) of *Auerbachichara* is Early Permian, the LO of *Clavatorites* is Middle Permian, and the LOs of *Stellatochara* and *Porochara* are Late Permian. However, note that there is no standard Permian succession of charophytes that can be tied directly to the standard global chronostratigraphic scale (SGCS, the "marine timescale"). Instead, the ages assigned to the Permian charophytes listed earlier are based on macrofossil plant biostratigraphy, palynostratigraphy or other criteria that, themselves, need to be tied to the SGCS, and the correlation of which to the SGCS is often imprecise.

Clearly, Permian charophyte biostratigraphy is in a very early stage of development. Wang et al. (2003, p. 199) well observed that "their [Permian charophytes'] sporadic occurrence renders an attempt to establish precisely successive biozonation scarcely feasible, and it is insufficient for precise determination and correlation in [on a] global scale." Nevertheless, the Permian charophyte record does establish some important datums for charophyte biotic events, including:

Early Permian extinction of the Palaeocharaceae. The Palaeocharaceae were a low diversity experiment in a gyrogonite with six sinistral coils. They are the last such experiment in coiling before the fixing of all gyrogonites to five sinistral coils.

Late Permian extinction of the "Trochiliscales." *Gemmichara* from the Late Permian of China is the last record of the "Trochiliscales," an early group with dextrally spiralled gyrogonites.

Carboniferous origin of the paraphyletic Porocharaceae, soon followed during the Permian by the origin of the multicellular basal plate.

Hopefully, the development of a more extensive fossil record, particularly of Permian charophytes, will improve the utility of Permian charophytes in biostratigraphy and provide even more precise temporal constraints on their evolutionary history.

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XVIII Congress of the Italian Paleontological Society (Trento and Predazzo, June 6–8, 2018): Report on the field trip 'Permian-Triassic terrestrial ecosystems of the Dolomites (Southern Alps)'

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The XVIII Congress of the Italian Paleontological Society, which was hosted by MUSE – Science Museum of Trento, NE Italy, June 6–8, 2018, gathered about 90 Italian and a few international palaeontologists for a three-days meeting. On June 7, the authors of this report organized and guided a full day excursion that visited two outcrops in the Dolomites region (Bolzano Province) where Permian and Triassic strata outcrop nicely and with easy access.

The field trip visited the well-known Bletterbach gorge, where the upper Permian succession crops out extensively along a 210 m thick succession, and a very peculiar section recently studied by the authors near Tramin/Termeno in the Adige valley, which exposes an upper Permian to Early Triassic succession along a forest road.

The Bletterbach gorge: Lopingian terrestrial ecosystems

The Upper Permian of the Bletterbach gorge, a deep canyon excavated on the western side of Weißhorn/Corno Bianco (the area is bilingual), is one of the classical exposures of the mainly terrestrial Gröden/Val Gardena Sandstone, studied since the XIX century for its abundant flora and tetrapod tracks (see Kustatscher et al., 2017 and Bernardi et al., 2017 for reviews). Here, the stratigraphic section starts with the Auer/Ora Formation of the Athesian Volcanic Group (andesites, rhyolites, ignimbrites), formed during the Cisuralian (Early Permian) by a mega-caldera-system, having its centre near Bozen/Bolzano (Bargossi et al., 2007). The volcanic deposits are overlain by about 210 m of Gröden/Val Gardena Sandstone, which is mainly composed of terrestrial clastics reflecting depositional environments of alluvial plains and proximal to distal floodplains (Italian IGCP 203, 1986). The lower boundary of the Gröden/Val Gardena Sandstone is poorly constrained, but palynological (e.g., the absence of *Crucisaccites*) and stratigraphical evidence (the lower part of the overlying Bellerophon Formation is considered late Wuchiapingian in age; Ceoloni et al., 1988) constrain the Gröden/Val Gardena sequence to a Wuchiapingian age (Kustatscher et al., 2017).

In this stop of the field trip, the recent palaeoenvironmental and ecosystem reconstructions by Kustatscher et al. (2017) and Bernardi et al. (2017) were presented. By means of a large review of all specimens discovered at this site in the last century, including palynomorphs, plant megafossils, ichnofossils of plant-insect interactions, and tetrapod footprints, Bernardi et al. (2017) recently proposed that the Bletterbach middle Wuchiapingian ecosystem (Fig. 1) would have been supported by a rich flora dominated by ginkgophytes (51% of the association) and conifers (39%), followed by taeniopterids (2%), seed ferns (1%) and sphenophytes (1%). Primary consumers would have been herbivorous insects containing taxa as diverse as mandibulate orthopteroids, piercing-and-sucking hemipteroids and the likely exophytic and endophytic larvae of basal holometabolous lineages. As demonstrated by plant-arthropod interactions, this entomofauna preferentially fed on taeniopterids, conifers and ginkgophytes, and was probably preyed upon by the small secondary consum-

Figure 1. The reconstructed Lopingian lush equatorial ecosystem at the Bletterbach site. Artwork by Davide Bonadonna.

ers documented by footprints, such as lizard-like insectivores. Pareiasaurs, small- to medium-sized herbivorous therapsids and captorhinids would have been the high-fibre herbivores in this ecosystem. Although no direct evidence exists, crosschecking abundance data suggest that pareiasaurs might have fed upon ginkgophytes and conifers in the Bletterbach flora. Other primary consumers, such as dicynodonts, might have fed on sphenophytes and ferns. Captorhinids, which had broad dentaries, multiple rows of peg-like teeth and highly developed chewing mechanisms, would have been able to pierce or grind tough plant material such as sphenophytes and some seed plants. Herbivorous therapsids, captorhinids and neodiapsids probably were preyed upon by large secondary consumers such as archosauriforms and therapsids, which constitute the majority of large-sized faunivorous tetrapods represented in the trackway assemblage. Using the classification proposed by Olson (1966), the Bletterbach community seems to represent a Type II community with fully terrestrial tetrapod herbivores, and to a lesser degree herbivorous insects, forming the primary link between primary producers and tetrapod secondary consumers. This general structure is comparable to what is seen in the dicynodont-dominated ecosystems of southern Gondwana (Bernardi et al., 2017).

The Tramin/Termeno section: Changsingian and the PTB

The stratigraphic section is located just upstream of the Tramin/Termeno village, at the base of the eastern slope of the Mendola chain, the mountain ridge that borders the Adige Valley to the W in the stretch south of Lana and Bolzano. At the base of the Mendola chain the uppermost unit of the Athesian Volcanic Group (Lower Permian) crops out, followed by the continental Permian deposits of the Gröden/Val Gardena Sandstone and the Bellerophon Formation. The overlying Triassic sedimentary succession is represented by the Werfen Formation, several lower Anisian mixed carbonate-terrigenous units (Lower Serla Dolostone, Voltago Conglomerate, Giovo Formation), the Middle Triassic carbonate platform deposits (Contrin and Schlern/Sciliar formations) and their heteropic basinal counterparts (Moena and Buchenstein formations and Val Vela Limestone). Locally, the Middle Triassic units are topped by the andesitic-basaltic volcanic rocks of the Ladinian cycle and by a few tens of metres of alternating calcareous-terrigenous deposits (Travenanzes Formation; Carnian) on which the Norian carbonate platform unit (Hauptdolomit/Dolomia Principale) rests, which forms the highest peaks of the Mendola chain.

The stratigraphic section shows the transition between the uppermost Permian Bellerophon Formation and the overlying Lower Triassic Werfen Formation (basal oolitic Tesero Member up to the overlying Mazzin Member). The field trip stop mainly focused on the uppermost part of the Bellerophon Formation, here characterized by bivalve tempestites with bivalves mainly assigned to *Permophorus* sp., followed by a dark grey marly bed, showing variable thickness, that marks the transition to the overlying succession of marly dolostone and grey mudstone with roots traces, which pass upwards to a laminated pelitic layer, followed in turn by yellowish dolostone with large cavities and possible ooids (Fig. 2). The boundary with the Werfen Formation (Tesero Member) is marked by the occurrence of tabular beds made up of dolostones with sorted ooids.

Several shaly/marly layers of the Bellerophon Formation yielded organic-walled microfossils dominated by non-taeniate bisaccate pollen grains, such as *Klausipollenites* Jansonius, 1962, *Jugasporites* Leschik, 1956, *Gardenasporites* Klaus, 1963,

	Tramin/ Termeno (Adige Valley)	Pizzo Forca (San Pellegrino Pass)	Seres (Badia Valley)
Average $\delta^{13}C$ (‰ VPDB)	-24.4	-26.0	-26.6
Standard deviation (‰)	1.1	1.4	0.9
Number of analyses	26	28	40

Table 1.

Falcisporites Leschik, 1956 and *Paravesicaspora* Klaus, 1963. Taeniate and striate forms are represented by *Lunatisporites* Leschik, 1956 and *Protohaploxypinus* Samoilovitch, 1953. A few specimens of prepollen (*Nuskoisporites* Potonié et Klaus, 1954 and *Trizonaesporites* Leschik, 1956) have also been recovered. Spores are very rare. This suggests a vegetation dominated by conifers and seed ferns (Balme, 1995; Meyen, 1997). Plant debris, including wood and cuticle fragments, is present in varying abundance. Residues from a black silty layer at the top of the Bellerophon Formation contain a particularly high amount of plant fragments and possible algae. A common component in this assemblage is *Reduviasporonites* Wilson, 1962.

The isotopic curve for the $\delta^{13}C$ of bulk organic matter along this ca. 20 meters of the Bellerophon Formation does not present any notable excursion, as is expected for this stratigraphic interval (e.g., Korte & Kozur, 2010), but the carbon isotopic composition of this locality can nevertheless be compared with coeval intervals in the region (Table 1). The organic matter in Tramin/Termeno has values that are on average heavier than in the rest of the Dolomites. This could be explained by a palaeogeographic position closer to the coastline, in agreement with palaeogeographic reconstructions (see Italian IGCP 203 Group, 1986) and consequently with a higher proportion of continental organic matter, which is heavier than marine organic matter during the Lopingian.

Concluding remarks

This field trip of the XVIII Congress of the Italian Paleontological Society was an exceptional opportunity to discuss the most recent developments in the reconstruction of Lopingian terrestrial ecosystems, both at local and global scales, and to confront the peculiarities of the Dolomites stratigraphy around the PTB. Furthermore, the different levels of knowledge of the two visited sites led us to reflect on the future directions of the geo-palaeontological research in this region and beyond.

The Bletterbach site, with a long history of studies and palaeontological discoveries, stands out as one of the few Lopingian (Wuchiapingian) sites worldwide where terrestrial floral and faunal associations have been found in the very same or adjacent strata. This has recently made possible a reasonably complete reconstruction of the palaeoecosystem and a meaningful comparison with other well-documented Lopingian terrestrial ecosystems across the world (Bernardi et al., 2017). This highlights the importance of restudying classical sites with the aim of integrating the available data (in the past often published in separate papers) into the global picture.

The new Permian–Triassic boundary section visited at Tramin/Termeno is evidence of the equally important tasks of moving away from the best-known sites, which might not be

Figure 2. The authors studying the bivalve (*Permophorus* sp.) tempestite and the dark marly beds in the uppermost part of the Bellerophon Formation at Tramin/Termeno.

representative of a regional pattern, and search for new sections in order to provide new comparative data. As of now, several Permian–Triassic stratigraphic sections have been studied in extreme detail in the Dolomites region (among the most cited are those of Tesero and Pufels/Bulla; e.g. see Italian IGCP 203 Group, 1989; Posenato, 2009), while many others, which often show striking differences with respect to the best-known ones, are still waiting to be studied. Given the articulated palaeogeography of this sector of Pangaea in the late Paleozoic to early Mesozoic, findings that 'do not conform to the rule' can be expected, dramatically improving our understanding of a still patchy picture.

Acknowledgements

We thank the past (Lorenzo Rook) and present (Lucia Angiolini) presidents of the Italian Paleontological Society for selecting MUSE – Science Museum of Trento as organizer of our XVIII Congress, and for invitation to submit this report.

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Report of the Italian-Iranian working group: the Permian-Triassic successions of Zal and Ajabshir (NW Iran) and Abadeh (Central Iran)

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In May 2017, a research group composed by an Italian team with R. Rettori, S. Cirilli, V. Gennari, A. Spina and A. Sorci and an Iranian team with M. Ghorbani, M. Ovissi and M. Ghorbani visited the Zal section (Figs. 1-2), located 26.5 km SSW of Jolfa city and the Ajabshir section (Fig.1), located in the northeastern Ajabshir City and northern Tapik-Darreh village (NW Iran). This field trip followed that lead by the same group in 2015 which investigated the Abadeh section, located in the Hambast Valley, approximately 60 km SE of the Abadeh town (Central Iran; Fig. 1). In this work, we report preliminary results on depositional setting and biostragraphy of these three key areas of NW and Central Iran. We analysed the Zal section from the Middle Permian Gnishik Formation up to the Lower Triassic Elikah Formation, the Abadeh section from the Middle Permian Abadeh Formation up to the Lower Triassic Elikah Formation and the Ajabshir section from the Middle Permian Vazhnan Formation up to Upper Permian Hambast Formation.

The present study aims: (1) to characterise the palaeoenvironmental evolution of the Permian to Lower Triassic formations by an integrated study of facies, petrofacies and microfacies with biostratigraphic and palaeontological data; (2) to a detailed definition of foraminiferal and microfloristic biozonation; (3) to discuss

Fig. 1. Geographic map showing the location of Zal, Abadeh and Ajabshir sections.

the correlation of these zonations with those of other regions of the Tethyan domain; (4) to define bioevents as markers to characterise the stratigraphic position of the GLB (Guadalupian-Lopingian boundary) and of the PTB (Permian-Triassic boundary).

The Zal and Abadeh sections are considered by the Permian researcher community two of the most important sections in the world to study the global phenomena occurred at PTB (Fig. 3) (Iranian-Japanese Research Group, 1981; Heydari et al., 2003; Korte et al., 2004; Kozur, 2007; Shen and Mei, 2010; Angiolini et al., 2013, 2017; Leda et al., 2013; Liu et al., 2013). They are also key sections to analyse in detail the Permian biostratigraphy, due to their continuity without significant tectonic disturbances and interruptions. The preliminary results coming from this study on small benthic foraminiferal assemblages highlight their important stratigraphic value and their potentiality as biostratigraphic indices.

Benthic smaller foraminifers are one of the most important fossil groups that bloomed during the Middle-Late Permian (Vachard, 2016; Vachard et al., 2017), nevertheless from a biostratigraphic point of view, they are often considered as a subordinate group in comparison to large fusulinids (Groves, 2000). Consequently, smaller foraminifers are even now comparatively little studied and used in correlation schemes. Our new investigations show that the classes more diversified are: Fusulinata, Miliolata, and Nodosariata. The most biostratigraphically important genera identified within these classes are, among others, *Altineria*, *Pseudovidalina*, *Septoglobivalvulina*, *Dagmarita*, *Sengoerina*, *Paraglobivalvulinoides*, *Paraglobivalvulina*, *Retroseptellina*, *Baisalina*, *Hemigordiopsis*, *Hemigordius*, *Robuloides* and *Rectostipulina*. Moreover, the biostratigraphic importance of the *incertae sedis* genus *Sphairionia*, already taken into account in others studies (Vachard et al., 2002; Zhang et al., 2016; Vachard, 2016), has a significant role in the age attribution.

In the Ajabshir area, the continue and well-exposed section comprises the Vazhnan, Surmaq, Abadeh and Hambast formations. Preliminary studies on facies, microfacies and palynofacies analyses suggest a depositional environment evolving from coastal marine (Vazhnan Formation) to a carbonate-siliciclastic ramp (Surmaq Formation and basal Abadeh Formation) to a more distal basin (Hambast Formation). The preliminary recorded palynological assemblage, from the Vazhnan Formation, shows close morphological similarities with OSPZ5 biozone documented from the Upper Gharif Member in Oman and possibly attributed to the Roadian-Wordian (Stephenson et al., 2003; Stephenson, 2006; 2008).

Moreover, the preliminary recognised foraminiferal assemblages let to refer the Surmaq Formation to the Wordian and the lower-middle part of the Abadeh Formation to the Capitanian. The most part of the Hambast Formation results to be barren in terms of foraminifers and palynomorphs content.

The available preliminary results allow a better stratigraphic correlations between the studied successions of NW and Central Iran and constrain the stratigraphic boundaries within them. The recognised assemblages and bioevents will be correlated with data from coeval assemblages from other provinces of the Tethyan Realm in order to obtain a future integrated biozonation.

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Fig. 2. Panoramic view of the Zal stratigraphic section.

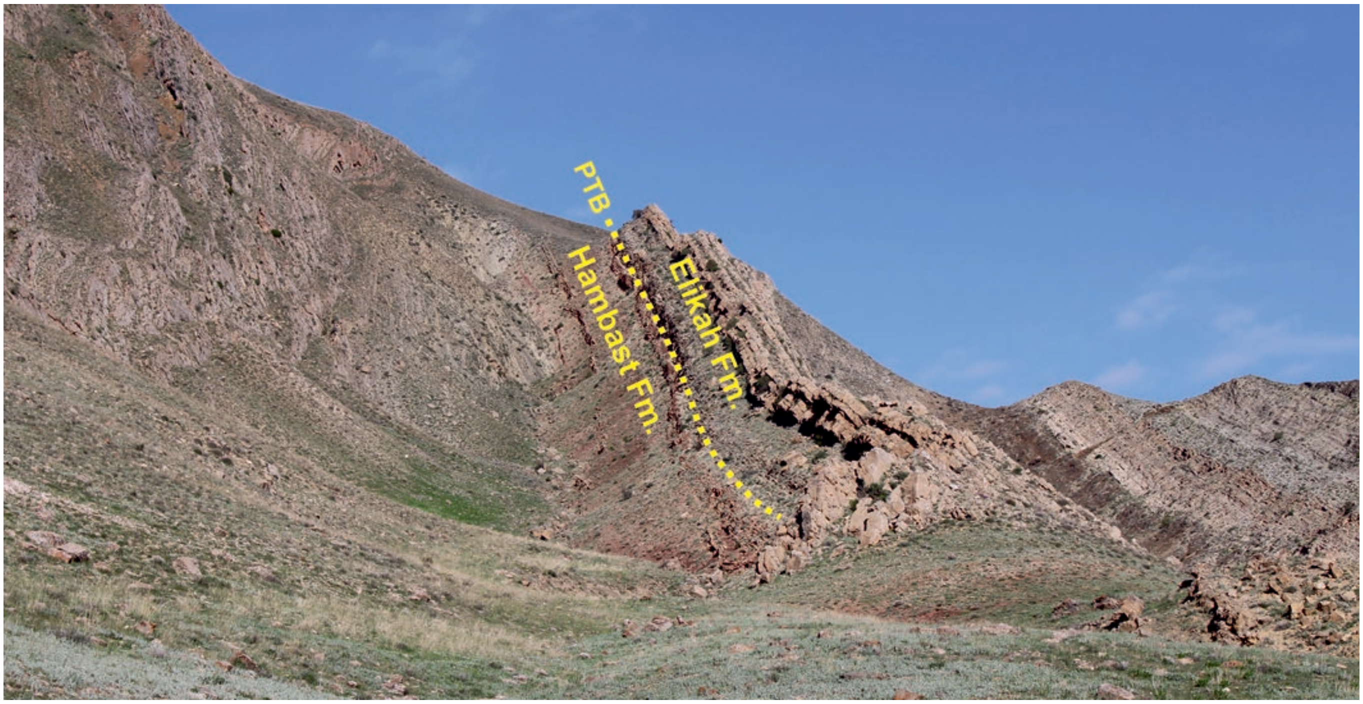

Fig. 3. Hambast and Elikah formations at the Zal section and the putative Permian-Triassic boundary.

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OBITUARY

Professor Maurizio Gaetani (1940-2017)

Maurizio Gaetani, world-renowned Professor of Geology and Stratigraphy at the University of Milan, passed away prematurely on December the 19th, 2017. The event was so unexpected that it slipped through our fingers almost unintelligibly. Friends, scholars and former students joined his family on a grey winter afternoon with a deep inner notion that there, in that church, an epoch had ended. Obituaries are gentle and nostalgic reminders of a person's work of a lifetime. They usually consist of a list of achievements embellished with pleasant or even funny anecdotes to help fixate the memory of the dear deceased, but most importantly, they are necessary because as we guide our children on the right path in life, we ought never to forget who guided us in the first place. But how to acknowledge, and most importantly thank, a gigantic figure of modern geology like Maurizio?

Rossirhynchus adarnantinus is a brachiopod from the Carboniferous of Iran, first described by Maurizio in 1964 when he was 24 at the beginning of a brilliant career as paleontologist and stratigrapher that brought him to explore in the years to come the most secluded and uncharted corners of Asia. He dedicated this new brachiopod genus to the then Professor of Palaeontology of the Milano Department, but, despite this in the years after, he himself never wanted a taxon named after him. We did it anyway because of his great standing as a scientist.

Maurizio was a passionate challenge-seeker. He worked in his early days on various aspects of the Triassic stratigraphy of the southern Italian Alps, and he could have continued doing that forever, almost certainly to become an internationally renowned expert of iconic places like the mighty Dolomites; but his eager desire to see beyond the horizon turned him quickly from a 'back-

Maurizio Gaetani at the Baroghil Pass, Karakoram (1992). This is how we want him to be remembered, with his gaze and smile disclosing the thirst for knowledge and the desire to explore the unknown and unwritten.

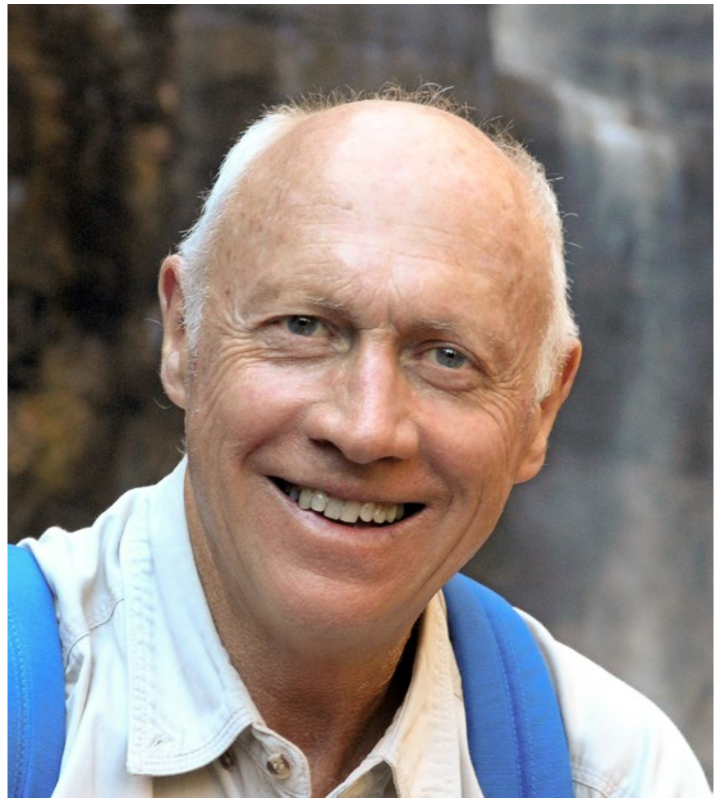
door, local geologist' to the 'Marco Polo of geology'. Why settle for ''just'' the southern Alps when there's a blank on the map in the majestic Karakoram? And so he devoted 25 years of his life organizing and leading countless expeditions and international scientific teams to the Himalayas and mostly the unexplored and impervious Karakoram, contributing to the geological mapping of uncharted territories while mastering stratigraphy to disclose the secrets of the evolution of the Tethyan margin of India in the Paleozoic and Mesozoic. He did all this not only to quench his thirst for adventure, but also with the intent to raise and nurture a generation of highly qualified and visionary professionals in various disciplines of geology, ranging from his favorite palaeontology and stratigraphy to distant but related subjects such as structural geology, palaeomagnetism, and petrology. To this "once-young" generation, he taught the way to walk the treacherous paths of the Pashtun warriors and granted his support through the years if they survived the test (Gaetani, M., 2016. Blank on the Geological Map. *Rendiconti Lincei*, *27*(2), 181-195 and references therein).

The Balkans were another spot of interest for Maurizio: the Albanian Alps, Dobrogea, the islands of Chios and Hydra… fascinating places where he sought geologic connections between the west and the east in a continuous effort to define the easternmost shores of his geological homeland Adria facing the vast stretches of the Tethys Ocean leading to the mighty peaks of his beloved Karakorum (e.g., Gaetani, M., et alii, 2015. The Permian and Triassic in the Albanian Alps. *Acta Geologica Polonica*, *65,* 3, 271-295). Maurizio worked eagerly to tranfer his immense knowledge on the stratigraphy and geology of territories stretching from the southern Alps to India into comprehensive (and useful) palaeogeographic maps of the world, contributing to the Peri-Tethys Programme, one of the most successful scientific projects involving hundreds of scientists from Europe, Africa and Asia that generated palaeogeographic and palaeotectonic scenarios from the Carboniferous to Pleistocene (Gaetani, M., Dercourt, J., & Vrielynck, B., 2003. The Peri-Tethys programme: achievements and results. *Episodes*, *26*(2), 79-93) and the subsequent paleogeographic Atlas of the MEBE Project (Barrier, E., & Vrielynck, B., eds., 2008, Paleotectonic maps of the Middle East: Atlas of 14 maps. Middle East Basin Evolution (MEBE) Programme). In his scientific life, Maurizio completed a perfect circle, as he loved to say, devoting his last years of research to Iran and to the brachiopods, the country and the fossils that inaugurated his career in the sixties.

Maurizio Gaetani was a man of science, and a pioneer. He was a man of passion for his work. He introduced his students to new paths of science and life, teaching them not to be afraid of the uncharted - not to be hasty - but to peer deep into the data. And this is precisely what an authoritative mentor should do.

Lucia Angiolini and Giovanni Muttoni
Two of his former students

Vale: Emeritus Professor John Roberts (1938 –2018)



John Roberts in the Northern Territory, Australia, 2004

Emeritus Professor John Roberts, an eminent expert on Australian and global Carboniferous and Permian stratigraphy, biostratigraphy and timescales died in May 2018 aged 80 years. John was a long-time Voting and Corresponding Member of both the Subcommission on Carboniferous Stratigraphy (SCCS) and Subcommission on Permian Stratigraphy (SPS). He served as Chairman of the SCCS from 1997 to 2000 and was a member of the Permanent Committee for the International Congress on the Carboniferous and Permian (ICCP) held every four years. John was born in Armidale, NSW, Australia and attended Armidale High School and then the newly formed University of New England (UNE) in Armidale graduating with a First Class B.Sc. (Hons) in Geology in 1959. Speaking of John as a student, his former lecturer and mentor at UNE, Emeritus Professor Richard Stanton commented "he was a fine fellow and one of our great early students". After his graduation in 1959 John gained a Commonwealth Post-Graduate Fellowship at the University of New England to pursue a PhD studying Carboniferous marine faunas. After moving to Perth in 1961 to take up a position as Senior Demonstrator in the Department of Geology, University of Western Australia, John transferred his PhD studies to UWA and was awarded his Doctorate by UWA in 1963. Soon after gaining his PhD John joined the Bureau of Mineral Resources (BMR) in Canberra in 1963 where he undertook significant field mapping and biostratigraphical projects in particular relating to the Carboniferous of the Hunter Valley of NSW. It was during this time that he honed his excellent field mapping skills that he later passed on to students in his later academic career. I remember well when dining out with John on a number of occasions that he was obviously a connoisseur of red wine, no doubt developed during long periods of fieldwork in the Hunter Valley wine region! In 1971 John moved from the BMR to join the University of New South Wales (UNSW) as Lecturer in Geology. John then spent the rest of his academic career at UNSW in the School of Applied Geology. He was appointed to a Personal Chair in 1986 and served as Head of Department in 1988-89. John retired in 1998 but continued his association with UNSW as Emeritus Professor and remained extremely active and productive.

John Roberts was an outstanding scholar and intellectual who excelled in his teaching, research, editorial and administrative activities. He was always keen to share his knowledge and provide support and advice to both students and colleagues. He was a plain-speaking person with strong opinions who was not afraid to be frank in discussions but he would always listen and could be persuaded by well-presented arguments. John's outstanding publication record began with his first paper published in 1961 in the Journal and Proceedings of the Royal Society of NSW on Carboniferous faunas. He subsequently published more than eighty high-quality scholarly articles. John's work on Carboniferous brachiopods was substantial and has contributed greatly to knowledge of brachiopod taxonomy, phylogeny and palaeobiogeography. He was the main author and coordinator for the chapter on Australia in the SCCS/IUGS publication The Carboniferous of the World Volume II.

In the 1990s John took an initiative to globally calibrate the largely endemic Carboniferous and Permian biostratigraphic schemes of Australia by U-Pb isotopic dating of zircons in air-fall tuffs and ignimbrites in those sequences using the Australian-developed Sensitive High Resolution Ion Microprobe (SHRIMP) in collaboration with Mark Fanning (ANU) and Jon Claoué-Long (BMR). He also realised that better calibration of Carboniferous and Permian sequences in Australia could provide vital constraints on the age and age-durations of both regional and global geological processes including basin development, orogenesis (in particular the New England Orogen), Late Palaeozoic glaciations, magnetostratigraphy (in particular the important Kiaman reversal) and global climate change. This for me is probably the greatest lasting legacy of John's international contributions for it was this innovative move that has led to immense strides forward in both regional and global timescales and correlation both in Australia and globally. Several important and influential papers resulted from this work and its significance was acknowledged by being awarded the F.L. Stillwell Award for the best paper of the year in the Australian Journal of Earth Sciences for his 1996 paper with Jon Claoué-Long & Clinton B. Foster on SHRIMP zircon dating of the Permian System of eastern Australia. Recognition of problems with the SL13 standard used for SHRIMP dating by John and colleagues threw the reliability of their many dates into question and this undoubtedly caused John quite a bit of discomfort. Limitations of the accuracy and precision of SHRIMP dating in the Phanerozoic have now been largely addressed with new standards and instrument development but recent times have seen a move to using the much more precise and accurate CA-TIMS method the development and early application of which I had the privilege of being involved with initially in China and then Australia.

John energetically engaged in the wider earth science community both nationally and internationally and served on the Australian Research Council (the peak national competitive research granting body in Australia} in various capacities including Member and Chair of the Earth Sciences Advisory Sub-Panel, Deputy Chair of the Engineering, Earth and Applied Science Panel, and member of the Research Grants Committee. He also acted as the ARC representative on the working party for Towards 2005: A Prospectus for Research and Teaching and Research Training in Australian Earth Sciences (1991 – 1992). I also had the privilege of working with John in the early 1990s on Australia's involvement in the International Ocean Drilling Program (ODP), John being the Chairman of the Australian ODP Council when Richard Arculus (Director) and myself (Science Coordinator) took on the Australian ODP Secretariat at UNE. John was a corresponding and voting member of the SCCS from 1974 to 2000 and Chairman of the SCCS from 1997 to 2000 during a traumatic period for the SCCS with voting members split down the middle regarding the two major subdivisions of the Carboniferous, their rank and naming. In Australia John was extremely active in the Geological Society of Australia (GSA) and served as Editor for the society's publications Alcheringa (1978-82) and Australian Journal of Earth Sciences (1986-1990). He was President of the Association of Australasian Palaeontologists from 1988 to 1990, Secretary of the Australasian Palaeontological Group, Chairman of the NSW division of GSA in 1974 and Secretary of the WA division 1961-1962.

John Roberts was the recipient of many distinctions and awards including a Norman McKie undergraduate scholarship, the Archibald D. Olle prize (1965) and the Clarke Medal (1989) of the Royal Society of New South Wales, a Harkness Fellowship of the Commonwealth Fund of New York (1967 – 1969) to study Palaeobiology at the Smithsonian Institution and University of Illinois, a Commonwealth Bursary of the Royal Society, London (1977) and UNE Distinguished Alumni Award (2009). In addition John received many significant grants from the Australian Research Council to support his research activities.

John is survived by his wife Yvonne and daughter Karen but sadly his son Antony predeceased him by some decades.

Emeritus Professor John Roberts was a scholar and a gentleman of immense intellect who has left an enduring legacy for the Earth Sciences both in Australia and globally. He will be sorely missed.

Ian Metcalfe
Adjunct Professor, University of New England, Australia
(with input from John Pickett, Dick Glen, Al Dunlop, Peter Flood, Richard Stanton and Paul Lennox)

ANNOUNCEMENTS

3RD International Congress on Stratigraphy - STRATI 2019

The first circular of the 3rd International Congress on Stratigraphy, STRATI 2019, is now available at the website http://www.strati2019.it. Ten themes (T1 to T10) have been selected by the Scientific Committee, in order to invite contributions and promote discussions.
The potential convenors are invited to submit proposals for sessions taking into account the suggested themes, however theme 11 is open and may include specific sessions dedicated to special topics.

The list of the proposed themes is as follows:
T1. History of Stratigraphy
T2. Stratigraphic tools
T3. Erathemes, Systems, Series and Stages
T4. Stratigraphy of carbonates and carbonate platforms
T5. Stratigraphy of volcanoes and of volcanic areas
T6. Antarctica and Arctic
T7. Stratigraphy and geological mapping
T8. Subsurface stratigraphy
T9. Geochronology and time scales
T10. Stratigraphy in crystalline rocks
T11. Open theme

You are all invited to submit proposals! You are requested to use only the online procedure through the STRATI 2019 website.
The deadline for the submission of the proposals has been extended to September 15, 2018. The proposals will be examined by the Scientific Committee in the second half of September. The list of the accepted sessions are included in the Scientific Program of the Congress, that will be is released in October, 2018.
Information will be available in the website of the Congress and in the 2nd circular.
The submission of the Abstracts will be open by the end of 2018.
For more info and most recent updates, please visit the website and join the Facebook Community at https://www.facebook.com/strati2019/.

SUBMISSION GUIDELINES FOR ISSUE 67

It is best to submit manuscripts as attachments to E-mail messages. Please send messages and manuscripts to Lucia Angiolini's E-mail address. Hard copies by regular mail do not need to be sent unless requested. To format the manuscripts, please follow the TEMPLATE that you can find on the new SPS webpage at http://permian.stratigraphy.org/ under Publications. Please submit figure files at high resolution (600 dpi) separately from text one. Please provide your E-mail addresess in your affiliation. All manuscripts will be edited for consistent use of English only.

Prof. Lucia Angiolini (SPS secretary)

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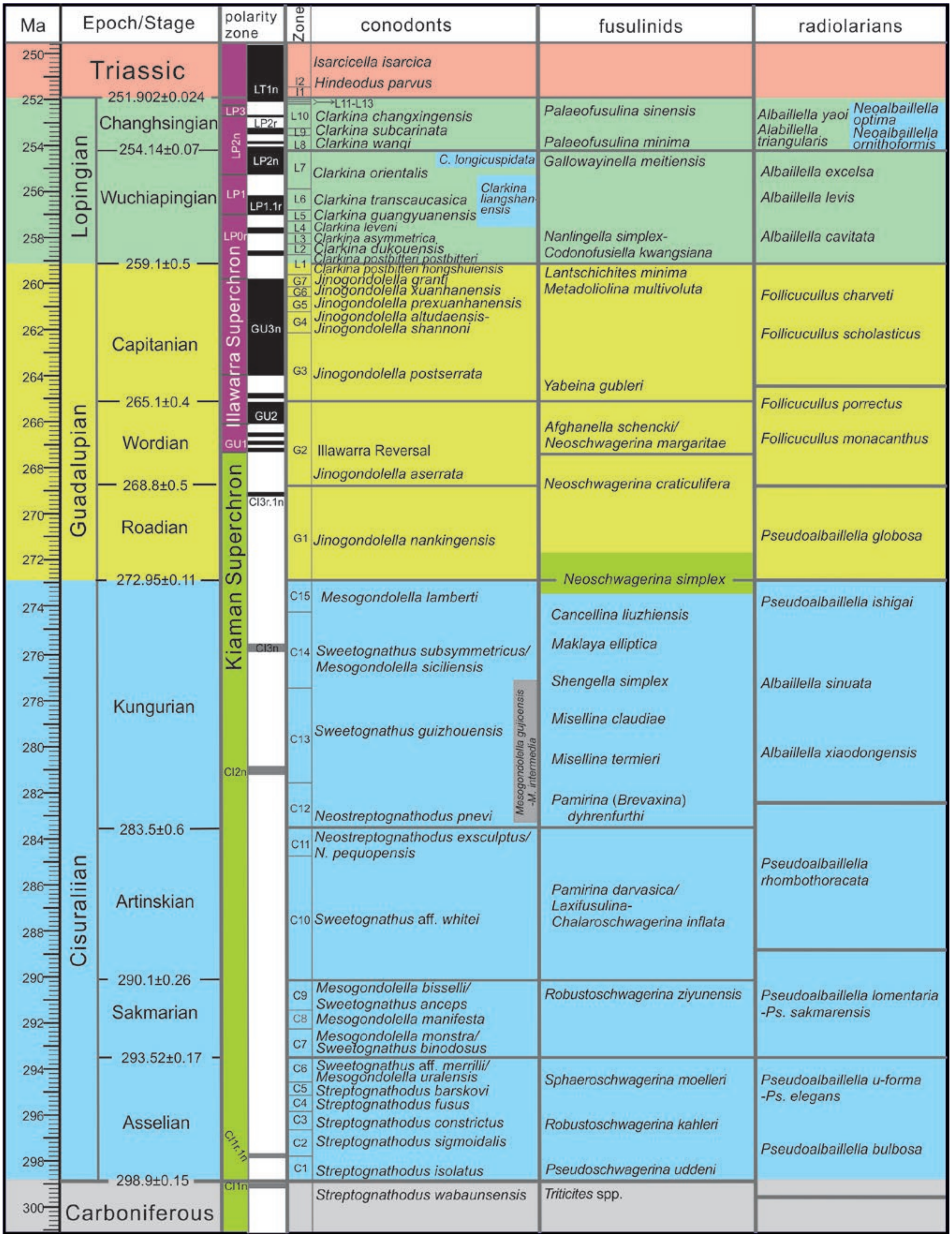
The deadline for submission to Issue 67 is December, 31th, 2018.



This is the latest timescale of the Permian System credited by Shuzhong Shen and Lucia Angiolini. The data are integrated from the online publications by Ramezani and Bowring (geochronology), Zhang and Wang (fusulinids), Henderson (conodonts), Zhang et al. (radiolarians), Hounslow and Balabanov (magenetostratigraphy) in the Special Publication 450 of Geological Society, London (http://sp.lyellcollection.org/online-first/450). This special publication will be formally published with page number in early 2018.