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INTERNATIONAL ICHNOLOGICAL ASSOCIATION

ICHNIA 2016

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edited by
Andrea Baucon
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Joana Rodrigues

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Preface

Ichnia, the International Congress on Ichnology, ran for twelve years from 2004. Over this range of time, evolution of ichnology has been rapid, therefore the question is: where is ichnology going from now? The purpose of this book is to tackle this question by presenting the abstracts of Ichnia 2016, the 4th Congress on Ichnology.

The book has been designed to parallel the structure of the congress.
It consists of 8 chapters, each of which corresponds to a specific session of Ichnia 2016, and includes more than 140 abstracts. As such, the book reflects the collective work of the international ichnological community.

One of the issues we faced in editing the book has been how to represent the ichnological objects discussed in the abstracts. For this reason, emphasis has been placed on the graphical layout of the book. With more than 150 figured traces, this book is intended not only as a collection of abstracts, but also as a visual atlas of where ichnology is going.

We hope that this book will represent the first of the outcomes of Ichnia 2016: Ichnology for the 21st century!

The editors

Andrea Baucon

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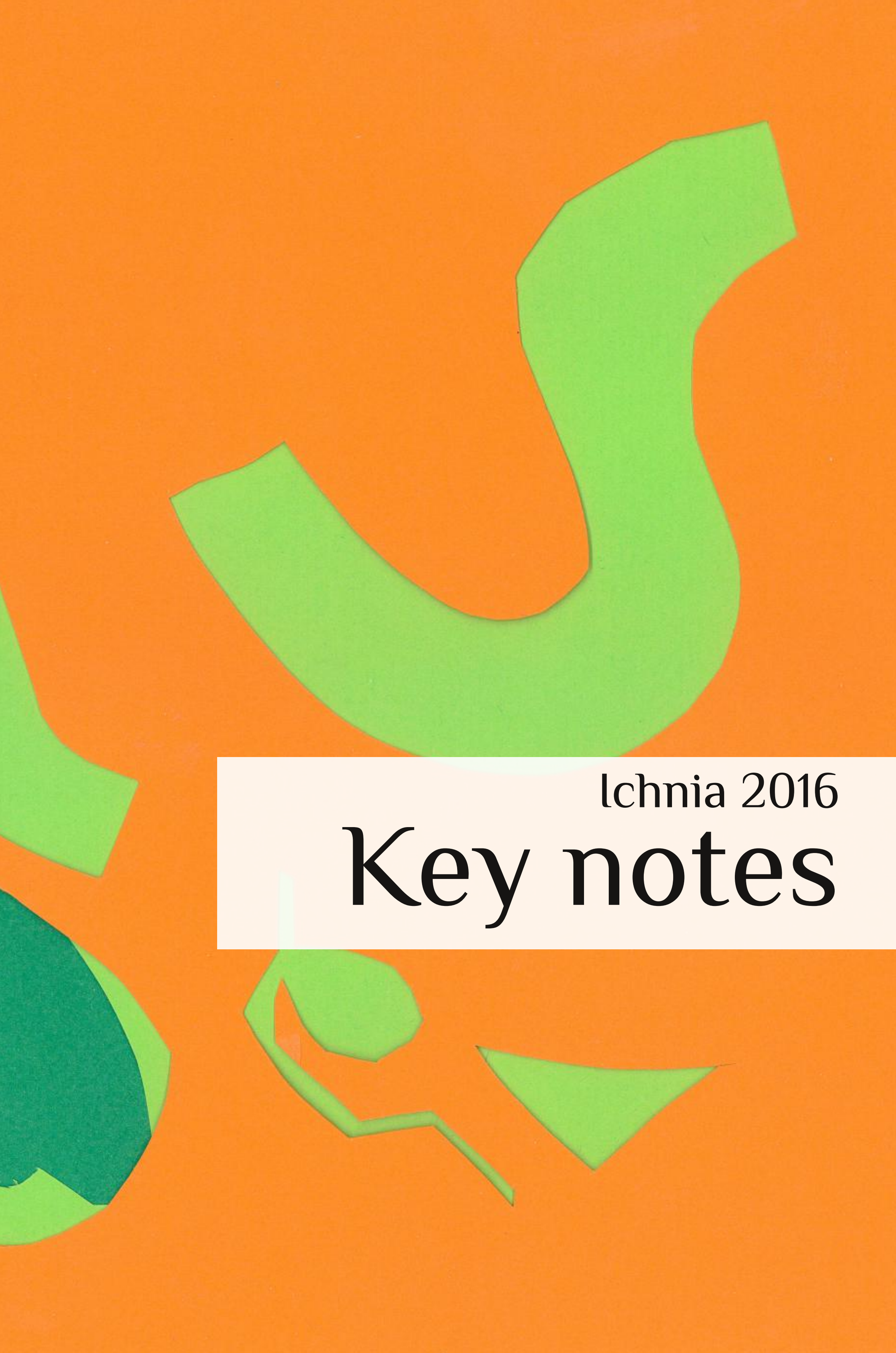

Ichnia 2016

Key notes

1971-2016, 45 years of Spanish dinosaur Paleoichnology: an amazing Mesozoic record and an impressive heritage

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Keywords: dinosaurs, palaeoichnology, Mesozoic

The first technical publication on a Spanish dinosaur tracksite was historically very late (Casanovas & Santafé 1971), that is, 169 years after the first discovery of dinosaur footprints (1802). These authors described theropod tracks from the Lower Cretaceous of the Cameros Basin. Since then and during the last 45 years, the amount of discoveries of new Spanish tracksites, field works, divulgative and technical publications has become very abundant.

The main Spanish area for the Jurassic is undoubtedly the Asturias coast (north of Spain): these Upper Jurassic layers have yielded abundant tracks of theropods, ornithopods, big sauropods, and tyreophorans; moreover, the ichnological record is plenty of turtle, crocodile and very well-preserved pterosaurs tracks.

However, the main chapter of the Spanish Paleoichnology is actually the Lower Cretaceous, that is extended into three main areas: Basque-Cantabrian Basin (north), Cameros Basin (north-east) and Maestrazgo Basin (east). Cameros Basin constitutes an impressive amount of more than 300 dinosaur track localities extended throughout 6,500 km2 (La Rioja, Burgos and Soria provinces). It ranges from the top of the Jurassic up to Middle Aptian (about 40 millions of years). Cameros is very abundant on tracks of theropods, ornithopods, sauropods, tyreophorans, birds, pterosaurs, and crocodiles. This fossil record is strongly influenced by both time and environment (fluvial or lacustrine) through the evolution of the Iberian Rift, with important ideas on dinosaur groups, behavior, paleoecology and paleobiogeography. Lastly, the Upper Cretaceous is located more through the north-east of Spain, and it is represented mainly by sauropod tracks.

References

Casanovas, M.L. & Santafé (1971). Icnitas de reptiles mesozoicos en la provincia de Logroño. Acta Geológica Hispánica, 9(2): 45-49.

Figure 1. Los Cayos dinosaur tracksite (Cornago, La Rioja province). One of the best preserved dinosaur tracksites from Lower Cretaceous of the Cameros Basin.

Figure 2. Theropod trackways from the Los Cayos A locality (Lower Cretaceous, Cornago, La Rioja province, Spain).

Figure 3. Ornithopod footprint from the La Magdalena tracksite (Lower Cretaceous, Préjano, La Rioja province, Spain).

Shinier and shinier toys in neoichnology

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Keywords: neoichnology, experiment, arthropod trackways, 4D ant nests, remotely operated vehicles.

Neoichnology is a common tool for answering questions about (i) potential producers of trace fossils in the geological record; (ii) elucidating the behavioural rules at play during the production of traces; and (iii) understanding the physicochemical parameters that control the environmental distributions of different biogenic sedimentary structures. The first examples of what may be considered to be neoichological experiments can be traced back to 1828 and William Buckland. These experiments involved crocodiles and tortoises walking over, amongst other things, pie crust. Hopefully we have moved on somewhat from this but the basic principle remains the same – to have analogue organisms interact with different substrates under controlled conditions. In this talk I will run through some of my own experiences with neoichnology, from: (i) what may be affectionately described as sand pit and stick experiments for arthropod trackways; to (ii) the application of time series micro-CT scanning to unravel the dynamics and feedback between organismal behaviour and the environment with regards to ant nest excavation; then (iii) outline current work involving remotely operated vehicles, seafloor video, and vibracoring within modern submarine canyons; and finally (iv) look to the future and the role of mesocosm experiments and modelling for understanding the impact of bioturbation on past, present and future biogeochemical cycles.

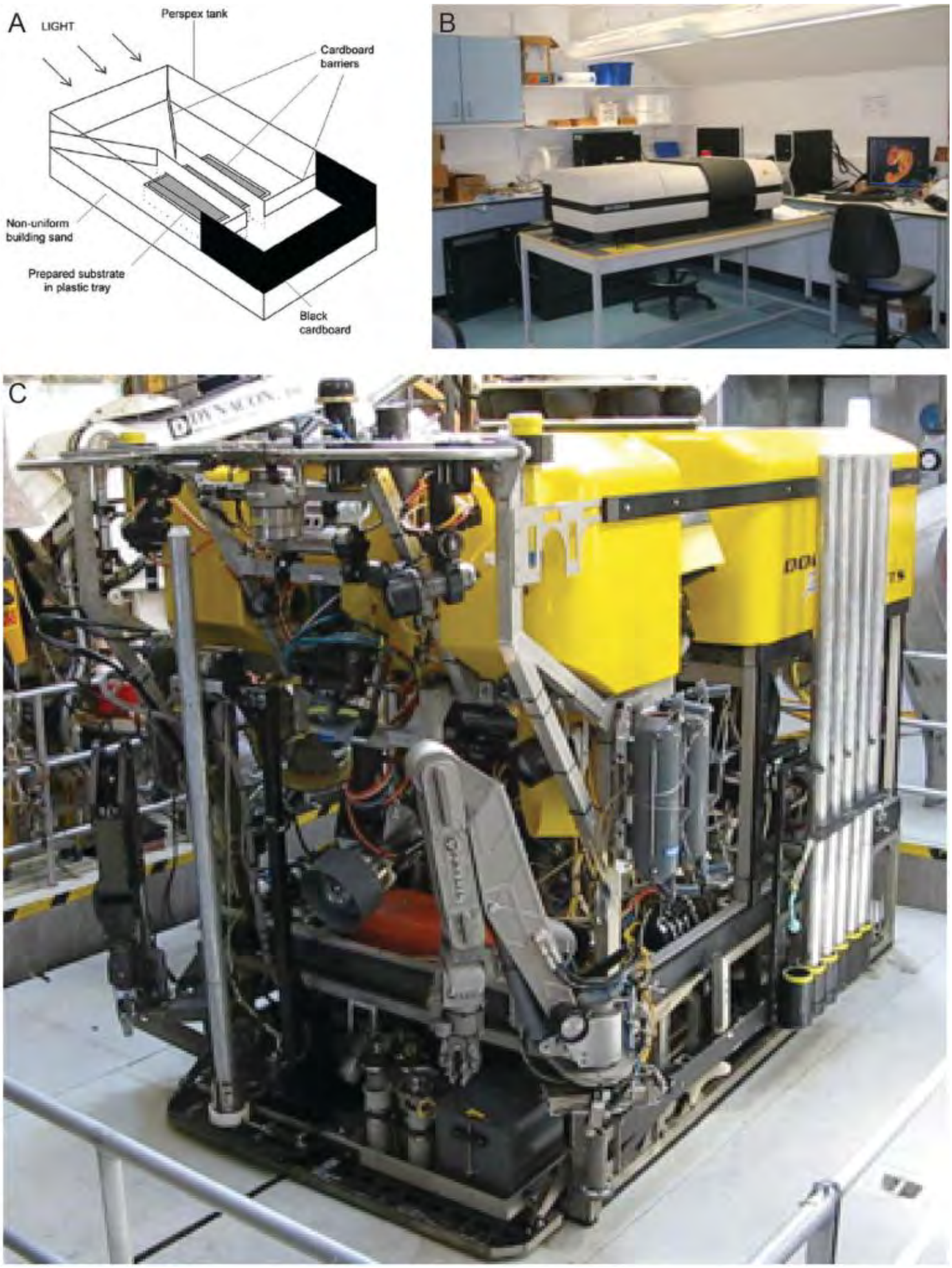

Fig. 1. Shinier and shinier toys in neoichnology. A, “sand pit and stick” experimental setup for arthropods to create trackways on different substrates; B, micro-CT scanner for four-dimensional ant nests; C, ROV Doc Ricketts on board the Monterey Bay Aquarium Research Institute’s RV Western Flyer for exploring surface and subsurface bioturbation within submarine canyons.

UNESCO Designated Sites and Ichnology

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Keywords: World Heritage Sites, UNESCO Global Geoparks, ichnological sites

Geological sites of international importance, including those with ichnological value, can gain global recognition from UNESCO, the only UN-organisation with a mandate in Earth Science, through two mechanisms. Since 1972, the international convention concerning the protection of the world cultural and natural heritage provides a mechanism for sites of outstanding universal value to be inscribed as World Heritage Sites. In November 2015 UNESCO adopted the new designation of UNESCO Global Geopark, its first new site designation since 1972. UNESCO Global Geoparks contain sites of geological heritage of international value where those sites support local sustainable economic development through involvement with local communities.

Several UNSECO Global Geoparks such as Terra.vita in Germany and Naturtejo in Portugal have internationally important ichnological sites. However, despite at least 5 nominations, no World Heritage Sites have yet been inscribed on the basis of ichnology alone. Four of these nominations were based on dinosaur trackways. Despite trace fossils recording the activity and behaviour of living animals there has, to date, been a lack of recognition of the significance of these fossils and their difference to body fossils to justify them being of outstanding universal value that would allow designation as a World Heritage Sites.

This presentation will highlight some of these sites, from both World Heritage Sites and UNESCO Global Geoparks, and will look at the issue of inscription on the World Heritage List.

Fig. 1. Here is a view of the Cal Orko dinosaur trackway site, Bolivia. Taken during the site evaluation visit in 2007 as part of its nomination for World Heritage Site.

Ichnotaxonomy: the foundation for ichnological work

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Keywords: Ichnotaxonomy, Trace fossils, Systematics, Nomenclature, Treatise

Ichnotaxonomy, the description and classification of trace fossils, is the backbone of ichnology, because accurate nomenclature at the ichnogenus and ichnospecies levels remains crucial for proper communication. Unfortunately, our science has an overwhelming number of introduced ichnotaxa that are very hard to keep track of. Since the last edition of the Trace Fossil volume of the *Treatise* by Häntzschel (1975), the number of valid invertebrate ichnogenera alone has more than doubled and now approaches 700 (Knaust, 2012). Only a small fraction of these data are being utilized effectively in ichnological studies. In fact, the introduction of a large number of ichnotaxa could have been avoided if established guidelines had been followed (Rindsberg, 2012). A new edition of the *Treatise* volume is overdue but its preparation has been initiated, and an update of its current status will be presented. In the meantime, some recommendations are given for making ichnotaxonomy more objective.

References

Häntzschel, W., 1975. Trace fossils and problematica. In: Teichert, C. (Ed.), Treatise on Invertebrate Paleontology, Part W, Miscellanea Supplement 1. Geological Society of America/University of Kansas Press, Boulder/Lawrence, pp. W1-W269.

Knaust, D., 2012. Trace-fossil systematics. In: Knaust, D., Bromley, R.G. (Eds.), Trace Fossils as Indicators of Sedimentary Environments. Developments in Sedimentology 64, pp. 79-101.

Rindsberg, A.K., 2012. Ichnotaxonomy: finding patterns in a welter of information. In: Knaust, D., Bromley, R.G. (Eds.), Trace Fossils as Indicators of Sedimentary Environments. Developments in Sedimentology, vol. 64. Elsevier, Amsterdam, pp. 45-78.

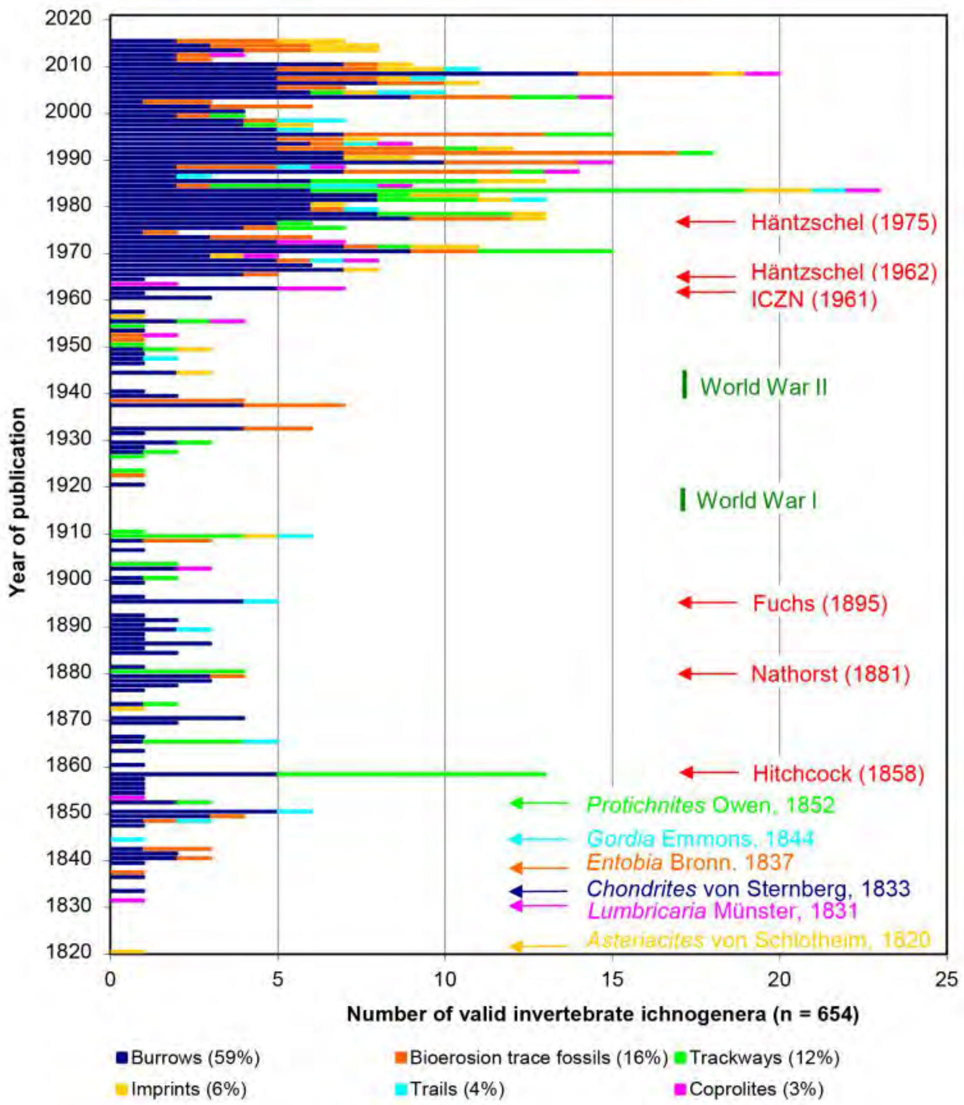

Fig. 1. Cross plot of the number of valid invertebrate ichnogenera erected over time, subdivided into different trace fossil groups. The introduction of the first trace fossil in each category is highlighted, and major events and publications with an impact on ichnotaxonomy are indicated. Updated from Knaust (2012).

Ichnoentomology

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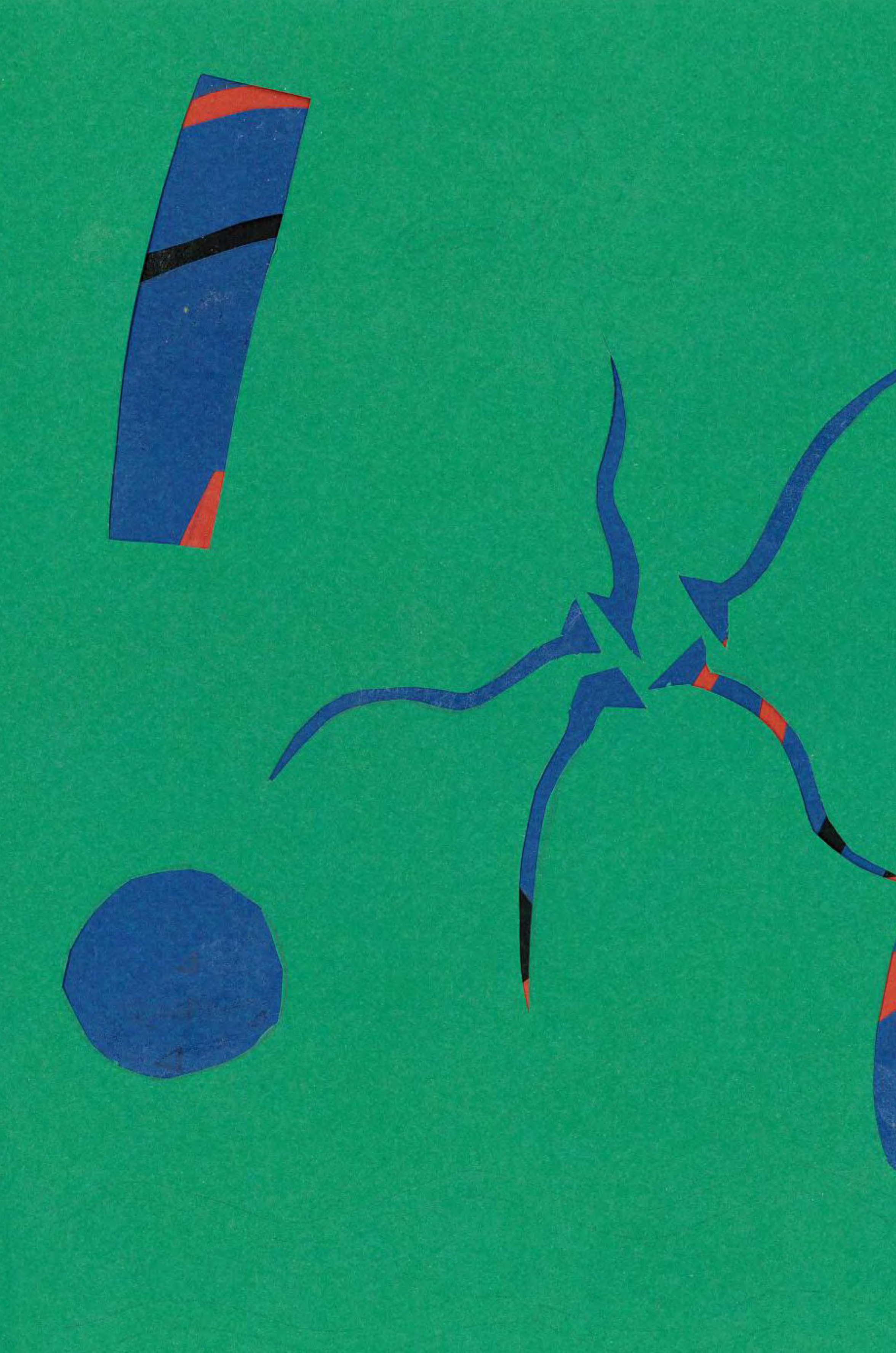
Keywords: insects, traces and trace fossils, soils and paleosols, other substrates, other paleosol traces

About three decades ago insect ichnology began to leak in the scenario of ichnology. However, insect trace fossils scarcely fitted into its theoretical framework. In a few years the leak became a true outbreak in most ichnological fields, such as types of wall, ethological classification, ichnotaxonomy, the attribution to extant taxa, ichnofacies, ichnofabrics, and traces in traces (Genise, 2016). The diversity and combination of type of walls, attested by micromorphological studies, is unique. Boundary wall, free standing wall, and six types of linings: fluidized, stained, pelletal, organic, clay, multilayered and their combinations. New ethological categories have been created to comprise insect trace fossils, such as calichnia, pupichnia, xylichnia, although the traditional ethological classification still needs a major revision. Insect trace fossils in paleosols comprise now more than 70 ichnotaxa grouped in four ichnofamilies, caddisfly fossil cases (which have been disputed as true trace fossils) more than 200 ichnospecies, and insect trace fossils in plant remains are countless. Insect trace fossils in paleosols have been unequivocally attributed to dung beetles, bees (Fig. 1), wasps, termites, ants, moths, cicadas, chafers, and weevils. In many cases they provided data about their biologies, age, phylogenies, evolution of behavior and past distributions, interacting with entomology and paleoentomology. Three new Seilacherian paleosol ichnofacies have been created based on insect trace fossil associations, and one more based on earthworm and crayfish trace fossils. Ichnofabrics in paleosols deserved its own methodology and the record of traces in traces provided a previously unknown insight into past insect biocenosis.

References

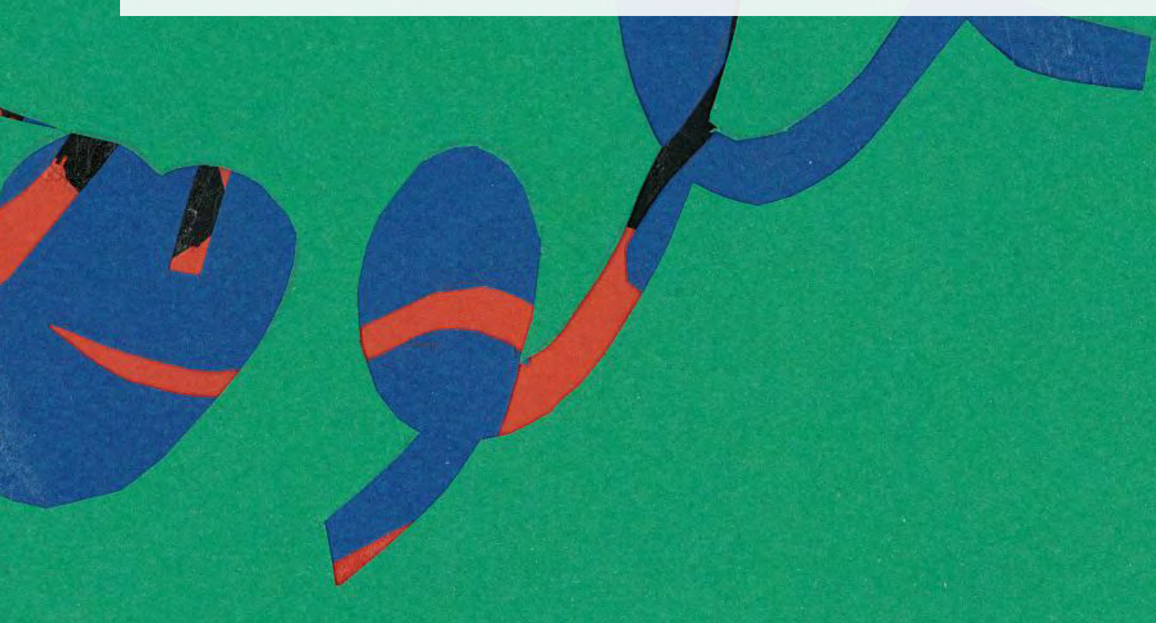
Genise, Jorge Fernando. Ichnoentomology. Insect Traces in Soils and Paleosols. New York: Springer, 2016. Print. Topics in Geobiology Vol. 37.

Fig. 1. *Cellicalichnus chubutensis* a fossil bee nest from the Late Cretaceous Laguna Palacios Formation of Argentina.



Ichnia 2016

Trace Fossils as Indicators of Sedimentary Environments



Postglacial trace-fossil assemblages of western Gondwana and their implications: An example from Pennsylvanian deposits of the Paganzo and Calingasta-Uspallata basins of western Argentina.

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Keywords: Pennsylvanian, postglacial, ichnofauna, ichnofacies, calibration.

Pennsylvanian deposits of the Paganzo and Calingasta-Uspallata basins of western Argentina provide an opportunity to document and compare postglacial ichnofaunas forming under contrasting depositional settings. Progradational deposits above the maximum flooding interval that marks the culmination of the postglacial transgression contain distinctive trace-fossil assemblages which provide valuable evidence for reconstructing the environmental conditions that operated after the final glacial retreat. The postglacial facies of the Paganzo Basin document deltaic sedimentation in lacustrine to transitional settings (fjords), hosting freshwater ichnofossil assemblages. This ichnofauna is composed of simple forms, especially *Mermia carickensis, Gordia marina, Treptichnus bifurcus, T. pollardi, Helminthopsis tenuis* and *Helminthoidichnites tenuis,* representing the *Mermia* Ichnofacies. Coeval units in the Calingasta-Uspallata Basin record deposition in a marginal marine environment affected by deltaic discharge, containing brackish trace fossil assemblages. This ichnofauna is dominated by typical marine ichnotaxa such as *Psammichnites plummeri, P. implexus, Protovirgularia* isp., *Ptychoplasma vagans, Lingulichnus verticalis,* together with local occurrences of *Treptichnus bifurcus, Lockeia* isp. and a few arthropod trackways, characterizing the depauperate *Cruziana* Ichnofacies. Ichnologic data allow reconstruction of paleosalinity levels within the same postglacial unit, refining the calibration of ichnofacies models in glacial-related settings.

Sedimentology and Ichnology of Ordovician deposits (Lashkarak Formation), Central Alborz, Iran: Assessing paleoenvironmental controls and biotic responses

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Keywords: Ordovician, Lashkarak Fm., facies associations, ichnology, sedimentology, hyperpycnal flows.

The integration of sedimentological and ichnological characteristics for the deltaic and non-deltaic siliciclastic succession of the Lower Ordovician Lashkarak Formation in the Alborz Mountains of northern Iran has led to more reliable determinations of the relative degree of influence imposed by river influx, waves, and storms on the coastal regime. Ichnology combined with sedimentological evidence permitted the characterization of the relations between the behaviors of organisms and physico-chemical environmental stresses, such as variations in oxygenation, salinity, water turbidity, shifting and/or soupy substrates, and sedimentation rates. Relying on the facies characteristics and stratal geometries, the siliciclastic succession is divided into two facies associations, FA1 (wave-dominated shoreface complex), and FA2 (mixed river- and wave-influenced delta). High diversity of trace fossils, high bioturbation and the occurrence of trace fossil suites characteristic of both the archetypal Cruziana ichnofacies and the Skolithos ichnofacies, in a wave-dominated shoreface complex, reflect homogeneous distribution of food, normal salinity, and oxygenated water due to persistent wave agitation, and hence, a wide colonization window. In the deltaic succession FA2, hyperpycnal flows create several stress factors, such as increased sedimentation rate, freshwater discharges, and salinity fluctuations, water turbidity, and loading and dewatering that impact on the benthic faunas. The resulting ichnological suites are characterized by impoverishment in trace fossil diversity, low degrees of bioturbation, and their sporadic distribution of throughout the deposits. The increase in environmental instability and thus physico-chemical stresses upon infaunal communities registered in the prodelta to delta-front deposits of FA2 is also reflected by the dominance of current-generated structures, normal and inversely graded beds, soft-sediment deformation, syneresis cracks, and inferred hypopycnal and hyperpycnal flows.

References

Bayet-Goll, Aram, and Carlos Neto De Carvalho. "Ichnology and Sedimentology of a Tide-influenced Delta in the Ordovician from the Northeastern Alborz Range of Iran (Kopet Dagh Region)." Lethaia, 2015. DOI: 10.1111/let.12150.

Geyer, G., Bayet-Goll, A., Wilmsen, M., Mahboubi, A. & Moussavi-Harami, R. 2014: Lithostratigraphic revision of the middle and upper Cambrian (Furongian) in northern and central Iran. Newsletters on Stratigraphy 47, 21–59.

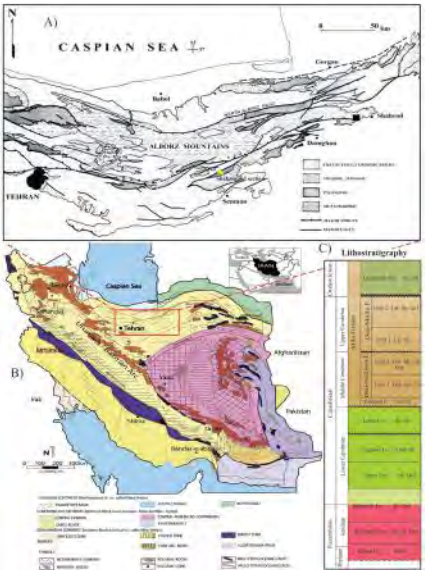

Fig. 1. A) Structural map of the Central Alborz, with the examined area and, location map: Shahmirzad section. B) Geological map of Iran with its structural provinces (modified from Geyer et al., 2014). C) Palaeozoic succession in the central Alborz (modified from Geyer et al., 2014).

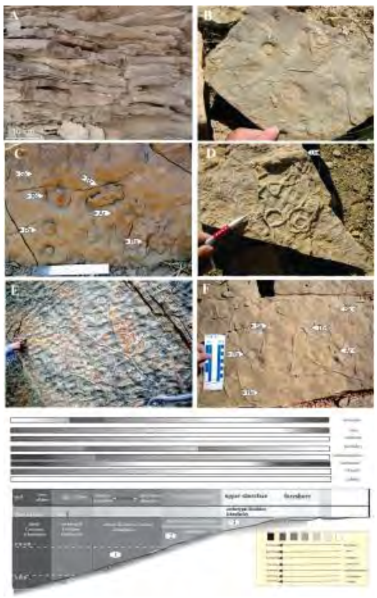

Fig. 2. A) Sedimentary structures and trace fossils of shoreface facies; Vertical section of heterolithic bedding in fine-grained sandstone, shale and muddy siltstone with microhummocky cross-stratification ripples and horizontal lamination. B) Planolites isp. (Pl),Treptichnus pedum, Rosselia isp. (Ro) in fine-grained muddy siltstones of shoreface facies. C) Trace fossils of delta facies with high abundance of Rosselia socialis (Rs), R. rotatus (Rr), Arenicolites isp. (Ar), and Skolithos isp. (Sk). D) proximal prodelta facies with abundance of Treptichnus pedum. E, F) Trace fossils of distal delta front facies. Interlaminated of highly bioturbated thin heterolithic intervals with diverse and robust trace fossil suites in distal delta front facies contain Taphrhelminthopsis isp. (Th), Helminthopsis isp. (He), Skolithos isp. (Sk), Rosselia isp. (Rs), Arenicolites isp. (Ar). Graphical representation of the characteristic sedimentological features and ichnofossils of wave-dominated shoreface complex of the Lashkarak Formation. Along-strike variations in ichnological characteristics reflecting spatial changes in prevailing physical-chemical conditions and the range of occurrence and maximum cited abundance for each ichnotaxon.

Deep sea trace fossils of the Numidian Flysch in the Ain Berda area (eastern Algeria)

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Keywords: Numidian Flysch,Oligocene, Miocene, Turbiditites, Nereites ichnofacies

The Numidian Flysch (Oligocene–Miocene) of the eastern Algeria is a anallochthonous unit. Its outcrops in the Hadjar Nahal Mountains are located near Ain Berda town. The Numidia Flysch consists of two formations: the Argiles sous numidiens Formation and th eoverlying Grès numidien Formation. The former is characterized primarily by coarse-grained turbidite successions. The successions of thick beds with graded bedding (T_a, Bouma, 1962) are interpreted as turbiditic sandstones deposited in schannel complexes. They contain a very lowdiversity trace fossils.The thin bed series with planar lamination and convolute bedding typical of the T_{bc} Bouma intervals () represent the interchannel deposits. Several ichnogenera have been recorded in this facies, including Acanthorhaphe, *Chondrites, Halopoa*, *Helminthopsis, Megagrapton, Neonereites, Nereites irregularis, Palaeophycus, Paleodictyon, Phycodes, Planolites, Scolicia,* and *Thalassinoides*. This ichnoassemblage is interpreted as the *Nereites* ichnofacies.

Most of the trace fossils are associated with episodically deposited thin sandstone beds. The rarity of trace fossils in the lower formation (the basal thick sandstone layer) is related to stressful conditions for trace makers. The abundance of trace fossils in the upper formation seems to correspond to favorable environmental conditions.

Reference

Bouma AH (1962) Sedimentology of Some Flysch Deposits, a Graphic Approach to Facies Interpretation. Elsevier, Amsterdam, pp. 168.

Upper Eocene Ichnofauna of the Tbilisi Suite in the Eastern Segment of the Achara-Trialeti Fold and Thrust Belt, Georgia: Revised Data

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Keywords: ichnofauna, *Zoophycos*,turbidite, euxinic basin, Eocene

On the basis of additional studies of the Upper Eocene 'nummulitic' Tbilisi suite (Lisi anticline, the eastern segment of the Achara-Trialeti fold and thrust belt) ichnocomplex conducted over the past several months, previously existed data(Beridze et al., 2015) have been revised and specified. According to the field observations and petrographic studies, thin- to medium-bedded sandy and muddy turbidites of the Tbilisi suite could preliminarily be attributed to fine-grained turbidite systems type (Buatois & Mángano, 2011). The suite contains single fragmentary samples of two pre-depositional ichnogenera (*Megagrapton, Paleodictyon*) and diverse and abundant post-depositional ichnofauna represented by *Avetoichnus, Chondrites, Nereites, Palaeophycus, Phycosyphon(?), Planolites, Ophiomorpha, Taenidium, Thalassinoides and Zoophycos*.

As a result of the ichnological analysis in the Tbilisi suite ichnocomplex have been defined transitional Zoophycos ichnofacies (*Zoophycos,Chondrites,Phycosyphon*) and deep-sea *Paleodictyon* (*Megagrapton, Paleodictyon*) and Nereites (*Avetoichnus, Nereites*) ichnosubfacies of Nereites ichnofacies. Occurence of Paleodyction ichnosubfacies in the thin-bedded sandy turbidites of the Tbilisi suite suggests outer fan environment. Represented in the muddy turbidites of the suite Nereites ichnosubfacies indicates the distal fan fringe environment (Buatois & Mángano, 2011).

In contrast to the Upper Eocene Tbilisi suite, Oligocene sediments of Lisi anticline lack signs of bioturbation and indicate dramatic changes in environmental conditions of the basin. The study area during Pre-Oligocene time was covered by Mediterranean type 'nummulitic' sea, while in Oligocene it represented the Black Sea type euxinic basin (Adamia et al.2011). Accordingly, ichnological analysis of the Upper Eocene-Oligocene suites of the study area is important for solving of regional stratigraphic problems.

References

Adamia, Sh., Zakariadze, G., Chkhotua, T., Sadradze, N., Tsereteli, N., Chabukiani, A., & Gventsadze, A. 2011. Geology of the Caucasus: A Review. *Turkish Journal of Earth Sciences.* Geology of the Circum-Black Sea Region – Part A Caucasus, 2011, vol. 20, p. 489-544.

Beridze, T., Lebanidze, Z., Koiava, K., Chagelishvili, R., Khutsishvili, S.,& Khundadze, N., 2015. The first evidence of trace fossils in Upper Eocene sediments of Tbilisi environs (the Achara –Trialeti fold-thrust belt, Georgia) and their geological significance. In: *Abstracts of 31st IAS Meeting of Sedimentology held in Krakow on 22nd–25th of June 2015.* Polish Geological Society, Kraków, p.63. Available online at http://www.ing.uj.edu.pl/ims2015/

Buatois, L. & Mángano, M., 2011. *Ichnology: Organism-Substrate Interactions in Space and Time.* Cambridge University Press, Cambridge, 358 pp.

Brachyuran crabs modify Bahamian island landscapes: neoichnology and paleoenvironmental applications

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Keywords: brachyurans, neoichnology, trace fossils, bioturbation, Bahamas

Semi-fossorial brachyuran crabs are prominent in the terrestrial ichnocoenosis of all-carbonate islands of the Bahama Archipelago (Curran, 2007) and a dominant source of bioturbation of coastal landscapes, with each crab species having a distinctive burrow form. The ghost crab Ocypode quadrata is common in beach berm to primary dune settings. These crabs create large J-, U-, and Y-shaped burrows with circular openings (Seike & Curran, 2014) that preserve well as trace fossils and are valuable indicators of past sea-level positions. Fiddler crab burrows, such as those of Uca speciosa, are smaller in diameter (<2 cm), consist of simple near-vertical shafts, commonly with J-shaped endings, and can be abundant in protected supratidal areas (Rodríguez-Tovar et al., 2014). Burrows of Cardisoma guanhumi, the blue crab, are large, distinctive, and have circular openings (up to ~20 cm diameter) with inclined shafts leading to expansive living chambers. C. guanhumi is a powerful bioturbator and occupies the back-barrier supratidal zone and margins of some tidal blue holes. Preservation potential of both Cardisoma and Uca burrows is high. If discovered in the fossil record, they will be useful sea-level markers. Finally, burrows of Gecarcinus lateralis, the black-back crab, are abundant on both modern and ancient coastal dunes and are laterally extensive with characteristic oval-shaped openings (Seike & Curran, 2014). They can generate a distinctive ichnofabric in carbonate paleosols. Future recognition of the different forms of brachyuran burrows in ancient carbonate sequences will provide a valuable new tool for paleoenvironmental reconstruction of coastal landscapes in tropical-island settings.

References

Curran, H. Allen. “Ichnofacies, ichnocoenoses, and ichnofabrics of Quaternary shallow-marine to dunal tropical carbonates: a model and implications.” Trace Fossils: Concepts, Problems, Prospects. Ed. W. Miller, III. Amsterdam: Elsevier B.V., 2007. 232-247.

Rodríguez-Tovar, Francisco J., Koji Seike, and H. Allen Curran. “Characteristics, distribution patterns, and implications for ichnology of modern burrows of Uca (Leptuca) speciosa, San Salvador Island, Bahamas.” Journal of Crustacean Biology. 34.5 (2014): 565-572.

Seike, Koji, and H. Allen Curran. “Burrow morphology of the land crab *Gecarcinus lateralis* and the ghost crab *Ocypode quadrata* on San Salvador Island, The Bahamas: comparisons and palaeoenvironmental implications.” *Spanish Journal of Palaeontology.* 29.1 (2014): 61-70.

Fig. 1. Specimen of *Psilonichnus upsilon* newly exposed by cliff-face erosion of Holocene backshore beds, Hanna Bay Member, Rice Bay Formation, San Salvador Island, Bahamas. Diameter of main burrow shaft = 3

Fig. 2. Large burrow opening of *Cardisoma guanhumi*, the blue land crab, in supratidal zone, North Pigeon Creek, San Salvador. Note the very large spoil pile of excavated substrate material; length of rock hammer = 26 cm.

Fig. 3. Burrows of *Gecarcinus lateralis*, the blackback land crab, exposed in vertical cut of carbonate protosol material, Hanna Bay Cliffs, San Salvador.

Trace Fossils of slope deposits from the Ceylan Formation (Upper Eocene-Lower Oligocene), Gelibolu Peninsula, NW Turkey

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Keywords: slope deposit, trace fossil, Ceylan Formation, Upper Eocene–Lower Oligocene, Gelibolu Peninsula, Turkey

The Ceylan Formation (Upper Eocene–Lower Oligocene) from the Thrace Basin (Gelibolu Peninsula, NW Turkey), is composed of pelagic mudstone shales, marls, clayey limestones, turbiditic sandstone-shale beds and local conglomerates, debris flow mixtites, slumped deposits and silicified tuffites. These deposits, which are about 1000 m tkick, accumulated in different parts of a submarine slope, with a transition to the proximal basin plain. They show vertical and lateral changes showing variability of the slope. The variability is expressed in the trace fossil content. The pelagic sediments are totally bioturbated and contain among others *Chondrites intricatus, Ch. targionii*, *Trichichnus* isp. and *Phycosiphon incertum*. Sandstone-siltstone beds contain *Ophiomorpha annulata*, *Ophiomorpha rudis*, *Scolicia prisca*, *Nereites* isp., *Zoophycos* isp., *Helminthoidichnites* isp., cf. *Rutichnus* isp., *Planolites* isp., ?*Thalassinoides* isp., *Helminthopsis* isp. and *Saerichnites* isp. Generally, abundance and diversity of trace fossils increases with frequency of sandstone intercalations. Turbiditic sandstones contain variable graphoglyptids, including *Paleodictyon* ispp., *Helminthorhaphe flexuosa, Urohelminthoida appendiculata*, *Desmograpton* isp., *Belorhaphe zigzack, Megagrapton* isp. and *Helicolithus ramosus*. The background dark grey mudstones show *Trichichnus* isp. and *Phycosiphon incertum*. The continuous reworking of background sediments points to a good or moderate oxygenation in pore waterers. The trace fossil assemblage from the pelagic fine-grained sediments with isolated sandstone beds can be ascribed to the *Zoophycos* ichnofacies. Some ichnotaxa typical in turbiditic sediments (e.g., *Ophiomorpha annulata*) can be present in the sandstone beds. Series of turbiditic sandstones with graphoglyptids are typical of the *Paleodictyon* ichnosubfacies of the *Nereites* ichnofacies.

Ichnology of the Bearpaw and Dinosaur Park formations (Campanian) in southwestern Saskatchewan, western Canada: Characterizing marginal-marine inclined heterolithic stratification deposits

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Keywords: Inclined Heterolithic Stratification, marginal marine, Campanian, Saskatchewan, Dinosaur Park Formation

The Dinosaur Park Formation (DPF) is an alluvial to marginal marine deposit in southern Alberta and Saskatchewan. The transition between the DPF and the Bearpaw Formations records one of the last major advances of the Western Interior Seaway (WIS) in North America. Inclined Heterolithic Stratification (IHS) deposits are ubiquitous throughout the DPF, and were originally interpreted to reflect tidal influence in fluvial channel systems. Recently, IHS in Alberta DPF deposits has been reinterpreted as representing autocylic flow variation in fully fluvial channels. Ichnologic, sedimentologic, and vertebrate paleontologic data collected from outcrop and core in southwestern Saskatchewan are being utilized to test IHS deposits for adherence to the brackish water model, as well as to understand lateral changes in IHS facies across the basin. Lowermost DPF heterolithics show little or no bioturbation, with rare *Skolithos* and *Taenidium*. Terrestrial and freshwater vertebrate fossils have been recovered within the lowermost IHS beds. The ichnofauna in the uppermost IHS deposits consists of sparse and diminutive *Planolites*, *Teichichnus* and *Skolithos*, in agreement with the brackish water trace fossil model. Furthermore, terrestrial, brackish, and marine vertebrate fossils are associated with these deposits. This indicates a wide environmental range for IHS deposits in the DPF. Continued transgression results in marginal marine deposits being replaced by bioturbated sands and shales of the fully marine Bearpaw Formation. This study highlights the importance of an integrated approach when interpreting depositional settings, and utilizing trace fossils as an indicator of shoreline proximity in complex heterolithic facies.

Neoichnology of the Sonoran Desert, U.SA.: Continental Ichnocoenoses from Desert Floor to Mountain Top

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Keywords: terrestrial, paleoecology, mammals, reptiles, arthropods.

Biogenic structures of soil organisms in the semiarid Sonoran Desert, southern Arizona, U.S.A. were investigated to develop an ichnological model to better interpret analogous soil paleoecosystems. The field sites consisted of scrubland (~1000 m elevation, MAT 18.2° C, MAP 420 mm) and pine forests (~2500 m elevation, MAT 10.4° C, MAP 940 mm) (Fig. 1). Field methods included surface mapping of vegetation and biogenic structures, soil descriptions, imaging with high-frequency ground-penetrating radar, and burrow casting (Fig. 2). Scrubland soils were thin Entisols and Inceptisols dominated by pervasive, fine (3-5 mm) to very fine (<1 mm) roots and burrows of ground squirrels and ants as well as burrows of lizards, scorpions, spiders, centipedes, termites, and insect larvae. Burrows included vertical shafts, ovoid chambers, subhorizontal tunnels, subvertical to subhorizontal networks of branching tunnels, and branching galleries. Forest soils were thick, organic-rich Inceptisols with large (1-5 cm) roots and pervasive, fine (<1 cm) roots. The upper 10 cm was completely bioturbated by earthworms, ants, beetle larvae, and mole crickets, but most conspicuously by pocket gophers. These burrows included 50+ cm long, subhorizontal tunnels as well as networks of branching tunnels, galleries, and helical subvertical shafts (Fig. 3). Despite their close proximity (~8 km), the two field sites were characterized by very different ichnocoenoses due to differences in parent material, climate, and biota. Results from this study will be invaluable to the interpretation of ancient soil ecosystems and advance our understanding of the traces produced by soil organisms and their impact on pedogenesis.

Fig. 1. Location of the study area in the Sonoran Desert, southern Arizona, U.S.A. Three different field sites were studied representing desert scrubland (1) and pine forest (2, 3).

Fig. 2. Excavated burrow cast of a soil arthropod (spider or insect) from the desert scrubland soil.

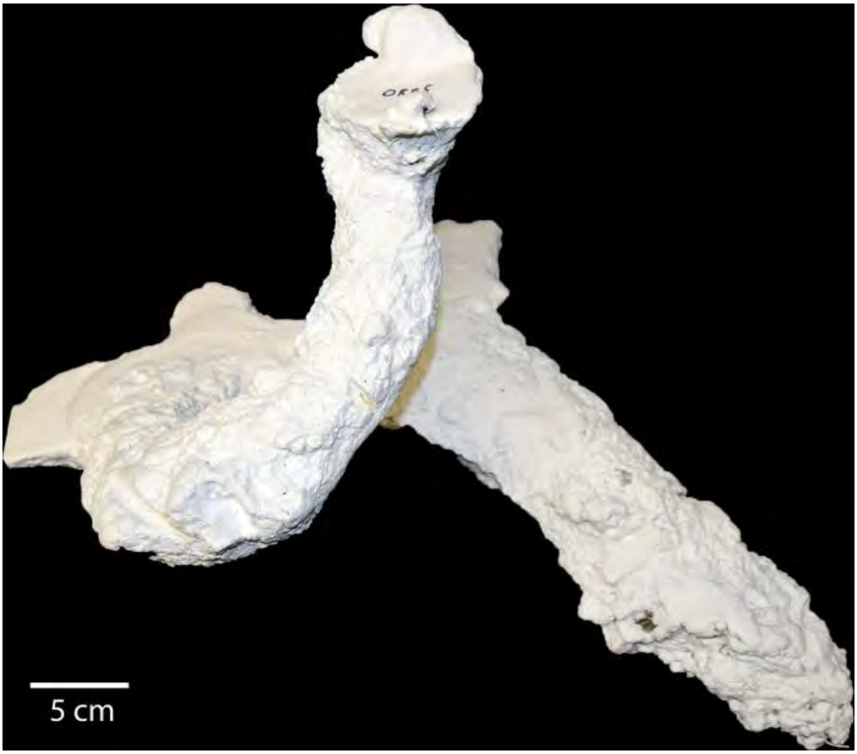

Fig. 3. Cast of a helical burrow of a pocket gopher from the pine forest soil.

Remarkable lower Cambrian deep-water trace fossils from the High Head Member, Meguma terrane, Nova Scotia, Canada

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Keywords: Nova Scotia, Meguma, Cambrian, deep-water, trace fossil.

The High Head Member of the Church Point Formation, Goldenville Group, in the Meguma terrane of southern Nova Scotia, contains an unusually diverse assemblage of lower Cambrian trace fossils in a deep-water setting. Previous studies have documented the presence of *Oldhamia*, *Treptichnus*, *Teichichnus*, stellate trace fossils, meniscate trace fossils and various meandering trace fossils. New observations include a large specimen of *Paleodictyon*, similar to earlier reports of this ichnogenus from other formations of the Goldenville Group, a specimen of *Squamodictyon*, and possible *Dictyodora.* The High Head deep-water trace fossil assemblage is remarkable not only for its age but also for the co-occurrence of forms that are generally interpreted as widely different ethologies, such as *Oldhamia, Paleodictyon, Treptichnus* and stellate traces, as well as the large size of the *Treptichnus*, *Paleodictyon* and stellate trace fossils. In many respects the High Head trace fossil assemblage is more similar to those first found in Ordovician deep-water settings, and it raises questions about the fidelity of the preserved Cambrian record of deep-water trace fossils.

Desert systems, climate change, and trace fossils

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Keywords: Entradichnus-Octopodichnus Ichnofacies, *Chelichnus* ichnofacies, eolian system

We present a model for trace-fossil distribution on desert eolian dunes and coastal eolian dunes developed in arid climates that reflects the partitioning of desert settings in a mosaic of landscape units; they are characterized by water content and its temporal fluctuations, nutrient availability, nature of the substrate, and the dominant organisms present. Landscape units, such as eolian sand seas, salt flat and playa lake systems, ephemeral rivers and alluvial fans, interact in response to regional-scale climate variations in hyper-arid, arid, and semiarid climatic settings. The model proposed results from the elaboration of a comprehensive database that summarizes all life known in eolian deposits from the Cambrian to the Recent, reported in the literature. Ancient deserts completely developed under hyper-arid climatic conditions rarely preserve ichnofossils due to the absence of moisture near the surface in addition to a lower biomass of bioturbating organisms. The alternation of wet periods may represent windows for life and thus, preservation of biogenic structures. Arid deserts display complex patterns of dunes combined with dry, wet, and flooded interdunes. Dry desert elements (dunes, interdunes, sand sheets) typically record the *Entradichnus-Octopodichnus* and *Chelichnus* ichnofacies. Slight rises in regional precipitation produce elevation of the water table and increase of fluvial discharges that provide water and sediment to the system. These processes may result in the intense bioturbation of wet interdunes and ephemeral fluvial systems, illustrating the *Scoyenia* and *Chelichnus* ichnofacies. In semiarid systems playa lakes expand by the addition of freshwater, evolving into freshwater lakes, and fluvial systems may become more common; lake margins and fluvial overbanks typically contain trace-fossil assemblages that may be ascribed to the *Scoyenia* ichnofacies.

Trace Fossils in the Paleogene Deposits of Borjomi Area (the Central Segment of the Achara-Trialeti Fold and Thrust Belt, Georgia): Preliminary Data of Ichnological Studies

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Keywords: extensional basin, flysch, turbidite, *Chondrites*

Our research is focused on the central segment of the Achara-Trialeti fold and thrust belt (Borjomi area) which during the Cretaceous-Paleogene time represented an intra-arc extensional basin. The Paleocene-Middle Eocene sedimentary basin-fill of the segment is constructed by thick terrigenous flysch, basaltic volcanic, volcaniclastic and volcanogenic-sedimentary series (Adamia et al.2011).

Paleocene-Lower Eocene sedimentary succession of Borjomi area is built up by rhythmically stratified turbidities represented by alternation of calcareous sandstones, mudstones and marls (Borjomi Flysch). Two ichnogenera of *Nereites* ichnofacies - *Chondrites* and *Avetoichnus* have been distinguished for the first time in calcareous marls of the Borjomi Flysch. This assemblage is characteristic for the distal muddy turbidites of fine-grained turbidite systems with oxygen-deficient conditions of sedimentation (Uchman, 2008).

Composed of volcaniclastic turbidites Likani suite (the lowermost part of the Middle Eocene volcanogenic-sedimentary succession) comprises more diverse assemblages of trace fossils with simple and complex grazing, farming and locomotion traces: *Circulichnus, Cochlichnus, Glockerichnus, Gordia, Gyrochorte, Helicorhaphe(?), Helmintopsis, Helmintorhaphe, Scolicia* and *Spirophycus.* The dominance of horizontal grazing traces of deposit and detritus feeders suggests low energy environments with sufficient food supply. Poor preservation of trace fossil morphology indicates very soft substrates, while moderate ichnodiversity implies stable and well-oxygenated settings (Buatois, L. & Mángano, M., 2011). Apparently in the beginning of the Middle Eocene the study area represented a shallow, calm water body (closed bay, lagoon and etc.).This supposition is supported by co-existance of simple, unspecialized patterns (Circulichnus, Cochlichnus, Gordia, Helmintopsis) and complex patterns characteristic to *Nereites* ichnofacies (*Glockerichnus, Helmintorhaphe, Scolicia, Spirophycus*) in the Likani suite ichnocomplex.

References

Adamia, Sh., Zakariadze, G., Chkhotua A, T., Sadradze, N., Tsereteli, N., Chabukiani, A., & Gventsadze, A. (2011). Geology of the Caucasus: A Review. Turkish Journal of Earth Sciences. Geology of the Circum-Black Sea Region – Part A Caucasus, 2011, vol. 20, p. 489-544. Buatois, L. & Mángano, M., 2011. Ichnology: Organism-Substrate Interactions in Space and Time. Cambridge University Press, Cambridge, 358 pp.

Uchman, A. (2008). Stop 8, Zbludza, Beloveza Formation (Eocene) and Bystriaca Formation (Eocene): Outer fan ichnology and sequential colonization of turbidites. In The Second International Congress on Ichnology, Cracow, Ichnological sites of Poland: The Holy Cross Mountains and the Carpathian Flysch, The Pre-congress and Post-congress Field Trip Guidebook, ed. G. Pielkowski and A. Uchman,
Warsaw: Polish Geological Institute, pp. 124–130.

Circumpolar Fluvial Trace Fossils from Lower Cretaceous Strata of Victoria, Australia: A Ten-Year Summary Report

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Keywords: ichnology, polar, fluvial, Cretaceous, trace fossils.

A significant assemblage of plant, invertebrate, and vertebrate body fossils in the Wonthaggi and Eumeralla Formations (Aptian-Albian) of Victoria, Australia represent fluvial, lacustrine, and terrestrial ecosystems from a circumpolar setting during the Early Cretaceous. Nonetheless, other than a few dinosaur tracks discovered in the 1980s, trace fossils were nearly unknown in these strata. Thus in 2006 we began searching for and documenting their invertebrate and vertebrate trace fossils. Invertebrate trace fossils in fluvial facies include small-diameter vertical burrows (*Skolithos, Arenicolites*), meniscate burrows (*Ancornichnus*, *Taenidium*), and burrow networks (*Thalassinoides*, *Camborygma*). Vertebrate trace fossils are represented by dinosaur (ornithopod and theropod) tracks, bird tracks, dinosaur burrows, and other burrows credited to lungfish and turtles. However, despite this apparent ichnodiversity, most Wonthaggi-Eumeralla strata we examined lack trace fossils. This rarity likely reflects the selective effects of pronounced seasonality, such as voluminous discharges during polar springs and diminished biological activity during polar winters. Accordingly, we propose that most trace fossils were made and preserved in fluvial channel-margin, overbank, and floodplain environments from late spring through autumn. Noteworthy trace fossil discoveries during the past ten years include: the oldest known crayfish burrows in Australia; the oldest known dinosaur burrows; the best assemblage of polar-dinosaur tracks in the Southern Hemisphere; and the only known Early Cretaceous bird tracks from Gondwana, with one indicating flight. We anticipate these trace fossils and others from the Wonthaggi and Eumeralla Formations will continue to inform us of organismal adaptations to circumpolar conditions during the Early Cretaceous.

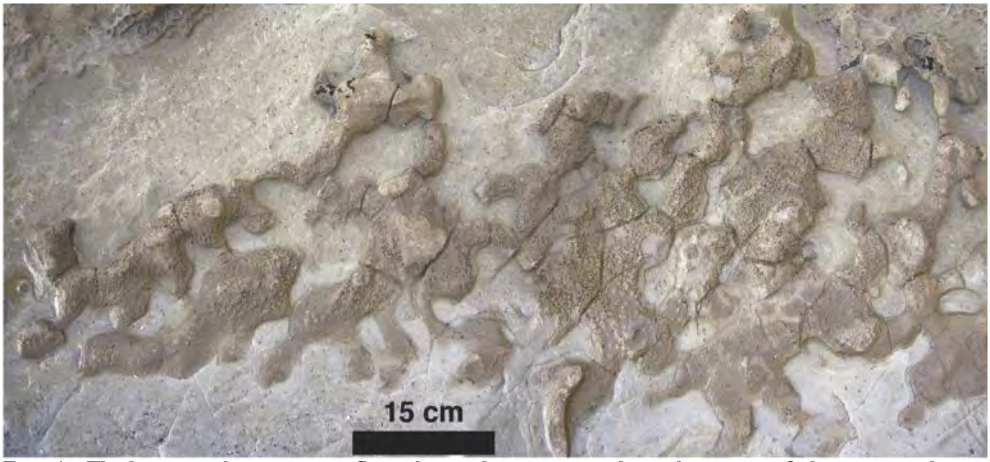

Fig. 1. *Thalassinoides* isp. in fluvial sandstone, attributed to crayfish tracemakers; Wonthaggi Formation (Aptian), Victoria, Australia.

Fig. 2. *Arenicolites* isp. in fluvial sandstone, credited to infaunal invertebrate (possibly insect); Eumeralla Formation (Albian), Victoria, Australia.

Fig. 3. Non-avian theropod track in fluvial sandstone, attributed to oviraptosaur or ornithomimosaur; Eumeralla Formation (Albian), Victoria, Australia.

Continental Ichnofacies of the Two Medicine Formation (Late Cretaceous, Montana USA) and Their Paleoecological Significance

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Keywords: Celliforma, *Mermia*, Scoyenia, ichnofacies, Cretaceous

The Two Medicine Formation (Campanian, Montana USA), composed mostly of fluvial-lacustrine sediments, is world famous for its dinosaur body fossils (*Maiasaura*, *Troodon*, *Orodromeus*) and evidence of dinosaur nesting in the Willow Creek Anticline area of north-central Montana. Initial ichnological research there focused on dinosaur coprolites, dung-beetle burrows in coprolites, and a *Troodon* nest structure, the first documented for a theropod. In our study, we documented ichnoassemblages reflecting well-defined continental ichnofacies; the most impressive was a recurring *Celliforma* ichnofacies. Ichnogenera in calcareous paleosols include *Rebuffoichnus*, *Teisserei*, and *Celliforma*, dominated by hymenopteran nesting traces (calichnia) and cocoons (pupichnia). A *Scoyenia* ichnofacies includes *Scoyenia*, *Camborygma*, *Thalassinoides*, and ornithopod (hadrosaur) tracks in fluvial sandstones and mudstones. A laterally restricted outcrop of lacustrine facies includes probable insect swimming traces and likely represents a *Mermia* ichnofacies. The *Celliforma* ichnofacies overlaps with dinosaur nesting sites, suggesting similar paleoecological conditions, with insects and dinosaurs nesting in and on well-drained soils. Beetles likely made *Scoyenia*, whereas *Camborygma* and *Thalassinoides* are credited to crayfish tracemakers. Hadrosaurs literally impacted overbank deposits adjacent to fluvial channels, their tracks cast by overlying channel sandstones and later burrowed. Interestingly, one stratigraphic succession demonstrates an upward transition of *Scoyenia* to *Celliforma* ichnofacies, which likely happened in an abandoned fluvial channel. In summary, invertebrate and vertebrate trace fossils of the Two Medicine Formation in the Willow Creek Anticline area further enhance our understanding of the paleoecological setting for dinosaur nesting in this paleontologically classic place.

Fig. 1. Abundant *Rebuffoichnus* isp., interpreted as wasp cocoons and in a calcareous paleosol of the Two Medicine Formation (Campanian, Montana USA), representing a Celliforma ichnofacies.

Ichnology and sedimentology of a tropical delta and associated shallow-marine environments, Ciénaga de Oro Formation (Oligocene), Colombia: Trace-fossil distribution and depositional dynamics.

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Keywords: Ciénaga de Oro Formation, Oligocene, Tropical delta, Shallow marine facies, Ichnofacies, South Caribbean.

The upper Oligocene-lower Miocene Ciénaga de Oro Formation (COF), cropping out in the San Jacinto Fold Belt Basin (SJFB) of northwest Colombia, contains deposits accumulated as a result of deltaic progradation, and wave-dominated shallow- marine deposits, formed during transgressions. Integration of ichnologic and sedimentologic datasets allows differentiation between these two depositional setting and recognition of associated subenvironments. Prograding deltaic deposits encompass distributary channels, interdistributary bays, delta plain, delta front and prodelta, whereas the transgressive open-marine deposits include foreshore, upper shoreface, lower shoreface and offshore transition. Channel-fill deposits are mainly characterized by erosionally based, sparsely bioturbated, very coarse to medium-grained sandstone, containing *Ophiomorpha*. Interdistributary-bay deposits display evidence of tidal influence, and illustrate a depauperate Cruziana Ichnofacies. The delta-front deposits consist of massive and cross-stratified sandstone with plant debris and are slightly bioturbated, containing trace fossils of deposit-feeders. Sparsely bioturbated heterolithic strata with lenticular bedding, coal lenses and dispersed shell fragments characterize the prodelta. The associated strandplain deposits are characterized by intense bioturbation and higher ichnodiversity, reflecting conditions of normal marine salinity. Well-sorted sandstone with low angle cross stratification and intensely bioturbated by *Macaronichnus*, characterize the foreshore deposits. The shoreface deposits consists of erosionally based, planar and trough cross-stratified, thick-bedded sandstone, showing elements of the *Skolithos* Ichnofacies, such as *Skolithos*, *Ophiomorpha*, *Arenicolites* and *Diplocraterion*. Because the COF represents an important reservoir in the SJFB and might constitute by itself a single petroleum system, our depositional model might help oil exploration by identifying major lateral and vertical changes in degree of deltaic influence.

Nummipera eocenica, a trace fossil from the upper Eocene San Jacinto Formation, Colombia: Morphology and palaeoenvironmental implications

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Keywords: Nummipera eocenica, San Jacinto Formation, Morphotype, Burrow.

The ichnospecies *Nummipera eocenica* occurs in a thick-bedded bioclastic massive sandstone of the upper Eocene San Jacinto Formation in the San Jacinto Fold Belt Basin, Colombia. During the late Eocene; relative sea-level rise, a Paleocene deltaic system was flooded, leading to the establishment of open to transitional shallow-marine environments in the area. During the subsequent highstand, prograding carbonates and deltaic siliciclastics accumulated in the basin. In particular, the San Jacinto Formation records deltaic deposition during such progradation. *Nummipera eocenica* is a vertical to oblique burrow locally displaying a conical shape. The wall is made of tests of the macroforams *Discocyclina* and *Nummulites*. The burrow infill is identical to the host rock, a sandstone with abundant bivalve fragments. The wall structure is variable and two morphotypes are recognized. The first morphotype consists of uniformly distributed *Discocyclina*, tests typically dipping towards the burrow wall. The second morphotype contains tests of both *Nummulites* and *Discocyclina* and the wall is slightly resistant. Both morphotypes occur in tabular sandstone, and the wall was constructed in order to provide reinforcement to the burrow, which is interpreted as a dwelling structure. Large forams are usually associated with high-energy regimes in the photic zone. *Nummipera eocenica* in the San Jacinto Formation is present in deltaic mouth-bar deposits.

Sedimentology, palaeoecology, and ichnology of early to middle Miocene, Southwest Japan Arc: Palaeoecosystems during rapid backarc spreading

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Keywords: Extremely active tectonics, basin evolution, environmental stress, ichnofabric analyses, benthic faunae

In the early to middle Miocene, the entire SW Japan Arc was rotated up to 50° clockwise, in accordance with the spreading of backarc basins. The rate of the arc movement was significantly rapid, which far exceeded the speeds of most modern plate motions. This event was associated with the opening of another backarc which was located to the south of the arc. Then, the very young and hot oceanic plate began to subduct underneath the arc. This caused rapid uplifting and enhanced the denudation of the arc in the post-early Miocene. Such a drastically active tectonism probably affected not only the environment but also the arc ecosystems at that time.

The author has reconstructed Miocene palaeoecosystems across the SW Japan Arc, and the most noteworthy is the basin-wide paucity of ichnofabrics in a forearc basin fill of the Misaki Group. For example, up to 96% of the total thickness of the measured offshore deposits are non- or very slightly-bioturbated (Nara and Aikou, submitted), despite the other “normal” offshore deposits (including those in the backarc of the Miocene SW Japan) are generally bioturbated.

Highly frequent and rapid sedimentation (estimated net aggradation rate attains more than 230 cm/kyr) that was taken place across the basin, caused by sediment mass-production in the outer arc region, most likely induced the colonisation of depauperated faunae, and diluted the ichnofabrics in the forearc basin (Nara and Aikou, submitted). The extremely active tectono-sedimentation occurred especially in the outer arc region of the Miocene SW Japan Arc probably played an important role in the development of the anomalous ecosystems.

References

Nara, M., Aikou, K., submitted, Rapid backarc spreading and shallow-marine ecosystems: Less bioturbated forearc basin fill of the early to middle Miocene, South-western Japan Arc. *Palaeogeography Palaeoclimatology Palaeoecology*.

Gas dome structures preserved in association with trace fossils

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Keywords: gas dome, trace fossils, taphonomy, paleoecology, pennsylvanian

Gas domes (GD) are structures formed during the development of microbial mats. The ephemeron character of these structures makes difficult its preservation in the fossil record. This work aims to report and characterize the presence of GD in Late Pennsylvanian deglaciation deposits and to discuss how the benthic fauna preserved as trace fossils interacted with them. The GD are preserved in 1 mm-thick claystone layers that compound thin-bedded fine-grained tabular rhythmites preserved at the top of Rio do Sul Formation (Paraná Basin, southern Brazil), deposited during deglaciation events that affected the Gondwana in the Late Paleozoic Ice Age. GD are a fairly common microbially induced sedimentary structures (MISS) in modern siliciclastic tidal flats, but also occur in freshwater ponds formed by rain showers in continental areas. The record of GD in Phanerozoic rocks is virtually unknown. Rio do Sul Formation's GD range from 14 cm to 21 cm in diameter and typically have circular edges. XRD (X-ray diffraction) ratio analyses showed that pyrite is absent in the claystone lamina containing the GD structures but occur in high concentration in the GD structure area. In opposition trace fossils (*Cruziana problematica*, *Diplichnites gouldi, Diplopodichnus biformis* and *Helminthoidichnites tenuis*) and dropstones are common outside the circular areas of the GD structures and virtually absent over them. These taphonomic signatures indicate that (i) the muddy substrate was firm; (ii) GD remained inflate for a period long enough to limit the benthic biota activity to their surrounds; and (iii) microtopography and toxic gas produced by microbial mediation inside GD might be blocked the invertebrate activity in the GD area.

Late Cretaceous long famine and short feast in Antarctica: Ichnological evidence from the Marambio Group

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Keywords: Upper Cretaceous, Antarctica, ichnology, Cruziana ichnofacies, famine and feast

The expression long famine and short feast reflects the key role of strong seasonality in food production and structuring of modern polar marine ecosystems, the origin of which has been influenced by the combination of high-latitude and extreme cooling characterizing Antarctica since the latest Eocene-Oligocene. Nonetheless, we present evidence that during an interval of significant climatic and biotic reorganization mostly endemic Late Cretaceous trace fossils of the *Cruziana* ichnofacies, Marambio Group, Antarctica represent behaviors reflecting a long famine and short feast scenario. During the Santonian-Maastrichtian the Marambio Group record a cooling trend of seawater temperatures from ~18C° to ~8C°, which is accompanied by remarkable shifts in the biogeography of mollusks (Olivero, 2012) and ichnofossils. Consequently, typical cosmopolitan trace fossils of the *Cruziana* ichnofacies where progressively replaced by a suite of geographically restricted complex spreite ichnofossils, dominated by *Paradictyodora antarctica*, *Tasselia ordamensis*, *Euflabella* ispp., and *Patagonichnus* ispp. (Fig. 1). Even though their complex spreite structures clearly classify them as fodinichnia important variations in their general bauplan suggest multiple feeding strategies. The trace markers of these ichnospecies, particularly those of *Tasselia ordamensis* (Fig. 2) and *Euflabella multiplex* (Fig. 3), are best interpreted as trophic generalists, well adapted for deposit feeding, surface detritus feeding, and bacterial gardening (Olivero and López C., 2010, 2013). Surface detritus feeding is denoted by the relative high concentration of calcispheres, diatoms and foraminifers in the backfill lamellae, whereas the systematic reworking of previous backfill laminae (negative phobotactic behavior) supports gardening, with the upper part of each laminae being used to culture bacteria, suggesting strategies to cope with seasonally fluctuating food resources and implying a Late Cretaceous long famine and short feast scenario as in the modern Antarctic fauna.

References

Olivero, E.B. "Sedimentary Cycles, Ammonite Diversity and Palaeoenvironmental Changes in the Upper Cretaceous Marambio Group, Antarctica." *Cretaceous Research* 34 (2012): 348-66. Print.

Olivero, Eduardo B., and María I. López Cabrera. "*Tasselia ordamensis*: A Biogenic Structure of Probable Deposit-feeding and Gardening Maldanid Polychaetes." *Palaeogeography, Palaeoclimatology, Palaeoecology* 292.1-2 (2010): 336-48. Print.

Olivero, Eduardo B., and Maria I. López Cabrera. "*Euflabella* n. igen.: Complex Horizontal Spreite Burrows in Upper Cretaceous–Paleogene Shallow-Marine Sandstones of Antarctica and Tierra Del Fuego." *Journal of Paleontology* 87.3 (2013): 413-26. Print.

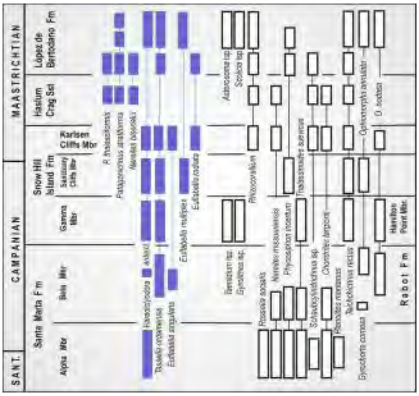

Fig. 1. Stratigraphic distribution of trace fossils of the Santonian-Maastrichtian *Cruziana* ichnofacies in the Marambio Group, Antarctica. Note the increasing dominance with time of geographically restricted trace fossils (blue rectangles) respect to typical, cosmopolitan ichnofossils (white rectangles).

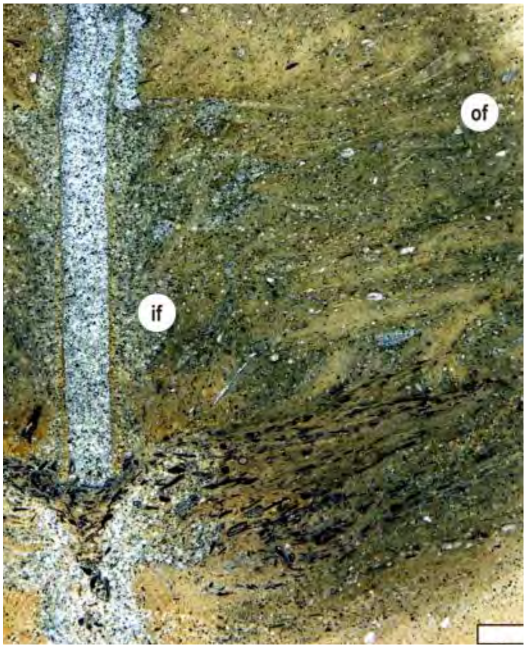

Fig. 2. The internal structure of *Tasselia ordamensis* in longitudinal section. The radial petaloid elements of the outer fill domain (of) contain abundant radiolaria, calcispheres, diatoms and plant debris and reflects deposit and surface detritus feeding. The elements of the inner fill domain (if) probably functioned as “culturing compartment” for bacteria and its secondary reworking implies ‘gardening’.

Fig. 3. Upper bedding plane view of *Euflabella multiplex* showing multiple cross-cutting of spreite body elements, the upper part of the back fill laminae of which are enriched in foraminifers and calcispheres suggesting deposit feeding, surface detritus feeding and bacterial culture and gardening.

Shallow Marine Trace Fossils from the Lower Sequences of Jaisalmer Formation of Jaisalmer Basin, Chelak area, Western Rajasthan, India.

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Keywords: Shallow Marine, Trace fossils, Jaisalmer Formation, Chelak area and Western Rajasthan.

Three trace fossils namely *Diplocraterion*, *Margaritichnus* and *Monocraterion* have been reported from the Lower Sequences of Jaisalmer Formation of Jaisalmer Basin at Chelak area of Jaisalmer district of Western Rajasthan, India. The Chelak area is located about 10kms south of Akal Fossil Park on Jairat –Jinjhinyali Tar Road. Here *Margaritichnus* trace fossils is found in bluish yellow fine to medium grained sandstone while *Diplocraterion* and *Monocraterion* occurs in whitish yellow fine grained siliceous limestone. The total thickness of the section of outcrop at Chelak area is about 15m. The *Margaritichnus* trace fossils is vertically compressed ball –shaped structures; generally arranged and preserved in a row like a string of pearls; rarely connected by ridges which show crescentric transverse grooves were mainly produced by worm –like deposits feeders such as sipunculids and priapulids, *Diplocraterion* vertically U –shaped burrow with spreite structure and the burrow opening is curved, dumbbell –shaped on the bedding surface are considered dwelling burrows of suspension feeding animals such as crustaceans and *Monocraterion* straight to slightly curved, unbranched, vertical funnel structure is interpreted as a dwelling structure formed by worm-like animals. Ethologically, they represent domichnia and fodinichnia groups and indicating variable hydrodynamic conditions. Thus the ichnological and sedimentological evidences suggests that lower sequence of Jaisalmer Formation of Jaisalmer Basin of Chelak area is belonging to shallow marine depositional environment. Singh (1996), attributed the Jaisalmer Formation to the Middle Jurassic, while it is difficult to attribute a more specific age to the Chelak section because of the long stratigraphic range of *Margaritichnus* (Permian-Cretaceous), *Dipolocraterion* (Cambrian- Recent) and *Monocraterion* (Cambrian-Recent).

References

Singh, 1996. Mesozoic–Tertiary biostratigraphy and biogeochronological datum planes in Jaisalmer Basin, Rajasthan. In: J. Pandey, R.J. Ajmi, A. Bhandari and A. Dave, (eds.), Contrs. XV Indian Colloq. Micropal. Strat., KDMIPE and WIHG Publication. Dehradun, 63-89.

New ichnological and sedimentological data on the Molfetta dinosaur tracksite (early Albian, Apulia, Italy)

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Keywords: Dinosaur tracks, Apulia Carbonate Platform, early Albian

To date a number of dinosaur tracksites have been discovered within the Mesozoic shallow marine deposits of the Apulia Carbonate Platform, spanning from the ?Tithonian to the lower Santonian. In a disused quarry near the town of Molfetta (central Apulia, southern Italy), a new diverse ichnoassemblage is exceptionally well exposed at the top of a circa 15 m thick carbonate succession, early Albian in age. The trampled surface covers an area of about 2700 m^2 and yielded more than 30 tridactyl footprints, most of which are arranged in seven different bipedal trackways. All these tracks can be confidently attributed to medium-sized theropods (Fig 1). Two short quadrupedal trackway segments, possibly pertaining to the same trackway, testify to the presence of small to medium-sized quadruped dinosaurs. Footprint morphologies, trackway pattern and parameters (heteropody index of about 1/2) hint at thyreophorans as possible producers.

Interestingly the surface is marked by an enigmatic and large L-shaped trace with a medial raised rim and several meniscate structures, possibly made by a sliding tetrapod.

Lithofacies analysis suggests that tracks developed on shallow subtidal wackestones, lacking clear sedimentological characters related to long-lasting subaerial exposure. By contrast, the occurrence of dinosaur tracks is the best evidence for occasional and brief periods of exposure, that however did not allow the development of sedimentary structures such as desiccation cracks (sediments were mainly wetted). Finally, the trampled surface was covered again by shallow subtidal sediments intensively burrowed by marine invertebrates.

Sedimentology and ichnology of the Mafube dinosaur footprint site (Early Jurassic, eastern Free State, South Africa): a preliminary report on footprint preservation and palaeoenvironment

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Keywords: Early Jurassic, Karoo, Elliot Formation, dinosaur tracks, Theropoda

Footprint morphology (e.g., outline shape, depth of impression) is one of the key diagnostic features used in the interpretation of fossil vertebrate tracks. Over 80 tridactyl tracks, confined to the same bedding surface in the Early Jurassic Elliot Formation at Mafube (eastern Free State, South Africa; Fig. 1), show large shape variability over the length of the study site. These morphological differences are considered here to be mainly due to variations in the substrate rheology as opposed to differences in the trackmaker's foot anatomy, foot kinematics or recent weathering of the bedding surface. The sedimentary features (e.g., desiccation cracks) preserved in association with and within some of the Mafube tracks suggest that the imprints are essentially contemporaneous and are true dinosaur tracks rather than undertracks or erosional remnants. They are therefore valuable not only for the interpretation of the palaeoenvironment (i.e., seasonally dry river channels) but also for taxonomic assessments as some of them closely resemble the original anatomy of the trackmaker's foot. The Mafube ichnotaxa are linked to large and small tridactyl theropod trackmakers, possibly to *Dracovenator* and *Coelophysis* based on the following criteria: a) lack of manus impressions indicative of obligate bipeds; (b) long, slender digits, asymmetrical, tapering, (c) often ending in a claw impression or point, and (d) the prints being longer than broad.

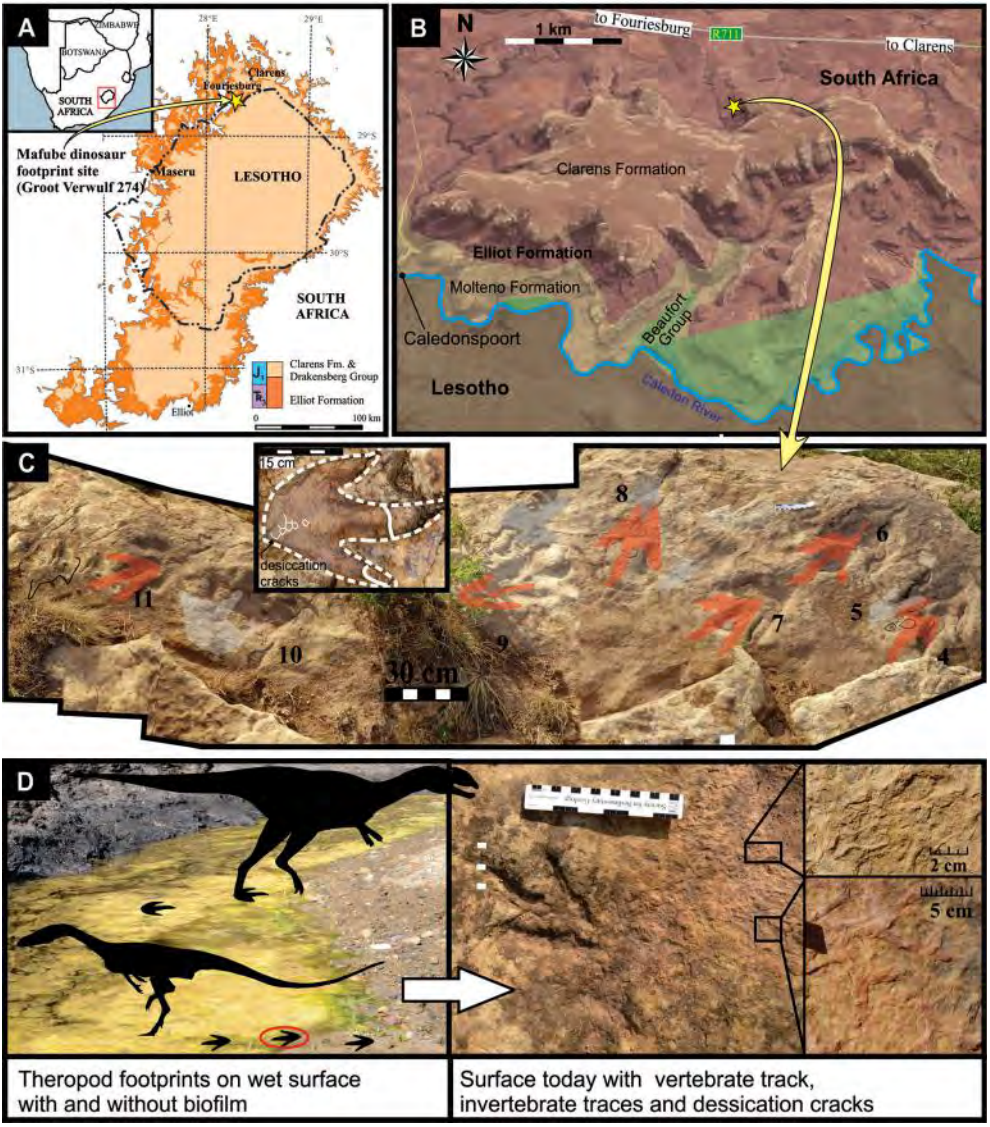

Figure 1. (A) Simplified geological map of the Upper Triassic to Lower Jurassic Elliot and Clarens formations (Stormberg Group, Karoo Supergroup) in Lesotho and South Africa showing the Mafube dinosaur footprint site (yellow star); (B) Google Earth coloured image with geological map overlay to show regional geological context of the Mafube site in the eastern Free State of South Africa; (C) Photograph mosaic of Slab I with well-preserved (in red) and poorly-preserved (in grey) tridactyl footprints, and inset showing a well-preserved true print with desiccation cracks; (D) Genesis of tracks at the Mafube site. Outlines of the theropods Dracovenator and Coelophysis (not to scale) are adapted from www.prehistoric-ildlife.com/species/d/dracovenator.html and www.oldearth.org/curriculum/dinosaur/dinosaur_coelophysis.htm

Biogenic sedimentary structures in shoreface deposits in a modern wave-dominated sandy coast

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Keywords: neoichnology, burrow, *Ophiomorpha*, *Bichordites*, beach

Trace fossils not only provide information on the autecology of ancient animals but also on the paleoenvironment in which the trace-producing animals lived; however, improving our understanding of trace fossils (i.e., their origin and paleoenvironmental usefulness) requires analysis of their modern analogues. Although there is an abundant and varied suite of trace fossils in ancient shoreface deposits, its modern analogue remains poorly understood because harsh waves hamper neoichnological investigations on modern coasts. We overcame this problem by in situ burrow casting and sediment coring using scuba equipment. Fieldwork was carried out on the Kashimanada Coast (Pacific coast of central Japan) at a water depth of 2–20 m. on The burrows of the upogebiid shrimp *Austinogebia narutensis* (incipient *Ophiomorpha*) and the burrows of the loveniid echinoid *Echinocardium cordatum* (incipient *Bichordites*) were observed in the study area. Observation of alongshore variability in bioturbation suggests that intensity of biotubation in shoreface settings depends on distance from a river mouth; the intensity increased with the distance from the river mouth.

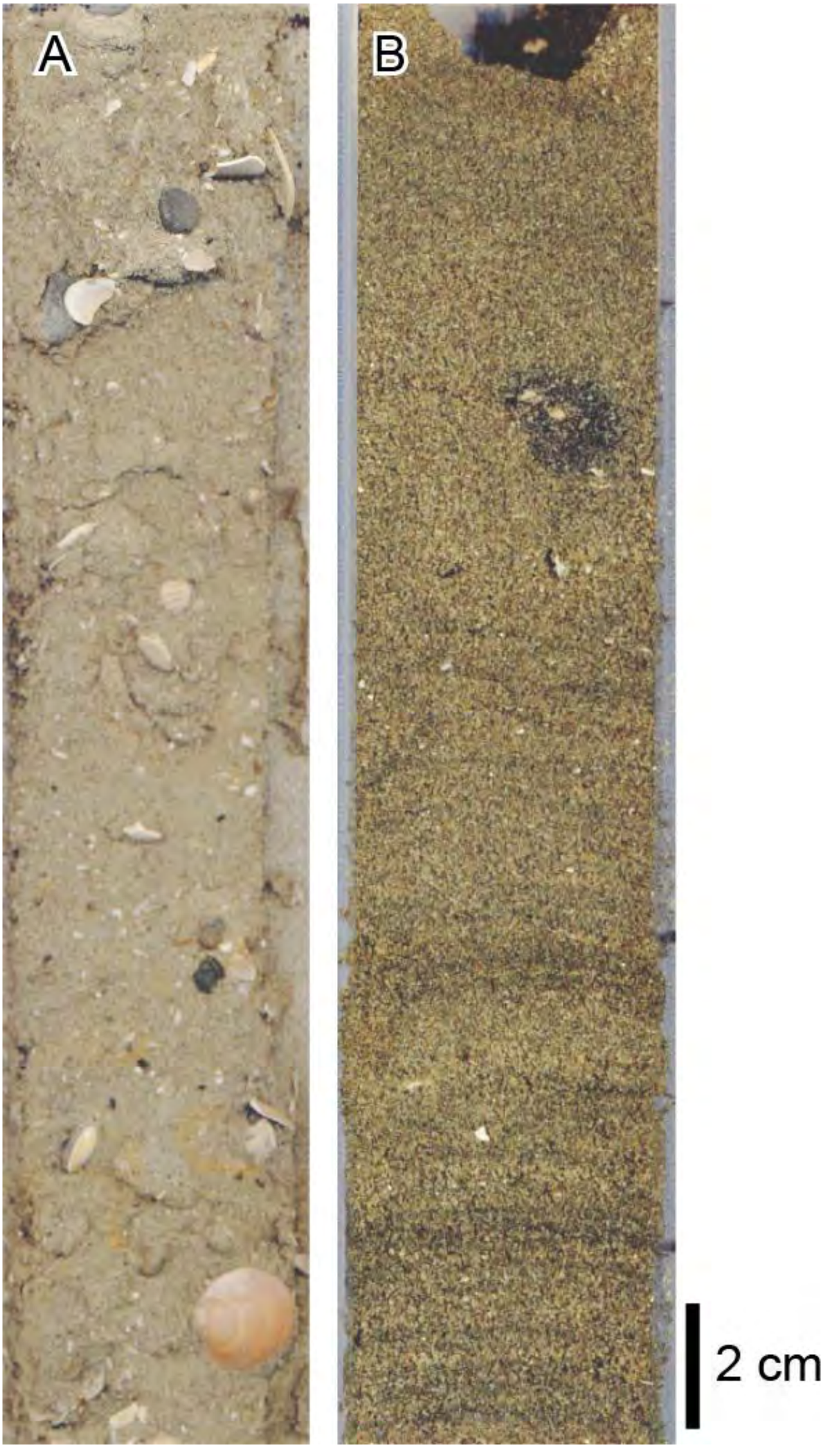

Fig. 1. Photos of the seafloor sediment cores. (A) An example of intense bioturbation. (B) An example of sparse bioturbation. Both cores were recovered at a water depth of 14 m, but the sampling stations of the former and latter were far and close from river mouths, respectively

Bioturbation in shallow marine deposits after a severe tsunami disturbance

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Keywords: Neoichnology, Bioturbation, tsunami, earthquake, event deposits

The huge tsunami waves induced by the 2011 M9.0 Tohoku-Oki Earthquake severely affected shallow marine ecosystems along the Pacific coast of northeastern Japan (Seike et al., 2013). This study focuses on sedimentary features (physical and biogenic sedimentary structures) of shallow marine deposits along Sanriku Coast, i.e., Funakoshi and Onagawa bays, northeastern Japan after the 2011 tsunami disturbance. Core samples were observed using X-ray radiography, computed tomography scanning, and grain size analysis to identify temporal changes in the physical and biogenic sedimentary structures following the 2011 tsunami disturbance. At Funakoshi Bay, sediment coring was conducted in September of 2014. The seafloor sediments of this bay were composed of laminated sandy deposits (tsunami-induced deposits). The upper section (between the surface and a depth of 20 cm) was totally mixed (bioturbated) by burrowing activity of the heart urchin *Echinocardium cordatum*, and contained no physical sedimentary structures. At Onagawa Bay, sediment coring was conducted between October 2012 and April 2013. In 2012 and 2013 observations of the bay, burrows produced by benthic animals were seen only in the mud layer just beneath the seafloor. In contrast, in 2014 observation, abundant burrows were seen in the core up to 20 cm deep from seafloor (Seike et al., 2016). These results indicate that recolonization of large and deep- burrowing animals began within three years of the 2011 tsunami. Also, the intense sediment mixing by large burrowing animals will homogenize the event layer (tsunami deposit).

References

Seike, Koji, Tomo Kitahashi, and Taisuke Noguchi. "Sedimentary features of Onagawa Bay, northeastern Japan after the 2011 off the Pacific coast of Tohoku Earthquake: sediment mixing by recolonized benthic animals decreases the preservation potential of tsunami deposits." Journal of Oceanography 72.1 (2016): 141–149.

Seike Koji, Kotaro Shirai, and Yukihisa Kogure. “Disturbance of Shallow Marine Soft-Bottom Environments and Megabenthos Assemblages by a Huge Tsunami Induced by the 2011 M9.0 Tohoku-Oki Earthquake.” PLoS One. 8.6 (2013): e65417.

Ichnology of the Cambrian Soltanieh Formation of northern Iran: The role of environmental factors in ichnostratigraphy

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Keywords: ichnostratigraphy, Cambrian, Soltanieh Formation, Enviromental factors

Strata in the Central Alborz Mountains, northern Iran are traditionally believed to show continuous sedimentation from Ediacaran through Cambrian. The Soltanieh Formation consists of five members: Lower Dolomite, Lower Shale, Middle Dolomite, Upper Shale and Upper Dolomite. The clastic deposits of the Soltanieh Formation comprise for the most part deposition below storm wave base, and immediately above the storm wave base in intervals of the upper part of the Upper Shale. These deposits contain abundant trace fossils of biostratigraphic utility. Four ichnozones have been recognized. Ichnozone I, containing *Helminthopsis* and *Cochlichnus,* is lower Fortunian based on small shelly fossils, and is regarded as a distal equivalent of the *Treptichnus pedum* zone. Ichnozone II, comprising the first occurrence of *T. pedum,* is late Fortunian, and is best regarded as the upper half of the *Treptichnus pedum zone*. Ichnozone III is late Fortunian–Cambrian Age 2, and is characterized by a sudden change in abundance and complexity of trace fossils. *Cruziana, Curvolithus, Helminthopsis, Palaeophycus, Phycodes, and Treptichnus* are common in this zone. Ichnozone IV is of Cambrian Age 2, and is characterized by the first appearances of *Psammichnites gigas, Rusophycus avalonensis* and *Didymaulichnus miettensis.* Integration of trace fossils with small shelly fossils suggests that the Ediacaran-Cambrian boundary should be placed at the base of the Soltanieh Formation. The delayed appearance of *T. pedum* and the low ichnodiversity in the Lower Shale and lower interval of the Upper Shale reflect limited colonization of settings below storm wave base during the early Fortunian.

Taenidium in the El Hoyo dinosaur tracksite (Lower Barremian, Teruel, Spain): variability and environmental control

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Keywords: Taenidium, ichnotaxonomy, paleoenvironmental conditions, dinosaur tracksite, Lower Barremian, Teruel.

Numerous papers on cylindrical, meniscate backfilled structures, including *Anchorichnus*, *Beaconites*, *Muensteria*, *Scoyenia*, and *Taenidium*, among others, have been published (D'Alessandro and Bromley, 1987; Keighley and Pickerill, 1994). From these meniscate filled structures, *Taenidium* reveals of interest to assessing palaeoenvironmental conditions, especially in the transitional zone between terrestrial and nonmarine aquatic environments. In El Hoyo dinosaur tracksite (Teruel, Spain; Alcalá et al., 2003), declared an Asset of Cultural Interest (*Bien de Interés Cultural*) in the category "*Conjunto de Interés Cultural*", Palaeontological Zone, a Lower Barremian bed shows an invertebrate ichnofabric composed near exclusively by abundant *Taenidium*. Bioturbation is characterized by meniscate-filled structures, preserved as epirelief, cylindrical, straight to sinuous, unbranched, showing the absence of lining, mantle and longitudinal striations. Ichnological features, allow for the characterization, in order of abundance, to the species *Taenidium satanassi*, *T. serpentinum*, *T. barretti*, and *T. recurvum*. Dominance to near exclusiveness of *Taenidium* in the invertebrate trace fossil assemblage suggests assignation to the *Scoyenia* ichnofacies, in agreement with the presence of vertebrate tracks, and the very low invertebrate ichnofossil diversity. A transitional zone between terrestrial and nonmarine aquatic environments, floodplain areas adjacent to rivers, affected by low energy, could correspond to the El Hoyo site. The pervasive ichnofabric of *Taenidium* reveals an opportunistic behaviour of the tracemaker, bioturbating rapidly after deposition, in moist to wet substrates, softgrounds, in shallow tiers into the sediment, during favourable yet ephemeral conditions. Rapid accumulation of nutrients, buried within the sediment, during alluvial discharges, could determine the opportunistic strategy.

References

Alcalá, L., A.Cobos, and R. Royo-Torres. "Icnitas De Dinosaurio En El Castellar (Teruel)." Libro De Resúmenes De Las XIX Jornadas De La Sociedad Española De Paleontología (2003): 28-29. Print.

D'Alessandro, A., and R.G. Bromley. "Meniscate Trace Fossils and the Muensteria-Taenidium Problem." Palaeontology 30.4 (1987): 743-763. Print.

Keighley, D.G., and R.K. Pickerill. "The ichnogenus *Beaconites* and its distinction from *Ancorichnus* and *Taenidium*." *Palaeontology* 37 (1994): 305-337. Print.

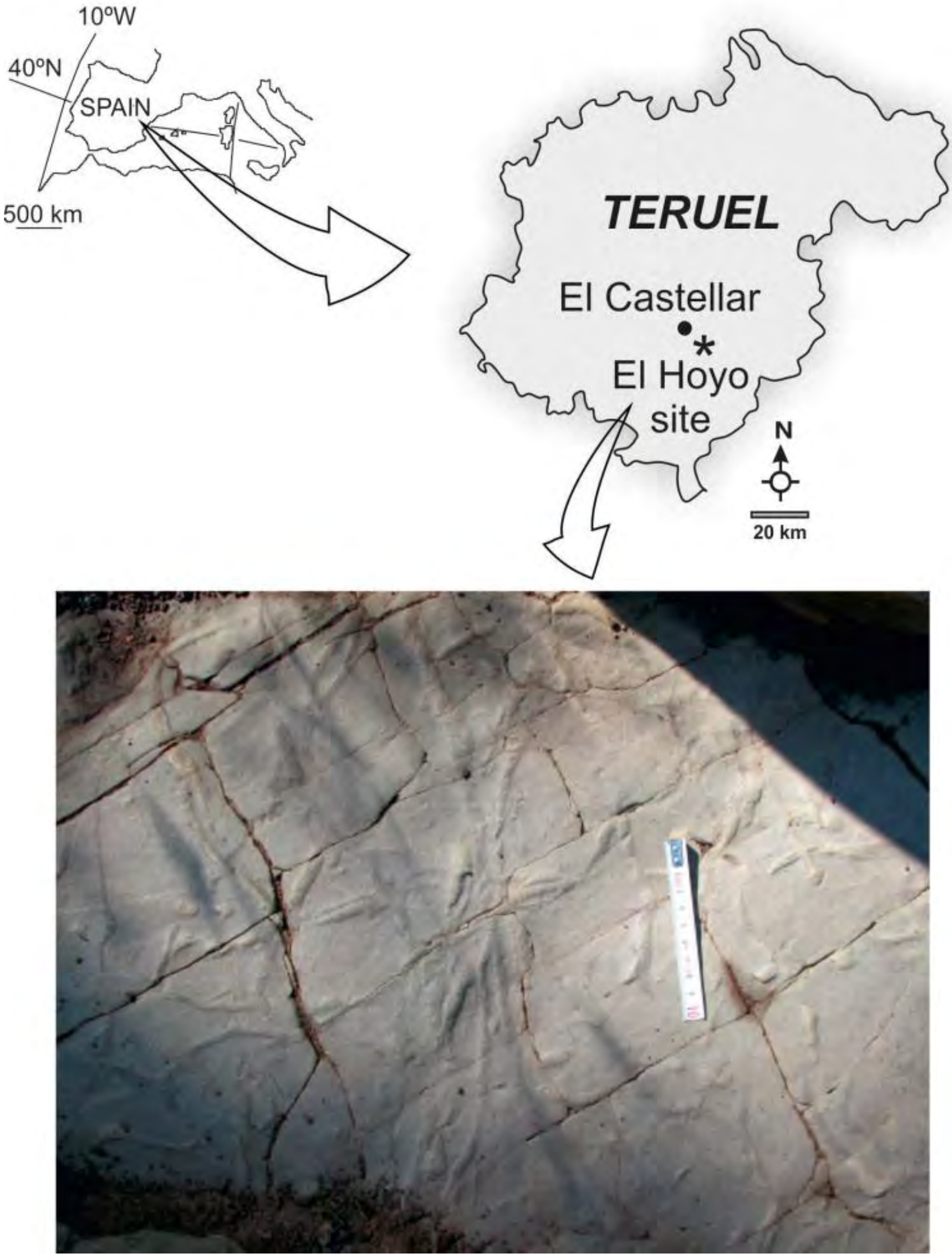

Fig. 1. Geographical location of the El Hoyo site (Teruel, Spain), and close-up outcrop view of the *Taenidium* ichnofabric.

Siphonichnus document – otherwise not recorded – sediment dynamics within Holocene incised-valley fill deposits

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Keywords: incised valley fill, Holocene, Siphonichnus, erosion, aggradation.

The Holocene muddy infill of the incised valley of the Red River documents a change of the depositional setting from fluvial, to estuarine and finally marine conditions. *Siphonichnus*, a mainly vertical trace fossil produced by burrowing bivalves, provides information about a highly dynamic depositional processes, which are otherwise not recorded.

Siphonichnus occurs preferably in sediments experiencing some marine influence as suggested by geochemical proxies. Therefore, the studied sediments are classified to have formed under estuarine conditions. Within these deposits, the producers of *Siphonichnus* moved several tens of centimeters up- and downward and hence, justify to classify these burrows as equilibrichnia. They document a highly dynamic depositional setting. Although the Holocene sediments aggraded in average at a high rate (~1 m/kyr), severe erosional events must have occurred because the Siphonichnus producers burrowed downward for in maximum 1 m. Also the fill of Siphonichnus burrows points to erosion and bypass of sediment. *Siphonichnus* burrows were produced in muddy sediment, but (parts of) the burrows are filled with sand that is otherwise not present in the sediment record. Obviously, the sand was present when the *Siphonichnus* producers fed from the sediment surface, but it has been eroded later.

In an estuarine setting erosional processes may occur when river runoff and ebb-tidal currents interact within the backwater limit. Furthermore, observations in the Recent show that during onset of the freshet (= high flood period) the river is in an erosive stage. As freshet proceeds the river shifts from erosion and sediment bypass to deposition.

Amphipod and callianassid shrimp burrows in the Piedras Estuary (Lepe, Huelva, SW Spain)

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Keywords: Amphipoda, Callinassidae, Bioturbation, Neoichnology, Lepe

The estuary of the Piedras river, located in the coast of Lepe (Huelva, SW Spain), constitutes a lagoon bounded on its marine side by a 12 km-long spit (known as Flecha de Nueva Umbria or Flecha de El Rompido) that runs parallel to the coast and extends to the east due to littoral drift. Several neoichnological studies have been carried out during the last years (e.g. Belaústegui et al., 2015; Gibert et al., 2013; Muñiz et al., 2015).

In particular, the burrowing activity of three species of crustaceans has been studied: a) *Talitrus saltator* (Amphipoda: Talitridae); b) *Corophium volutator* (Amphipoda: Corophiidae); and c) *Pestarella thyrrena* (Decapoda: Callianassidae). Neoichnological studies were carried out along the supra- and intertidal zones (mean tide range around 2 m) of this estuary, both in the salt marshes (secondary and tertiary channels) as in the main channel (inner part of the spit); either by direct observation in the field, simple excavation and/or resin casting.

Burrowing activity of the sand hopper *T. saltator* is restricted to the supratidal sandy areas of the main channel, and consists of simple unlined shafts (diameter up to 50 mm; *Skolithos*-like). By contrast, *C. volutator* has only been observed in the muddy secondary and tertiary channels of the salt marshes, excavating simple U-shaped burrows (up to 3 mm in diameter and 50 mm depth; *Arenicolites*-like). Finally, *P. tyrrhena* burrows have been observed in both studied areas (salt marshes and main channel), distinguishing two main morphologies: a) vertical burrows with horizontal blind and rounded chambers and b) irregular U-shaped galleries (comparable to ichnogenera *Thalassinoides* and *Parmaichnus*); in both cases, with thin vertical shafts (exhalant tubes).

References

Belaústegui, Zain, Fernando Muñiz, Rosa Domènech, and Jordi Martinell. " Ichnology of the Lepe Area (Huelva, SW Spain): Comparison between Modern and Fossil Ichnofabrics." Ed. Masakazu Nara. Abstract Book - 13th International Ichnofabric Workshop, Kochi, Japan, 2015. 48-49.

Gibert, Jordi M. de, Fernando Muñiz, Zain Belaústegui, and Matúš Hyžný. "Fossil and modern fiddler crabs (Uca tangeri: Ocypodidae) and their burrows from SW Spain: ichnologic and biogeographic implications." Journal of Crustacean Biology 33 (2013): 537-551.

Muñiz, Fernando, Zain Belaústegui, Carolina Cárcamo, Rosa Domènech, and Jordi Martinell. "*Cruziana*- and *Rusophycus*-like Traces of Recent Sparidae Fish in the Estuary of the Piedras River (Lepe, Huelva, SW Spain)." Palaeogeography, Palaeoclimatology, Palaeoecology 439 (2015): 176-83.

Ichnological analysis of Miocene sediments from the Ladrilleros-Juanchaco sequence: contributions to the study of sedimentary environments and palaeoecology in NW South America – Colombia

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Keywords: Trace fossils, palaeoenvironmental conditions, Ladrilleros, Colombia.

The stratigraphic section Ladrilleros - Juanchaco is a terrigenous succession of approximately 700m thick, located in San Juan sub-basin, in the southwest of the Colombian Pacific.

The sequence consists of interbedded sandstones and mudstones, predominantly muddy to the base and sandy to the top. Based on micropalaeontology (foraminifera and calcareous nannofossils) a Langhian-Tortonian (Miocene) age has been established.

Ichnological research, including ichnotaxonomic and ichnofabric analyses, of the entire Miocene succession allows characterization of an abundant and relatively diverse trace fossil assemblage, mainly consisting, in order of abundance, of *Planolites*, *Thalassinoides*, *Chondrites*, *Zoophycos*, *Nereites*, *Phycosiphon*, *Stelloglyphus*, *Ophiomorpha*, *Scolicia*, *Rhizocorallium*, *Diplocraterion*, *Skolithos*, *Palaeophycos*, *Cosmorhaphe*, *Helminthorhaphe*, and *Punctorhaphe*. This assemblage shows significant stratigraphic changes, allowing differentiation of several intervals from bottom to top of the succession that can be tentatively correlated with variations in palaeoenvironmental conditions. Two ichnofacies have been differentiated alternating along the studied interval: 1) ichnofacies of *Zoophycos*, with *Zoophycos* as dominant trace, and to a lesser extent *Nereites*, *Chondrites*, *Phycosiphon*, *Planolites*, *Palaeophycos*, *Rhizocorallium* and *Thalassinoides*, originated in a very stable environment with low energy and low sedimentation rate, and 2) ichnofacies of *Nereites*, consisting of *Cosmorhaphe*, *Helminthorhaphe*, *Diplocraterion*, *Nereites*, *Ophiomorpha*, *Planolites*, *Scolicia* and *Stelloglyphus*, related to bathyal-abyssal quiet but oxygenated waters, commonly influenced by turbidity currents. Moreover, records of monospecific traces (*Arenicolites*, *Planolites*, *Phycosiphon*, *Skolithos*, *Scolicia*, *Punctorhaphe*) occur locally, indicating specific conditions. Ichnology, facies and sequence analysis revealed that this unit was deposited in a deep marine environment influenced by bottom currents.

Ichnological analysis of the turbidite Solitary Channel Complex from drillcore data (Miocene, Tabernas Basin, SE Spain)

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Keywords: Ichnofabrics, deep-sea, turbidites, Miocene, Almería.

The Solitary Channel Complex (SCC), developed on a submarine slope, is about 80 m thick, hundreds of metres wide and several kilometres long. Most of the infill is made up of turbidite sandstones; conglomerate and mudstone are less than 10%. The channel was studied from two continuous drillcores together with 3D facies reconstruction from outcrop studies.

Three ichnofabrics identified in the channel-fill include: A) an *Ophiomorpha* ichnofabric (ii 2 *sensu* Taylor & Goldring, 1993), where *Planolites*, *Palaeophycus*, *Scolicia*, *Skolithos* and *Thalassinoides* may also be present; it occurs in fine- to medium-grained sandstones and gravelly sandstones (high-energy, channel axis facies) which were probably colonized by opportunistic mid- to deep-tier burrowing organisms; B) a *Planolites-Palaeophycus-Nereites* ichnofabric (ii 1 to 4), mainly associated to very fine- and fine-grained sandstones (low-to-moderate energy, off-axis facies); and C) a *Phycosiphon-Nereites-Planolites* ichnofabric (ii 4/5), in very fine-grained sandstones and mudstones (low energy, channel margin facies), exhibits the highest ichnodiversity with a combination of mid- and deep-tier burrows (*Chondrites*, *Palaeophycus*, *Planolites*, *Scolicia*, *Skolithos*, *Teichichnus*, *Thalassinoides, Zoophycos*). Below the channel, sandy mudstones (gravity flow deposits, probably turbidites) are characterized by a *Nereites-Phycosiphon* ichnofabric (ii 3/4) dominated by *Nereites* combined with common *Phycosiphon* and rare *Zoophycos*. In addition, several firmground omission surfaces associated to erosive events (*Glossifungites* ichnofacies) were identified. The presence of one of these surfaces on top of the basal sandy-mudstones and the marked ichnological contrast across this boundary support the interpretation that the basal bounding surface of the SCC records an episode of deep erosional encasing into pre-existing distal lobe fringe deposits.

References

Taylor, A. M., and R. Goldring. "Description and Analysis of Bioturbation and Ichnofabric." Journal of the Geological Society (1993): 141–148.

Dinosaur footprints as "Hard Under Layers" from the Upper Cretaceous of Gobi desert, Mongolia.

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Keywords: dinosaur, footprint, natural cast, underprint, Mongolia

Occurrence patterns of dinosaur footprints in the Upper Cretaceous of Gobi Desert, Mongolia are very different from the world standard (Ishigaki et.al. 2009). The majority of the footprints of Gobi Desert tracksites are not concave prints, but natural casts (abbreviated as "NC") and hard under layers (abbreviated as "HUL"). NC is originally consolidated infillings of true prints. HUL consists of hard under layers beneath the true prints which are observed as natural cast-like sandy blocks in the field. Both of these types of prints expose like stepping stones or weathered rock fragments.

About origin of HUL, as far as preservative and diagenetic conditions are concerned, there is only one difference between "hard under layers" and "surrounding softer layers". That is the gravitational impact by the trackmaker at the moment of imprinting. Courel and Demathieu (1984) stated that "the foot's impact compressed a column of sediment that subsequently resisted erosion while the surrounding sediments were winnowed away" (translated by Thulborn) (Thulborn 1990)) and emphasized the importance of the impact by trackmaker at the moment of imprinting. The occurrence patterns of HUL in the Gobi desert support their idea. Such gravitational impact has been often neglected in reconstructing the origin of footprints.

NC and HUL often appear on the eroded ground as scattered fragments of rocks. Previous expeditions in the Gobi Desert from 1920 to 1995 ignored those abundant footprints, as they did not place importance on this special occurrence. This revelation shall stimulate the new discovery of footprint sites in similar desert conditions worldwide.

References

Courel, Louis., and Demathieu, Georges. “Les inversions de relief dans les traces fossiles.” 109e congrès national des sociétés savantes, Dijon, sciences, Fasc. 1 (1984) : 373-383.

Ishigaki, Shinobu., Watabe, Mahito., Tsogtbaatar, Khishigjav. and Saneyoshi, Mototaka. “Dinosaur footprints from the Upper Cretaceous of Mongolia.” Geological Quarterly 53,4 (2009) : 449-460.

Thulborn, Tony. *Dinosaur tracks.* London: Chapman & Hall, 1990.

Zoophycos and its paleoenvironmental significance in Jurassic (Callovian; Nador mountains, Algeria) and middle Devonian (Ougarta mountains, Algeria) deposits

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Keywords: Zoophycos, Callovian, middle Devonian, Calcaire du Nador, Chefar El Ahmar.

Abundant and diverse trace fossils occur in the Jurassic (Callovian) deposits of the well-exposed Sidi Saadoun section (Nador Mountain, western Algeria, 300 km southern of Oran). The studied trace fossils are found in Calcaire du Nador Formation that is composed of two units. The basal unit is characterized by alternating marl and limestone beds with ammonites and belemnites; the upper unit is marked by limestones with slump deposits, nodular limestones and limestones with ammonites. Five ichnogenera have been found: *Chondrites*, *Rhizocorallium*, *Zoophycos* in the basal unit and *Zoophycos, Nereites Thalassinoides* in the upper unit. The studied ichnoassociation is attributed to the *Zoophycos* ichnofacies and suggests a slope environment. *Zoophycos* is the most abundant ichnotaxon and is morphologically corresponding to the Morphotype B of Olivero (2003), which confirms a slope environment.

The second section is represented by Chefar El Ahmar Formation (middle Devonian, (Saoura, Algerian Sahara), that is dominated by muddy shales, limestones and muddy nodular limestones. The studied ichnofauna is characterized by *Zoophycos*, *Chondrites, Thalassinoides*. and *Nereites* in a meso-distal shelf.

Comparison between the Jurassic *Zoophycos* of Nador and the Devonian ones of Chefar El Ahmar Formation show significant differences with respect to the formtiering and *Zoophycos* ichnofabric rate. bioturbation rate. The studied Devonian *Zoophycos* are J- or U-shaped, are characterized by low penetration depth a (few centimeters); the Jurassic ones are J-shaped and present a higher penetration depth.(from few centimeters to a few decimeters)

The *Zoophycos* of Nador do not have the same evolution by comparing with those of the French Subalpine Basin during the Callovian, which the *Zoophycos*of French Subalpine Basin are represented by the Morphotype C of Olivero (2003), characterized by a poly-lobed shape in a deposits environment from the basal slope to basin.

Reference

Olivero, D: 2003. Early Jurassic to Late Crestaceous evolution of Zoophycos in the French Subalpine Bassin (southeastern France).Palaeogeography, Palaeoclimatology, Palaecology, 192, 59-78.

Fig. 1. The different types of studied *Zoophycos*: Form the Middle Devonian of Chefar El Ahmar Formation (A, B, and C), from the Callovian of the Calcaire du Nador Formation (D, E, and F)

Trace fossil evidence for a catastrophic ice dammed lake drainage in the Arctic Ocean

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Keywords: Escape traces, bioturbation, mixed layer, Arctic Ocean, Quaternary

Ice dammed lakes formed during glacial stages behind large ice sheets that blocked the rivers' access to the ocean. The size of these lakes ranged from small ponds to huge inlands seas larger than any fresh water lakes found on Earth today. In the central Arctic Ocean, a distinct layer with extremely sharp lower boundary has been observed and is believed to be the result of the catastrophic drainage of one such lake situated on the Siberian Hinterland. Here we use composition and changes in bioturbation and trace fossils to test the hypothesis that this layer is the result of a very rapid process with an abrupt start and a gradual ending, consistent with a catastrophic ice dammed lake drainage.

If the event was abrupt and the sediment in the layer was deposited at sedimentation rates several orders of magnitude larger than the background sedimentation, then we would expect to find a diverse and abundant ichnofauna below the layer. In the layer itself, bioturbation should be absent or sparse, and any trace fossil should be of deep tiers. The top of the layer should show a gradual transition into fully bioturbated sediment.

Studies on radiographs from cores across the Eurasian part of the Arctic reveal distinct changes in bioturbation that agree with the proposed scenario. However, some cores from the same region do not display the expected pattern. In part this enigma may be explained by the extreme rapidity of the event, resulting in highly heterogeneous distribution of the layer.

Avetoichnus luisae ichnocoenosis in Paleogene bottom nepheloid layer deposits, Scaglia Toscana Formation, central Italy

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Keywords: Ichnocoenosis, *Avetoichnus luisae*, nepheloid, Paleogene, Italy.

Bottom nepheloid layers (BNL) are deep dense waters transporting suspended clay, silt or fine sand with organic matter particles in the central part of basins, with usual suspended sediment concentrations of <0.1 mg/l above background levels, reaching higher concentrations close to the continental rises, with near-bottom peaks >1 mg/l and lesser concentrations < 1 mg/l progressively towards the basin plain (Puig et al., 2013). BNL are very common in recent basin margins (e.g. the continental rise of French Mediterranean, North Atlantic), but poorly studied in the geological record. Some authors think that turbulent flow in BNL is more responsible for deposition of mud in flat basin plains than fine-grained turbidites (P. Pilgrim, personal communication 2010). The thickness of BNL deposits depends on bottom current velocity and the balance between gravitational settling of particles, basin plain morphology and turbulence of the current. Burrowing organisms intensively exploit the organic matter deposited in the sea floor by BNL; in Canadian Atlantic basin plain, the upper surface is extremely bioturbated with hundreds of burrow openings per m^2 (Hunkins et al., 1969, figs 3, 4). In the Paleogene Scaglia Toscana Formation (central Italy; Trasimeno area, Montanare, M. Solare, M. Maggio, Fig. 1), grey to red mudstones occur in beds which are 40 to 60 cm thick (Fig. 2). They are much thicker than typical mud turbidites of overlying Macigno Formation (Amendola et al. 2015). A typical increasing upward density of trace fossils (Monaco et al., 2012) has been detected. In lower tiers dominate deep endichnia (*Zoophycos*, *Taenidium*, *Planolites*); in middle and shallow tiers dominate very common *Avetoichnus luisae*, *Chondrites targionii*, *C. intricatus*, and *Cladichnus*. Then, utilizing ichnocoenoses is possible differentiate turbulent flow deposits (see Shanmugam, 2002; turbidites versus BNL deposits), because currents caused variation in food resources and the presence or absence of nutrient-rich fine-grained substrates. Ichnocoenoses of BNL sediments are a new interesting topic of studies in deep-sea depositional systems, as a proxy to elucidate paleoenvironmental and ethological conditions that influenced distribution, concentration, burrow diameter, burrow depth, ichnodiversity and traces fossil assemblages.

References

Amendola U., Perri F., Critelli S., Monaco P., Cirilli S., Trecci,T. Rettori R.. “Composition and provenance of the Macigno Formation (Late Oligocene-Early Miocene) in the Trasimeno Lake area (Northern Apennines).” *Marine and Petroleum Geology*, 30 (2015): 1-22.

Hunkins K., Thorndike E.M., Mathieu. "Nepheloid Layers and Bottom Currents in the Arctic Ocean." *Journal of Geophysical Research* 74 (1969): 6995–7009.

Monaco P., Trecci T., Uchman A. "Taphonomy and ichnofabric of the trace fossil *Avetoichnus luisae* Uchman & Rattazzi, 2011 in Paleogene deep-sea fine-grained turbidites: Examples from Italy, Poland and Spain." *Boll Soc. Paleont. Ital* 51 (2012): 28–38.

Puig, P., Durrieu de Madron, X., Salat, J., Schroeder, K., Martín, J., Karageorgis, A.P., Palanques, A., Roullier, F., Lopez-Jurado, J.L., Emelianov, M. “Thick bottom nepheloid layers in the western Mediterranean generated by deep dense shelf water cascading”. *Progress in Oceanography* 111 (2013): 1–23.

Shanmugam G. “Ten turbidite myths”. Earth-Science Review, 58 (2002), 311-341.

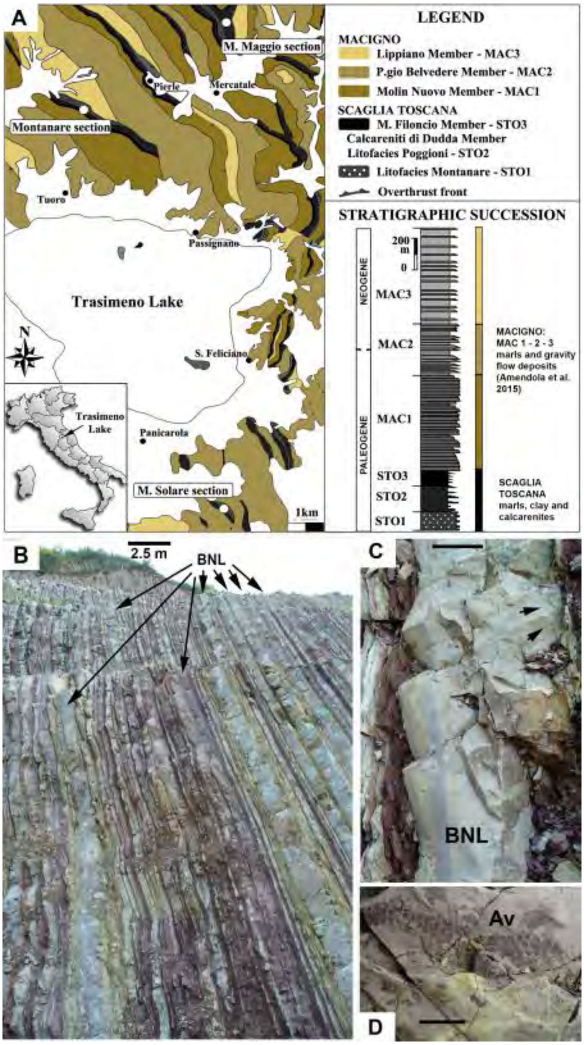

Fig. 1. A) Study area and stratigraphy of the studied sections; B) The Scaglia Toscana Formation with BNL mudstones, bar = 2.5 m; C) detail of the BNL mudstones, bar = 20 cm; D) Endichnial *Avetoichnus luisae* (Av) as endichnion in a BNL, bar = 1 cm;

First Occurrence of *Pallichnus dakotensis* in a Dinosaur Nesting Site from the Two Medicine Formation (Campanian, Upper Cretaceous) of North America.

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Keywords: fossil traces, coleopterans, dung beetles, Two Medicine Formation, Campanian.

Trace fossils can provide important information on paleoenviromental conditions and depositional processes. Invertebrate traces of the Upper Cretaceous Two Medicine Formation of Montana, USA are quite common and in several cases constitute a significant portion of the ichnoassemblage. At Egg Mountain, a dinosaur nesting site near Choteau, Montana, abundant fossil traces ascribed to apocritian and coleopteran pupation chambers occur in association with eggs and eggshell concentrations from dinosaurs and non-dinosaurs. Here we report the occurrence of a previously unreported trace fossil from these units, ascribed to *Pallichnus dakotensis* (Retallack, 1984). Specimens are slightly compressed, sub-spherical to ellipsoidal casts, typically showing a rimmed scar and a thin, brownish, oxidized coating. They are interpreted as possible paracoprid dung-beetle pupation chambers. In contrast to other trace fossils at the site, they are quite rare, which might reflect overall semi-arid environments of the Two Medicine Formation (Martin & Varricchio, 2010). Coleopterans, such as paracoprid dung beetles, usually increase their activity during the rainy season, as opposed to apocritians, such as wasps, which typically prefer well-drained soils and arid climate. Similarly, ecological constraints, such as seasonality and climate, might also have played an important role in dinosaur-nesting preferences. *P. dakotensis* was reported in Oligocene deposits of North Dakota, and more recently in Cretaceous deposits of Patagonia, Argentina (Genise et al., 2007).With this description, we add the first fossil record of this ichnospecies in Late Cretaceous deposits of North America.

References

Martin, Anthony J., and David J. Varricchio. "Paleoecological Utility of Insect Trace Fossils in Dinosaur Nesting Sites of the Two Medicine Formation (Campanian), Choteau, Montana." Historical Biology 23.1 (2011): 15-25. Web.

Genise, Jorge F., Ricardo N. Melchor, Eduardo S. Bellosi, Mirta G. González, and Marcelo Krause. "New Insect Pupation Chambers (Pupichnia) from the Upper Cretaceous of Patagonia, Argentina." Cretaceous Research 28.3 (2007): 545-59. Web.

Retallack, Gregory J. "Trace Fossils of Burrowing Beetles and Bees in an Oligocene Paleosol, Badlands National Park, South Dakota." Journal of Paleontology Vol. 58, No. 2, (1984): 571-92. Print.

Fig. 1. Specimen ascribed to *Pallichnus dakotensis* from Late Cretaceous dinosaur nesting site of Egg Mountain. The upper edge displays a scar approximately 0.5 cm wide. Scale = 1 cm.

The record of *Thalassinoides* across the Toarcian Oceanic Anoxic Event (T-OAE) in the Lusitanian Basin.

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Keywords: Toarcian Oceanic Anoxic Event, trace fossils, *Thalassinoides*, paleoenvironmental conditions, Portugal

The global marine mass extinction of the lower Toarcian, usually associated to black, organic-rich, sediments, is mainly related to a global oceanic anoxic event, the Toarcian Oceanic Anoxic Event (T-OAE). However, recently have been revealed that local factors can determinate the absence of anoxic conditions, being other limiting environmental parameters of higher significance (Rodríguez-Tovar and Uchman, 2010). The detailed study of the Fonte Coberta (Rabaçal area) section (Lusitanian Basin, Portugal; Duarte, 2007) shows significant changes in the macrobenthic community at the Lower Toarcian (Levisoni Zone) sediments characterized by light coloured marl-limestone alternations. An abundant and diverse brachiopod assemblage is registered prior and after the interval corresponding to the T-OAE, but this group is absent during the T-OAE (Comas-Rengifo et al., 2013). However, this interval present abundant bioturbation, showing a trace fossil assemblage with dominance, near exclussiveness, of *Thalassinoides*. Pelagic component, as ammonoids, shows a continuous record with diminution in abundance during the T-OAE. The disappearance of brachiopods and the presence of a well-developed macrobenthic tracemaker community dominated by *Thalassinoides* producer reveals a variable response of the macrobenthic community to the T-OAE. Other paleoenvironmental factors, apart of oxigenation, as temperature, nutrient availability, and sea level can induce the observed variations in the macroinvertebrate community during the T-OAE. Local palaeogeographic features may have been a cause of controlling the distribution of the paleoecological conditions throughout the basin.

References

Comas-Rengifo, María J., Luis Vitor Duarte, Fernando García Joral, and Antonio Goy. "Los braquiópodos del Toarciense Inferior (Jurásico) en el área de Rabaçal-Condeixa (Portugal): distribución estratigráfica y paleobiogeografía." Comunicações Geológicas 100, Especial 1 (2013): 37-42. Print.

Duarte, Luis V. "Lithostratigraphy, sequence stratigraphy and depositional setting of the Pliensbachian and Toarcian series in the Lusitanian Basin (Portugal)." *The Peniche section (Portugal). Contributions to the definition of the Toarcian GSSP.* Ed. Rocha, R.B. Lisbon: International Subcommission on Jurassic Stratigraphy, (2007). 17-23. Print.

Rodríguez-Tovar, Francisco J., and Alfred Uchman. "Ichnofabric Evidence For The Lack Of Bottom Anoxia During The Lower Toarcian Oceanic Anoxic Event In The Fuente De La Vidriera Section, Betic Cordillera, Spain." *PALAIOS* 25.9 (2010): 576-87. Print.

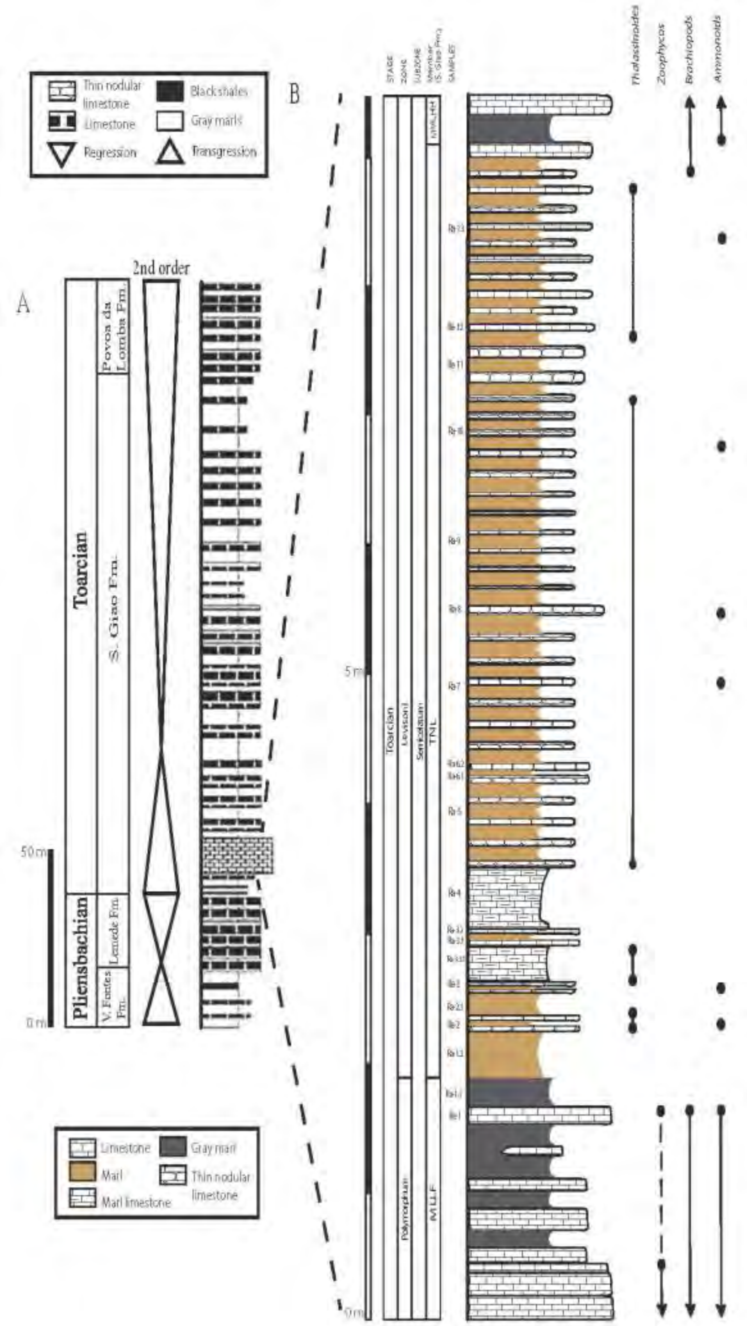

Fig. 1. A) General lithological column, formations, and 2nd order sea level changes in the upper Pliensbachian-Toarcian at the Rabaçal region (modified from Duarte, 2007). B) Detailed stratigraphic column of the studied interval (Thin nodular limestone member, TNL) at the Fonte Coberta section (Rabaçal region), showing the distribution of *Thalassinoides* isp., *Zoophycos* isp., brachiopods and ammonoids from the upper part of the Marly limestone with *Leptaena* fauna (MLLF) member to the lower part of the Marls and marly limestones with *Hildaites* and *Hildoceras* (MMLHH) member.

Role of Microbioerosion in the Development of Two Late Devonian (Frasnian) Carbonate Mud-Mounds in Rocky Mountains, Canada

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Keywords: microbioerosion, microboring, mud-mounds

The Upper Devonian Mount Hawk Formation in Willmore Wilderness Park of west-central Alberta hosts two well-preserved carbonate mud-mounds. This formation is composed of thin- to medium-bedded argillaceous limestone, carbonate mudstone, bioclastic wackestone/packstone, which are deposited in a deep shelf to ramp setting. Two mud-mounds are about 40-50 m thick and 50-60 m wide at their bases with steep flanks around 30-45°, suggesting probable early cementation helps maintain the shape. This character provided organisms a potential firm to hard substrate to interact. However, in the field no macroborings have been observed on both mud-mounds. Under the microscope, microborings (like *Eurygonum*, *Cavernula*, and *Saccomorpha*) on brachiopod shells, corals, and crinoids are detected. Cyanobacteria and fungi are the most likely tracemakers for those detected microborings, as suggested by abundant presence of calcimicrobe fossils such as *Girvanella*, *Rothpletzella, and Renalcis* in the surrounding matrix. The process of microbioerosion has helped produce some components contributing to the construction of these two mud-mounds, such as micobioclastic wackestone/packstone with irregularly shaped and poorly rounded coral and crinoid fragments, locally abundant cortoids, and also some peloids with a different appearance compared to the dominant microbial induced peloids in the mud-mounds. Nutrient supply and relative sea-level changing have an effect on the intensity of microborings and also products by microbioerosion, as a result of which, a paleobathymetry relation with the growth history of the mud-mounds can be revealed.

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Ichnotaxonomy

Cruziana and *Rusophycus* from the Ordovician of the Siberian platform

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Keywords: Cruziana, Rusophycus, Ordovician, Siberia.

The record of trilobite trace fossils from the Ordovician of the Siberian platform is relatively poor. Giant *Rusophycus* 32 cm long and 20 cm wide with well-preserved 3-clawed scratch marks have been found in the Middle Ordovician Baykit Sandstone (Vikhorevian regional stage) from the Podkamennaya Tunguska River valley (Kushlina & Dronov, 2011; Fig. 1). It was the first time Lower Paleozoic giant *Rusophycus/Cruziana* traces were reported from outside the ancient Gondwana continent. The other finding from the same stratigraphic level was a *Rusophycus* of ordinary size (8 cm in length and 5 cm in width) with flat central area and internal coxal impressions (10 pairs). It resembles *R. morgati* but pairs of coxal impressions in Siberian *Rusophycus* are symmetrical. Numerous *Cruziana* were also collected from the Middle Ordovician (Kirensk-Kudrino regional stage) sandstone of the Moyero Formation. These *Cruziana* traces constitute two groups: 1) *Cruziana* A. Deep endopodite V-shaped scratch marks on both sides of median groove have an angle varying from 110° to 170° (Fig. 2). "Claw formula" includes 4 to 6 scratches. 2) *Cruziana* B. Well-preserved endopodite and exopodite scratches (Fig. 3). The endopodite V-shaped scratch marks make an angle less than 90°. On the both lateral margins of the trace, the endopodite scratch marks are overprinted by delicate exopodite brushings consisting of 8-12 thin ridges parallel to the trace margins. *Cruziana* B resembles *C. semiplicata* but differs from later by absence of lateral ridges and age difference. All the Siberian *Cruziana* and *Rusophycus* have no direct analogues among the Middle and Upper Ordovician ichnospecies and probably represent endemic forms of the Siberian palaeocontinent.

References

Kushlina V.B. Dronov A.V. "A Giant *Rusophycus* from the Middle Ordovician of Siberia." *Ordovician of the World. Cuadernos Del Museo Geominero 14.* (2011): 279-85.

Fig. 1. Giant *Rusophycus*. Podkamennaya Tunguska River valley. Baykit Sandstone. Middle Ordovician of the Siberian platform.

Fig. 2. *Cruziana* A. Moyero River valley. Moyero Formation. Middle Ordovician of the Siberian platform.

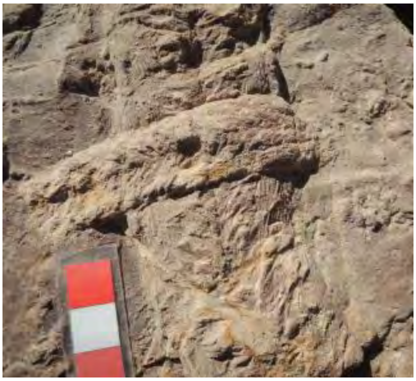

Fig. 3. Smaller *Cruziana* B crossing the wider one. Moyero River valley. Moyero Formation. Middle Ordovician of the Siberian platform.

Middle Jurassic avialan footprints from Imilchil in Morocco

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Keywords: bird footprints, Bathonian, Imilchil, Morocco.

The Jurassic bird track record is scanty in comparison with avian body fossils, which includes new finds from the Callovian-Oxfordian of China. The oldest Jurassic bird-like ichnotaxa is reported from the Lower Jurassic of Massachusetts (USA), Poland and Lesotho (Ellenberger, 1972). The youngest ichnogenus came from the latest Jurassic Tuchengzi Formation of China.

Plesiornis Hitchcock, 1858 and *Trisauropodiscus* Ellenberger, 1972, are the earliest bird-like ichnites. The latest one is *Pullornipes* Lockley, Matsukawa, Ohira, Li, Wright, White & Chen, 2006. Unnamed avialan tracks are also described from the Upper Jurassic of Asturias in Spain and the Middle Jurassic of Msemrir in Morocco (Belvedere *et al*., 2011).

The material reported here is discovered in Imilchil (N 32°09.960', W 005°36.474' - N 32°09.927', W 005°36.533), about 50 km north from Msemrir. Those tracks are 8.5-11.4 cm long, an angle between lateral digits (II – IV) varies between 80° and 90° and the reversed first toe is also seen. Among the Jurassic avialan ichnotaxa, the reported tracks (Fig. 1) are larger than *Plesiornis* (Fig. 2A) and *Pullornipes* (Fig. 2B). Their morphology resembles *Trisauropodiscus* original material from Lesotho, which demonstrates such avian traits like clearly reversed hallux and distinctive metarsophalangeal pad of the middle toe located centrally.

Very recently, similar tracks from the Middle Jurassic of central China are misinterpreted as anomoepodid ornithischian ichnites by Xing *et al*. (2016).

References

Belvedere, M., Dyke, G., Hadri, M., and Ishigaki, S. (2011). The oldest evidence for birds in Northern Gondwana? Small tridactyl footprints from the Middle Jurassic of Msemrir (Morocco). *Gondwana Research*, 19: 542–549.

Ellenberger, P. (1972). Contribution à la classification des pistes de vertebras du Trias: les types du Stormberg d'Afrique du Sud (I): *Palaeovertebrata, Mémoire Extraordinaire*: 1-111.

Xing, L.D., Abbassi, N., Lockley, M.G., Klein, H., Jia, S.H., McCrea, R.T. and Persons, W.S.IV. (2016). The First Record of *Anomoepus* tracks from the Middle Jurassic of Henan Province, Central China. *Historical Biology*, DOI: 10.1080/08912963.2016.1149480

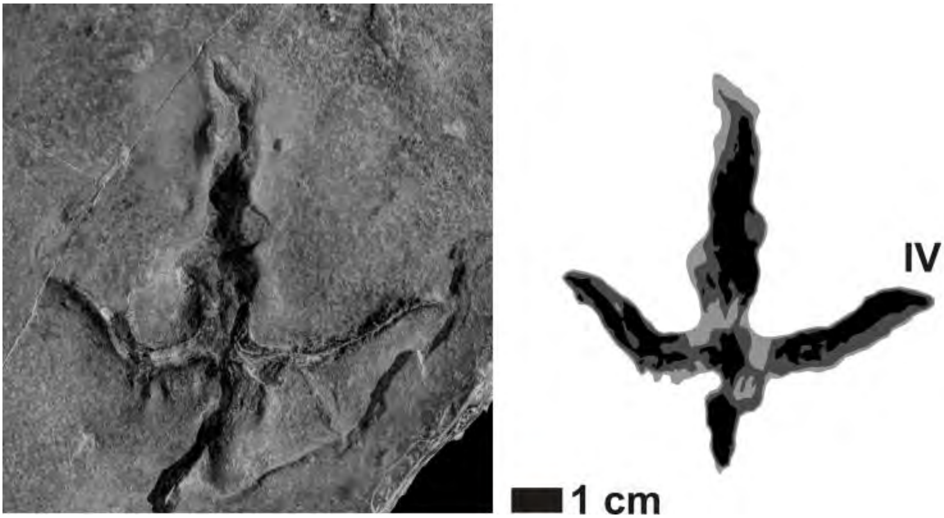

Fig. 1. *Trisauropodiscus* isp. from the Bathonian of Imilchil (Morocco).

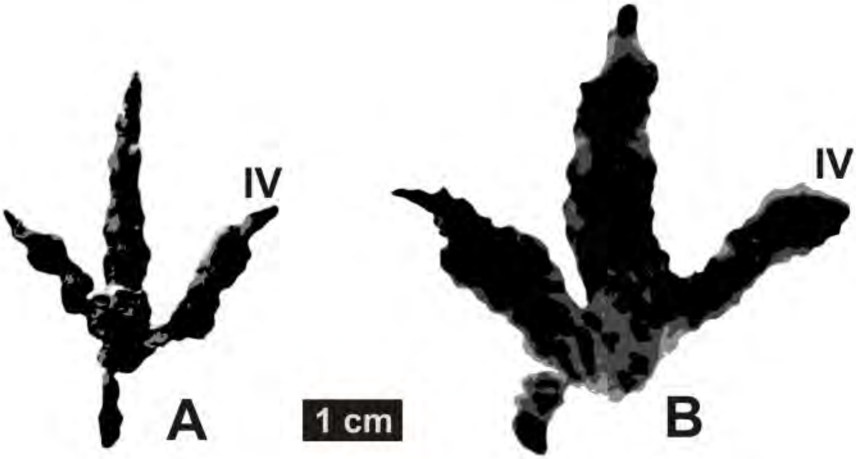

Fig. 2. A - *Plesiornis pilulatus* Hitchcock, 1858, specimen AC 13/1 from the Lower Jurassic of Massachusetts (USA); B - *Pullornipes aureus* Lockley, Matsukawa, Ohira, Li, Wright, White & Chen, 2006, specimen CU 214.21from the Upper Jurassic of Liaoning Province (China).

Life Underfoot: *Treptichnus* among Hitchcock's Dinosaur tracks

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Keywords: Hitchcock, *Fucoides*, *Treptichnus*, Jurassic, History of Ichnology

Edward Hitchcock is renowned for describing and classifying the trace fossils of the Lower Jurassic Hartford and Deerfield basins of Connecticut and Massachusetts, USA. In a career that lasted nearly three decades, he established approximately thirty invertebrate ichnogenera, many of which are still in use. Hitchcock was, however, working in the 19th century, a time known as the "Age of Fucoids" (Osgood 1975), and consequently misinterpreted some invertebrate traces as plant fossils. For example, he mistook *Scoyenia* for "vegetable remains" (Marché 1992). Upon re-examining some of the dinosaur track-bearing slabs in the Beneski Museum of Natural History, where Hitchcock's collection is now stored, we have discovered another example of mistaken identity of invertebrate traces. In transcribing his father's notes, C.H. Hitchcock (1865) mentioned "several trails...of vegetable origin" on ACM.ICH 14/4, a large slab from the Deerfield basin in Turners Falls, Massachusetts (Fig. 1). These fossils are shallow, bedding plane-parallel, zigzag structures exhibiting the forked morphology characteristic of the ichnogenus *Treptichnus*, and are nearly identical to undoubted *Treptichnus* found nearby in the Hartford basin. This brief description apparently represents the first mention of *Treptichnus* in the geological literature, nearly a quarter century before the taxon was described. Given the thoroughness of the descriptions of the fossils in his possession, we surmise that had Edward Hitchcock not been working under the assumption that the fossils were plant remains, he would have named the traces and we would be calling *Treptichnus* by another name.

References

Hitchcock, Edward, and Charles H. Hitchcock. Supplement to the Ichnology of New England. A Report to the Government of Massachusetts, in 1863. Boston: Wright & Potter, 1865. Print.

Marché, J.D. "Edward Hitchcock, Fucoides, and the ichnogenus Scoyenia." Earth Sciences History 11.1 (1992): 13-20. Print.

Osgood, R.G. "The history of invertebrate ichnology." The Study of Trace Fossils. Ed. R.W. Frey. New York: Springer-Verlag, 1975. 3-12. Print.

Fig. 1. *Treptichnus bifurcus* located below and right of a small dinosaur track. ACM.ICH 14/4.

The oldest dinosaur tracks record in the Neuquén Basin from a fluvio-aeolian Hauterivian forced regressive wedge (Avilé Member), Agrio Formation, Patagonia, Argentina.

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Keywords: sauropods, aeolian, Hauterivian, Patagonia, Avilé Member

The Agrio Formation (Hauterivian Barremian) contains a forced regressive fluvio-aeolian wedge (30 50m thick) known as Avilé Member (early Late Hauterivian). In the aeolian interval, at the Cerro Rayoso anticline, several vertebrate tracks were documented. Three track morphotypes (I III) are distinguishable: I) one isolated sub-circular shallow track with lateral rims-like, remnant stratification and a mark preserved inside (fig. 1); II) incomplete footprints wider than length, composed of three parts very flats (tridactilar) with rounded endings (fig. 2); III) a group of three tracks, crescent in shape and wider than length showing four-five short digits mostly rounded and blunt; the basal section is deepest incised frontally (fig. 3). Morphotype I resembles a sauropod pes track, but such producer is debatable; Morphotype II, even incomplete, is a tridactilar ornithopod-theropod track. Morphothype III was produced by a thyreophoran dinosaur, considering morphology, L/W ratio and short I IV/V digits. In South America, dinosaur tracks in fluvio-aeolian deposits during the Upper Jurassic Lower Cretaceous (see Francischini et al., 2015 table 1) were absent from Patagonia. Thyreophoran remains (stegosaurs) were documented in the Aptian Albian La Amarga Formation in the basin (Pereda-Suberbiola et al. 2012). Apesteguía and Gallina (2011) recorded thyreophoran tetradactilar tracks from the Jurassic Cretaceous of Bolivia, finding morphological differences with classical ichnogenera documented in Jurassic successions. The stegosaur tracks in the Parana Basin from fluvio-aeolian deposits are considered now sauropod tracks (cf. Pererda-Suberbiola et al. 2012). It is the first record of thyreophoran tracks in Argentina and the older record of dinosaur tracks in the basin.

References

Apesteguía, S. & Gallina, P. A. "Tunasniyoj, a dinosaur tracksite from the Jurassic-Cretaceous boundary of Bolivia". Anais da Academia Brasileira de Ciências, 83(1) (2011) 267–277. Print.

Francischini, H., Dentzien–Dias, P. C., Fernandes, M. A., & Schultz, C. L. "Dinosaur ichnofauna of the Upper Jurassic/Lower Cretaceous of the Paraná Basin (Brazil and Uruguay)". Journal of South American Earth Sciences, 63, (2015) 180-190. Print.

Pereda-Suberbiola, X., Galton, P. M., Mallison, H. & Novas, F. "A plated dinosaur (Ornithischia, Stegosauria) from the Early Cretaceous of Argentina, South America: an evaluation". Alcheringa: An Australasian Journal of Palaeontology, 37 (1) (2012) 1–14. DOI:10.1080/03115518.2012.702531. Print.

Fig. 1. Sub-circular track with rims-like, relic stratification and with a small crescent mark inside.

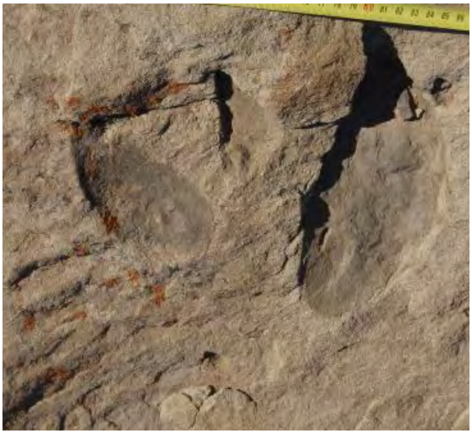

Fig. 2. Flat tridactilar track preserved in cross stratified sandstones with sharp and rounded borders.

Fig. 3. Track with four digits impressions and flat and inclined basal section.

Herradurichnus, *Gyrochorte* and *Daedalus* from the Balcarce Formation (?Silurian of the Tandilia System, Argentina) revisited.

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Keywords: ichnotaxonomy, lower Paleozoic, Gondwana, Balcarce Formation, Argentina

The Balcarce Formation is a tide-dominated unit outcropping in the Tandilia System which contains abundant ichnofossils firstly studied by Borrello (1966). Original assignments in the unit like *Cruziana* and *Arthrophycus* remain indisputable and suggest a Late Ordovician lower Silurian age. Conversely, others were later reassigned to other ichnogenera. In particular the material reexamined in the field (Cabo Corrientes locality) received the attention of Poiré and del Valle (1996) and Seilacher et al. (2003) that introduced new assignments (e.g. *Arenicolites*, *Didymaulichnus*, *Diplichnites* and *Diplocraterion*). Interestingly, some trace fossils present there were analyzed and also discussed or reassigned in these or other works, sometimes informally (e.g. *Heimdallia* and *Selenichnites*). One unusual case is the material originally assigned to *Palaeophycus* that was later reassigned to *Scolicia, Gyrochorte* or *Heimdallia*. Some field specimens (fig. 1) partially resemble *Arthrophycus brogniartii* but differ in the variable course (winding, irregular or angularly meandering), subtriangular shape, variable width and asymmetrical ribs. These features do not fit in *Arthrophycus* and probably neither in the other previously attributed ichnogenera. *Herradurichnus* is recorded as the classical horse-shoe form, but also crescent and subtriangular in shape (fig. 2); variable incised forms suggest different producers than xiphosuran-like animals, probably a worm-like animal. The horizontal displacement of the *Daedalus* examples resembles the activity of siphons (fig. 3), like some sections of *Hillichnus*. *Herradurichnus* and *Didymaulichnus* are cross cut by *Arthrophycus*-like trace fossils. Finally, other trace fossils are meniscate endichnial forms without walls and showing basal marks.

References

Borrello Alberto. “Trazas, restos tubiformes y cuerpos fósiles problemáticos de la Formación La Tinta, Sierras Septentrionales, provincia de Buenos Aires”. Paleontografía Bonaerense. La Plata: Comisión de Investigaciones Científicas, Provincia de Buenos Aires. Fascículo V. (1966). 1–42. Print.

Poiré Daniel G. & del Valle Analía. “Trazas fósiles en barras submareales de la Formación Balcarce (Ordovícico), Cabo Corrientes, Mar del Plata, Argentina”. Buenos Aires: Asociación Paleontológica Argentina, Publicación Especial. Número 4. (1996). 89–102. Print.

Seilacher Adolf, Cingolani Carlos & Varela Ricardo. “Ichnostratigraphic correlations of early Palaeozoic sandstones in north Africa and central Argentina”. Tripoli: The geology of northwestern Lybia. Vol. I. (2003) 275–292. Print.

Fig. 1. ?*Arthrophycus brogniartii* with thick pads. Epichnial preservation. Scale = 2 cm.

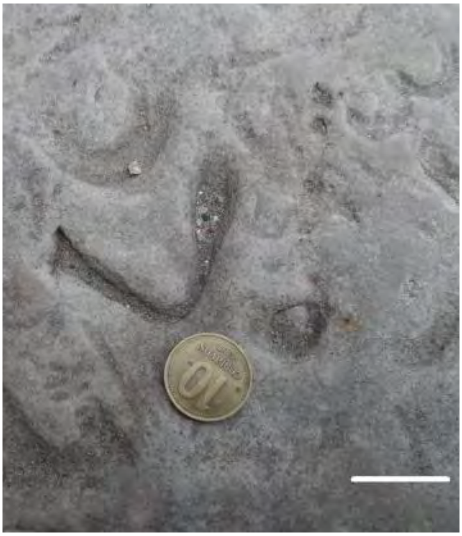

Fig. 2. *Herradurichnus scagliai* with horse-shoe shape and other subtriangular specimen. Concave epirelief. Scale = 2 cm.

Fig. 3. Trace fossil with a basal plane and upward siphon expressions resembling *Hillichnus* assigned to *Daedalus* by Poiré and del Valle, 1996. Scale = 2cm.

The Vale de Meios tracksite: first evidence of megatheropods from the Middle Jurassic of Iberia

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Keywords: Middle Jurassic, Theropod tracks, photogrammetry, *Megalosauripus*, Lusitanian Basin

Here we report the 7500 m2 Vale de Meios quarry from the Middle Jurassic micritic limestones from the Maciço Calcário Estremenho (Lusitanian Basin) of Portugal. This site, located near Alcanede village (Santarém, West-Central Portugal), has preserved dinosaur tracks on Serra de Aire Formation (Bathonian). More than 700 theropod tracks are organized in at least 80 unidirectional and bipolar trackways, normal to the orientation of the ancient coastline. Few of the numerous tracks are preserved as "elite" tracks, the rest is preserved as different gradients of modified true tracks according to water content, erosional factors, radial fractures and internal overtrack formations. Taphonomical determinations are consistent with paleoenvironmental observations (tidal flat setting). Photogrammetric models of three trackways have been carried out in order to provide general morphological descriptions of the tracks. Tracks are tridactyl, sometimes tetradactyl, large sized (intra-trackway track length range from 30 cm to more than 70 cm), elongated and asymmetric. Tracks are featured by the absence of clear pad impressions, the presence of pointed claw marks, a sigmoidal impression of digit III and a squared U-shaped metatarso-phalangeal impression. Quantitative and qualitative comparison with other tracks from North America and Europe revealed that the Vale de Meios tracks resemble the typical Late Jurassic-Lower Cretaceous *Megalosauripus* (*sensu* Lockley et al. 1998) ichnogenus in all morphometric parameters. This tracksite records the first presence of megatheropods (*sensu* Barco et al., 2005) in the Middle Jurassic of Portugal, expanding the *Megalosauripus* occurrence to this age.

References

Lockley, M.G., Meyer, C.A., dos Santos, V.F. (1998) *Megalosauripus* and the problematic concept of Megalosaur footprints. Gaia, 15: 312-337

Barco, J. L., Canudo, J. I., Ruiz-Omeñaca, J. L. & Rubio, J. L. 2005. Evidencia icnologica de un dinosaurio teropodo gigante en el Berriasiense (Cretacico Inferior) de Laurasia (Las Villasecas, Soria, España). *Revista Española de Paleontologia,* N.E. *X* , 59-7 1. ISSN 02 13-6937.

Exceptional preservation of the endolithic tracefossil *Dendrina belemniticola* Mägdefrau, 1937 in the Upper Maastrichtian greensand of Nasiłów (Central Poland)

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Keywords: Dendrina, borings, preservation, chalk, greensand

The rosette-shaped endolithic trace fossil *Dendrina belemniticola* Mägdefrau, 1937 is common in biogenous substrates in the Upper Cretaceous chalk facies of Europe, but badly preserved there. Chalk specimens are affected by an intensive calcite cementation. Basically all parts of borings are sealed if their internal diameter is less than the size of the calcite crystals and the 'casting embedding technique' fails in documenting such borings. Therefore, up to now only the 'macro-morphology' of *Dendrina*-borings could be recognized in chalk specimens.

In contrast to the chalk facies, calcitic biogenous substrates in the Upper Maastrichtian greensand from Nasiłów remained diagenetically almost unaltered (Fig. 1). Calcitic cementation is missing and endolithic traces can be studied with an exceptional high-resolution. Accordingly, new morphologic features of the ichnospecies *Dendrina belemniticola* can be described.

Examining casts of the *Dendrina*-boring systems a cover of unbranched, hair-like extensions was detected. Those extensions spread into the substrate from all parts of the boring and give the *Dendrina*-casts a hairy to furry appearance (Fig. 2). It is most likely that they had an exploratory function, i.e. locating the boundaries of the substrate and investigating cavities within it. This would explain the preventative behavior of the *Dendrina*-producer in limited substrates (stenomorphic traces).

Some casts of the hair-like extensions exhibit once again smaller, short needle-like structures (Fig. 3). Most probably these structures represent the first phase of the boring process. It is followed by expanding the needles to bulbous swellings that unify to the typical *Dendrina*-rosette having a verrucose surface (Fig. 4).

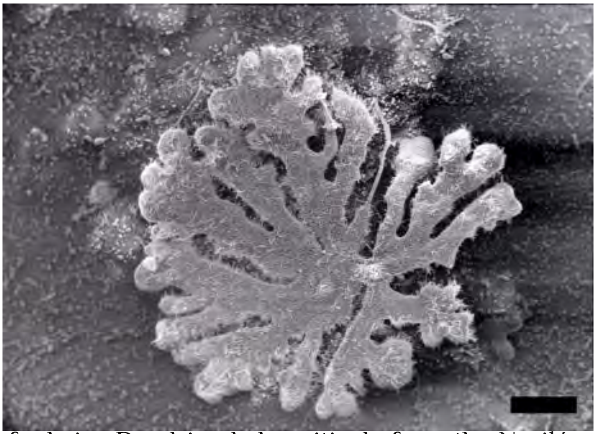

Fig. 1. Overview of a hairy *Dendrina belemniticola* form the Nasiłów greensand (scale 360µm).

Fig. 2. Detail of a *Dendrina*-rosette lobe form Nasiłów (scale 50 µm).

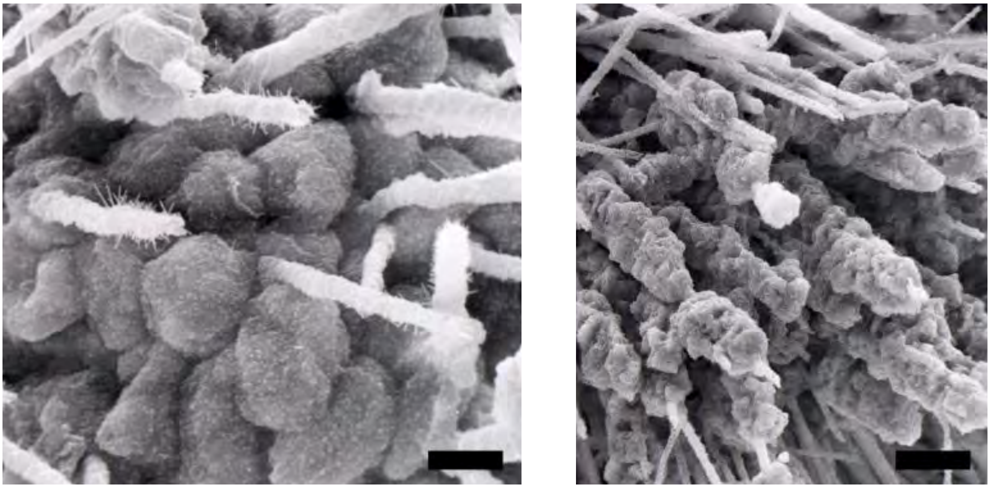

Fig. 3 (left) and 4 (right). Successive phases of the boring process, cf. text (scale in Figs. 3/4: 6/13 µm).

New discovery of reptile tracks from the Southiberian Triassic (Betic Cordillera, Southern Spain)

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Keywords: Southiberian Triassic, tracks, ichnofossil, quadruped, reptile.

The External Zones of the Betic Cordillera extensively expose the classic Germanic Triassic trilogy that encompasses siliciclastic, carbonate and evaporitic units of Buntsandstein, Muschelkalk and Keuper facies, respectively. All these units are included in the so-called 'Southiberian Triassic' (Pérez-López & Pérez-Valera, 2007). Recently, the discovery of new reptile tracks from several Buntsandstein and Keuper facies yielded sufficient material to allow us to begun their description in order to improve the systematic, biostratigraphic and palaeobiogeographic ranges of these scarcely known Triassic tracks in Southwestern Europe. There are few references of Triassic vertebrate tracks in the Iberian Peninsula, especially in the Betic Cordillera, although it must to be highlighted an important one attributed to the Brachychirotherium ichnogenus (Pérez-López, 1993). The here presented new Triassic vertebrate tracksite shows a high concentration of pes and manus tracks of reptiles, preserved as natural casts on the base of a stratum of Buntsandstein facies, near Calasparra (Murcia, Spain). Some tracks are overlapped, being difficult to identify trackways, but two different pes tracks and one manus track present well defined morphology (Fig. 1). One of the pes prints shows five digits while the other one shows only four digits and claw marks. The manus print is pentadactyl, digitigrade and is smaller than the pes footprint. These footprints could correspond to Chirotheriidae and Batrachopodidae trackmakers. Nevertheless, these reptile tracks are currently being studied and their detailed characterization will be given, yielding new data about the possible Triassic fauna of this area, where vertebrate remains are scarce.

Acknowledgements: To Dr. Fernando Barroso-Barcenilla from the Universidad de Alcalá de Henares. Research Project CGL2015-66604 of the Ministerio de Economía y Competitividad (Spain).

References

Pérez-López, A. 1993. Estudio de las huellas de reptil del ichnogénero Brachychirotherium, encontradas en el Trías Subbético de Cambil. Estudios Geológicos 49: 77-86.

Pérez-López, A, Pérez-Valera, F. 2007. Palaeogeography, facies and nomenclature of the Triassic units in the different domains of the Betic Cordillera (S Spain). Palaeogeography, Palaeoclimatology, Palaeoecology 254: 3-4.

Fig. 1. General view of the Triassic vertebrate tracksite, showing a high concentration of tracks preserved as natural casts on the base of a stratum of Buntsandstein facies (green bed), near to Calasparra (Murcia, Spain).

Cambro-Ordovician trace fossils from the Seydişehir Formation (Amanos Mountains, SE Anatolia, Turkey)

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Keywords: Seydişehir Formation, Late Cambrian, Early Ordovician, trace fossils, Turkey.

A diverse trace fossil assemblage is described for the first time from slightly metamorphosed siliciclastic rocks of the Seydişehir Formation in the Amanos region of SE Anatolia. The Seydisehir Formation, includes very low-grade metasedimentary rocks composed of slates, phyllites, metasandstones, and metasiltstones. This succession consists of coarsening- and thickening-upward successions that are interpreted as tempestites deposited in a shelf environment. The sequence contains an assemblage of abundant, diverse, and well-preserved ichnofossils comprising Archaeonassa isp., Bergaueria isp., Cruziana isp., Cruziana furcifera, Cruziana rugosa, ?Cruziana semiplicata, Didymaulichnus isp., Diplichnites isp., Diplocraterion isp., ?Gyrolithes polonicus, ?Gyrophyllites isp., Monocraterion isp., Palaeophycus striatus, Palaeophycus tubularis , Phycodes cf. circinatus, Phycodes palmatus, Phycodes isp., Planolites isp., Rusophycus isp., Skolithos isp., and Trichophycus isp. They belong to the archetypal Cruziana ichnofacies. Several of these trace fossils were probably made by arthropods. Cruziana ichnostratigraphy, used in Gondwana, allows an age determination of Middle Cambrian to Lower Ordovician for these metasediments, as indicated by the presence of Cruziana furcifera, Cruziana rugosa, Cruziana semiplicata, Didymaulichnus isp. and Rusophycus isp. (Knaust, 2004).

References

Knaust, D. "Cambro-Ordovician trace fossils from the SW-Norwegian Caledonides", 2004. Geological Journal, 39, 1-24.

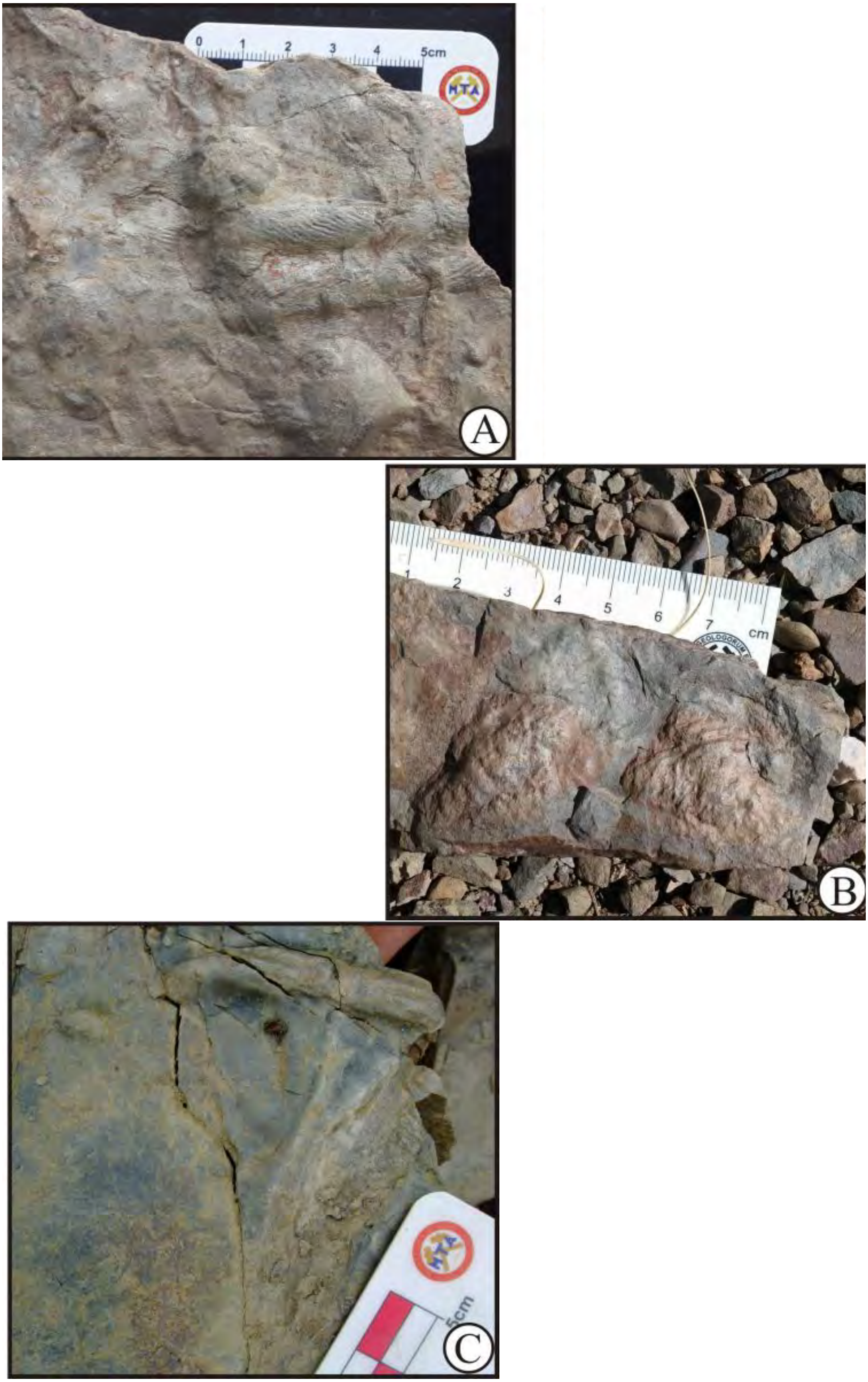

Fig 1. A) *Cruziana furcifera* B) *Rusophycus* isp. C) *Palaeophycus striatus*

Extraordinary examples of the outstanding *Phycodes* beds from the Lower Ordovician in the Armutludere Formation (Amanos Mountains, SE Anatolia, Turkey)

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Key words: *Phycodes* isp., Lower Ordovician, Armutludere Formation, Amanos mountain, Turkey

Outstandingly well preserved *Phycodes* have been found in the Lower Ordovician Armutdere Formation northeast of Değirmentaş village, along the Eastern Taurus mountain range near Tufanbeyli. The Armutdere Formation consists of very low-grade metasedimentary rocks including slates, phyllites, metasandstones, and metasiltstones. The trace fossils include *Phycodes* cf. *circinatus*, "*Phycodes*" *palmatus* and *Phycodes* isp., which are generally regarded as arthrophycid fodinichnia (Seilacher, 2000). Their morphology provides many valuable insights on their production, preservation and variation (Fig 1).

References

Seilacher, A. "Ordovician and Silurian arthrophycid Ichnostratigraphy", Geological Exploration in Murzuk Basin. By M.A. Sola and David Worsley. 2000, Amsterdam, Elsevier, 237-258.

Fig 1 (A-C) *Phycodes* cf. *circinatus*

Trace fossils from the Brioverian (Ediacaran-Fortunian) of Brittany (NW France)

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Keywords: Invertebrate ichnofauna, microbial mats, Brioverian, Ediacaran, NW France

The Ediacaran-Fortunian ichnofauna from Central Brittany (NW France) is revised for the first time after the pioneer work by Lebesconte at the end of the XIXth century. The study is based on fossils from the type-localities of the historical Brioverian taxa Montfortia (traces from Montfort-sur-Meu) and Neantia (wrinkle surfaces from Néant-sur-Yvel), and on a new outcrop from Saint-Gonlay. The ichnofossil assemblage includes Helminthoidichnites tenuis, Helminthopsis tenuis, Palaeophycus tubularis, ?Neonereites uniserialis, Gordia marina and Spirodesmos isp. Locally, the grazing traces are associated with pustular and wrinkle surfaces considered as formed due to stabilization in microbial mats. Dominance of clay- to silt-grained sediments associated with unidirectional current ripples, few load casts and flute casts, but also the presence of hummocky cross-stratification and gutter casts in the sandstone intercalations, argue in favor of deposition above storm wave base (i.e. offshore). Direct association of trace fossils and matgrounds suggests that microbial grazing was the dominant trophic strategy in benthic communities inhabiting offshore settings during the Ediacaran-Fortunian transition. New U-Pb datings performed on detrital zircons give a maximum age of 550 Ma for the fossiliferous deposits. These data, associated with observations regarding recent ichnostratigraphic models of this critical time, plead for an Ediacaran age of the fossiliferous deposits.

Bioerosion in Rugosa corals from the Devonian of Tindouf basin (Western Sahara)

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Keywords: Paleoecology, Ichnology, Bioerosion, Paleozoic, Western Africa.

The Tindouf Basin is a major sedimentary basin of Paleozoic age located in West Africa, extending from West to East 700 km in Algeria, Western Sahara and Morocco. The basin, formed in a continental margin, is infilled with transgressive sedimentary series ranging in age from Cambrian to Carboniferous. The basin was folded during the Hercynian orogeny, producing a regional E-W trending syncline; metamorphism is very low or absent. The sampled area is found in the South flank of this structure, along the Tindouf-Bir LehLou road. The Paleozoic series of this domain are gently dipping to the N and unconformably overlain Precambrian materials. The Devonian series of this area largely consist of platform sediments, mainly reef limestones and shales.

Rugose corals are mainly represented by the solitary horned genera Cystiphillum sp. and Heliophyllum sp. and the colonial *Phillistraea* sp. Other collected fossils belong to tabulata, trilobita, cephalopoda, and brachiopoda taxa. Identifications at a lower taxonomic level is being rather difficult because of the weathering erosive processes that affect fossils in the outcrop.

Solitary rugose corals exhibit several evidences of bioerosion represented by the ichnotaxa *Sulsichnus sigillus*, *Maeandropolydora* isp., *Caulostrepsis* isp., *Oichnus* isp., *Trypanites* (?) in horn corals. Moreover, some surficial *Oichnus*-like structures have been identified in a *Phillistraea* sp. colony.

Exceptional preservation of *Sphaerapus larvalis* in the Miocene Vinchina Formation of western Argentina

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Keywords: *Sphaerapus*, Vinchina Formation, Miocene, fluvial setting, water table

The Miocene Vinchina Formation of western Argentina is made up of more than 5100 meters of siliciclastic sediments deposited mostly in fluvial environments, including transitions from braided and meandering, to anastomosing systems. The Upper Member of the unit is characterized by the conspicuous occurrence of braided fluvial deposits, composed of heterolithic multistory channels, gravelly bars, sandy bars, and very thin intercalations of floodplain fines facies, hosting invertebrate and vertebrate trace fossil assemblages. The present contribution deals with the outstanding preservation of *Sphaerapus* within these facies. In particular, the trace fossils studied were recorded at the sole of a massive fine to very fine-grained sandstone bed interbedded with laminated claystones and siltstones, representing sedimentation in overbank environments. The trace *Sphaerapus larvalis* occurs as a positive or negative hyporelief. It is characterized by several horizontal burrows displaying raised, often imbricated, oval blocks generating nodular margins, and sometimes developing a discontinuous open medial depression. Occasionally, the medial depression is irregularly filled by smaller blocks. Individual blocks are smooth, sub-rounded to oval, 1– 4 mm in diameter, and identical in composition to the surrounding matrix. The burrow widths range from 12 to 4 mm, and their courses are mostly straight with gentle curves and decimetric lengths. Primary successive branching and intersecting of burrows are also present. Ongoing research suggests that these traces reflect a shallow dwelling behavior in soft, fine grained substrates subaerially exposed but proximal to the water table as channel margins, interchannel areas, and marginal zones of local ponds.

Contribution to the knowledge of the mammalian ichnofauna (Vertebratichnia, Mammalipedia) from the Upper Pleistocene (Lujanian Stage/Age) of Argentina (South America)

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Keywords: Paleoichnology, Pleistocene, Argentina, new ichnospecies.

Three new tetrapod ichnospecies, related to placental mammals, are recorded for the Upper Pleistocene (Lujanian Stage/Age) of "Laguna del Monte" Tracksite (Guaminí village), Buenos Aires province, Argentina:

1) Felipedidae nov. igen. et isp. hemi-digitigrade tetradactyl footprints, displaying a distinctive feloid-track's pattern; four subequal unclawed digits (II-V), arranged in asymmetric arc, in front a bilaterally symmetrical and transversely elongated interdigital-cushion; conformed by the fusion of three longitudinal lobes, of similar development (unlike another related ichnogenera); possible trackmaker: *Smilodon populator*.

2) *Ursichnus* nov. isp. plantigrade pentadactyl footprints, showing a noticeable heteropody (manus proportionally shorter than pes); five unequal clawed digits, disposed in opened arc, in front an unsymmetric metacarpal/metatarsal pad; carpal-cushion absent and reduced tarsal-cushion. It differentiates from the remaining ichnospecies of the ichnogenus by having a clear alignment of the digital-pad impressions and possessing graceful claw-marks (comparatively shorter, smaller and narrower); possible trackmaker: *Arctotherium bonariensis*.

3) *Eumacrauchenichnus* nov. isp. hemi-unguligrade tridactyl footprints, with hypertrophied central digits (III), reduced lateral toes (II and IV) and broad palmar/plantar cushions; differing from the type ichnospecies *Eumacrauchenichnus patachonicus* by exhibiting a larger size and an evident heteropody; possible trackmaker: *Toxodon platensis*.

The described ichnotypes, increase significantly (about of 25%) the tetrapod ichnodiversity known for the palaeoichnological site (see Oliva et al., 2013). Raising, on the other hand, the number of ichnotaxa documented for the latest Quaternary of the bonaerian territory; approximately 25: including about 10 avian morphotypes and 15 mammalian ichnospecies (see Aramayo and Manera de Bianco, 1987; Aramayo et al., 2015).

References

Aramayo, S. and Manera de Bianco, T. 1987. Hallazgo de una icnofauna continental (Pleistoceno tardío) en la localidad de Pehuen Co (Partido de Coronel Rosales) Provincia de Buenos Aires, Argentina. Parte I: Edentata, Litopterna, Proboscidea; Parte II: Carnivora, Artiodactyla y Aves. IV Congreso Latinoamericano de Paleontología, 1: 516-547. Santa Cruz de la Sierra, Bolivia.

Aramayo, S., Manera de Bianco, T., Bastianelli, N. and Melchor, R. 2015. Pehuen Co: updated taxonomic review of a late Pleistocene ichnological site in Argentina. Palaeogeography, Palaeoclimatology, Palaeoecology, 439: 144-165.

Oliva, C., Arregui, M., Lirusso, V. and de Valais, S. 2013. Laguna del Monte, un nuevo yacimiento paleoicnológico del Pleistoceno tardío (Piso/Edad Lujanense), Guaminí, provincia de Buenos Aires (Argentina). Segundo Congreso Latinoamericano de Icnología (SLIC II), Libro de resúmenes: 52.

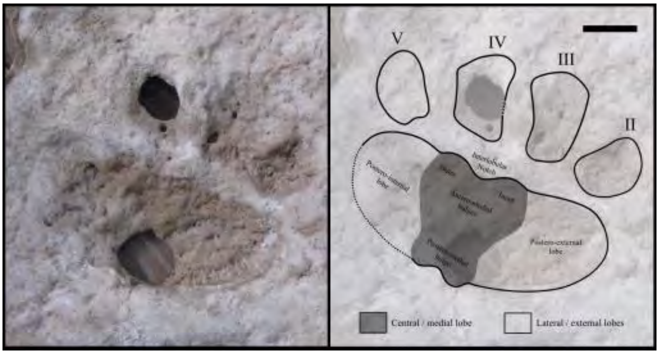

Fig. 1. Felipedidae nov. igen. et isp. left isolated footprint; tentatively related to *Smilodon populator* Lund. Scale bar: 30 mm.

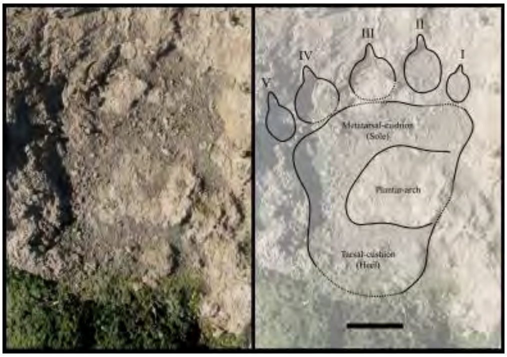

Fig. 2. *Ursichnus* nov. isp. left hindfoot impression; tentatively related to *Arctotherium bonariensis* Gervais. Scale bar: 50 mm.

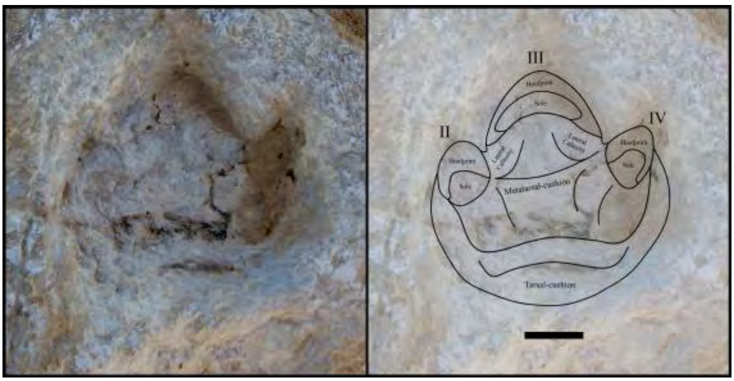

Fig. 3. *Eumacrauchenichnus* nov. isp. right hindfoot impression; tentatively related to *Toxodon platensis* Owen. Scale bar: 50 mm.

New report of Theropod (*Eubrontes glenrosensis*) dinosaur footprint from the Thaiat Member of Lathi Formation of Jaisalmer Basin, Western Rajasthan, India

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Keywords: Theropod, footprint, Lathi Formation, Jaisalmer Basin, India.

The present paper report well –preserved Eubrontes cf. glenrosensis attributed to theropod dinosaur from Thaiat scrap section of Thaiat Member, Lathi Formation of Jaisalmer Basin at Thaiat area in Jaisalmer district of Western Rajasthan, India. The present study area is located about 16 kms East of Jaisalmer on NH-15 Jaisalmer–Jodhpur road and the section is occurring at both side of the Road. Here Eubrontes cf. glenrosensis theropod dinosaur footprint is morphologically large about 30cm long, showing thick toes prints, and being preserved as concave epirelief on top of pinkish yellow silty to fine grained ferruginous sandstone bed (Fig.1). The present footprint has been formed by the movement of a large dinosaur over the loose sediments of a beach and or shoreline. The Thaiat Member of the Lathi formation is dominantly siliciclastic in nature and belong to Early Jurassic to Bajocian age based on theropod dinosaur footprints (Pienkowski et. al., 2015) and the Bajocian coral found in the lower part of the overlying Jaisalmer Formation (Pandey et. al., 2006). The Thaiat scrap section is comprised of an inter-bedded sequence of mudstones and fine grained sandstones of fluvial nature at the base. It is followed by about 10 m of an inter-bedded sequence of shales, siltstones and fine to medium grained sandstones representing near shore to shallow marine environments. The pinkish yellow ferruginous silty to fine-grained sandstone comprising Eubrontes cf. glenrosensis theropod dinosaur footprint represents environment of Early to Middle Jurassic age.

References

Pandey, D.K., Sha, J.G and Choudhary, 2006. Depositional history of the early part of the Jurassic succession on the Rajasthan Shelf, western Rajasthan. Progress in Natural Science, 16 (Special Issue on Marine and Non-marine Jurassic: Boundary, Event and Correlation), Beijing: 176-185.

Pienkowski, G., Branski, P., Pandey, D.K., Schlogl, J., Alberti, M. and Fursich, F.T., 2015. Dinosaur footprints from the Thaiat ridge and their palaeoenvironmental background, Jaisalmer Basin, Rajasthan, India. Volumina Jurassica, 2015 XIII (1):17- 26.

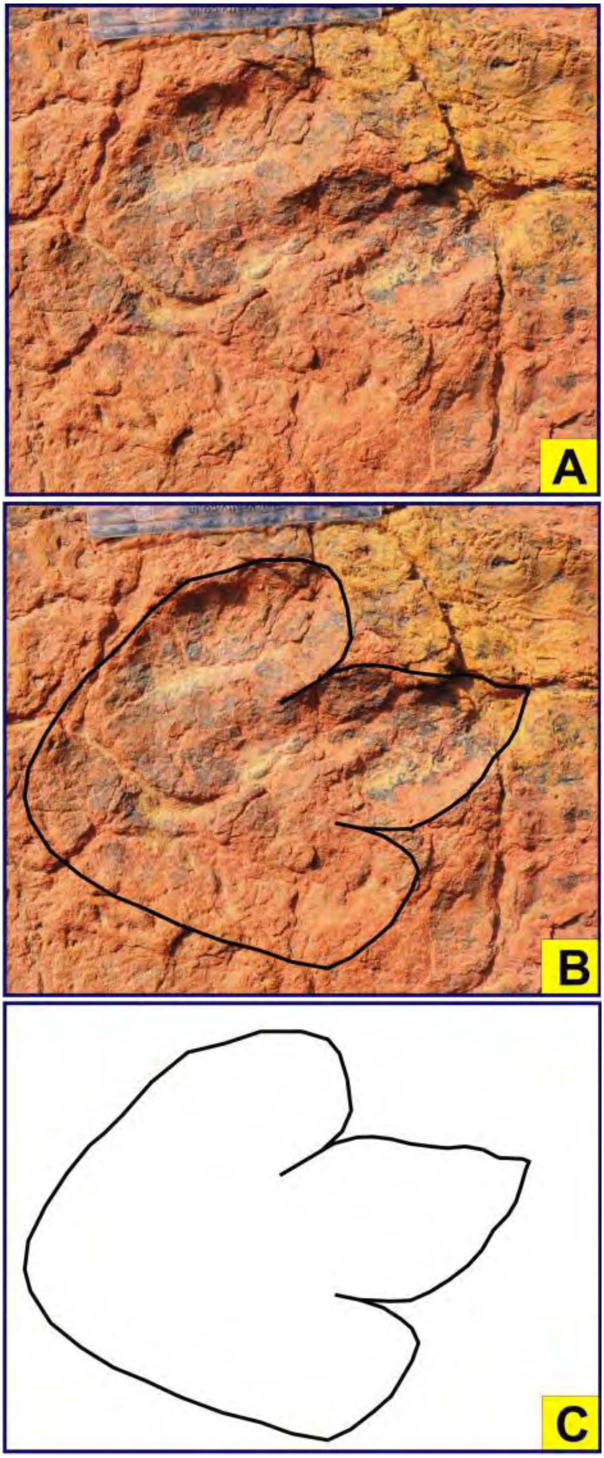

Fig. 1. A.: *Eubrontes cf. glenrosensis* theropod dinosaur footprint in concave epirelief preservation on top- of pinkish yellow silty to fine-grained ferruginous sandstone. B. : *Eubrontes cf. glenrosensis* theropod dinosaur footprint with outline. C. : Sketch diagram of *Eubrontes cf. glenrosensis* theropod dinosaur footprint.

Dinosaur footprints and bivalve trace fossils in a point-bar deposit. Lastres Formation (Kimmeridgian) of Asturias, North Spain

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Keywords: Dinosaur footprints, bivalve ichnofossils, point-bar, Kimmeridgian, Asturias

The Dinosaur Coast represents a littoral sector, about 57 km long, in the oriental part of Asturias. This name is due to the large number of fossils belonging to these reptiles, mainly footprints.
The Lastres Formation (400 m thick) consists of grey sandstones, mudstones and marls, with some conglomeratic levels. The general setting is considered as a fluvial-dominated deltaic system (García-Ramos et al., 2006) flowing into a shelf lagoon.
This study shows a meander point-bar sand body developed in an upper delta plain environment (Fig.1A) and including dinosaur footprints (Fig.1B,C) as well as the bivalve trace fossils Lockeia, Oravaichnium and Ptychoplasma (Fig.1D). The outcrop occurs at Lastres sea cliffs (Colunga), close to the Jurassic Museum of Asturias.
On the top of a sandstone bed in the upper part of this point-bar deposit, we find several theropod and sauropod tracks. The first ones are preserved as convex epireliefs (Fig.1B) and the second ones as concave epireliefs with a rim around due to sand extrusion (Fig.1C). Several deeper natural casts, belonging to sauropods, are also located in this meander top bed.
New freshwater bivalves, included in the families Unionidae and Margaritiferidae (Unionida), were described in several levels of this formation (Delvene et al., 2015). The Lockeia trace fossils were, probably produced by these bivalves.

References

Delvene, G., Munt, M, Piñuela, L., and García-Ramos, J.C. "New Unionida (Bivalvia) from the Kimmeridgian (Late Jurassic) of Asturias, Spain, and their palaeobiogeographical implications." Papers in Palaeontology 2.1 (2016): 1-21.

García-Ramos, J.C., Piñuela, L., and Lires, J. Atlas del Jurásico de Asturias. Oviedo: Ediciones Nobel, 2006.

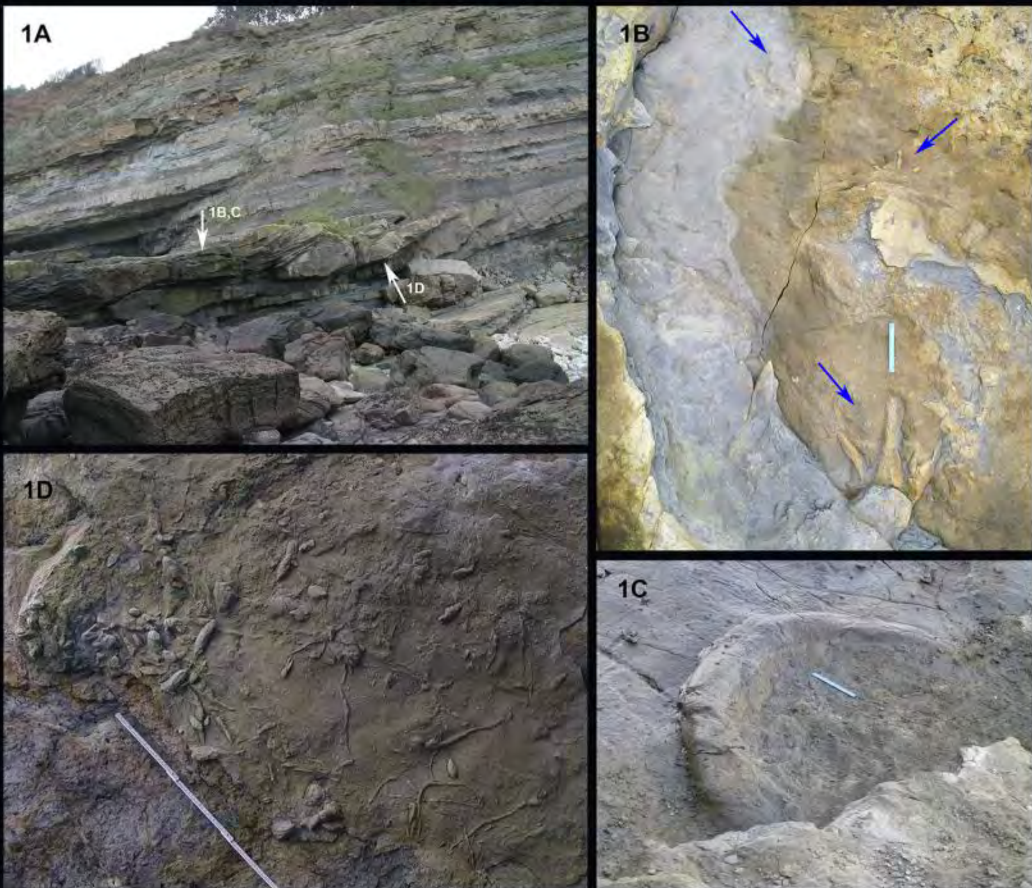

Fig. 1. 1A, Point-bar sequence at Luces seacliffs. 1B, Theropod footprints. 1C, Sauropod track with a sandstone rim. 1D, Ichnofossils of *Lockeia*, *Oravaichnium* and *Ptychoplasma*

Ploughing, tunnelling and biting in the Middle Ordovician of northern Portugal

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Keywords: Ordovician, trace fossils, bierosion, Central Iberian Zone, Portugal

Middle Ordovician shales from the Valongo and Moncorvo formations recorded temporary dysoxic environments, inhabited by opportunistic faunas that also include highly specialized deposit feeders. Resulting ichnofossils include Phycodes noa Mikuláš, a horizontally-ramified burrow complex, so far only known from older beds in the Prague Basin, as well as a large spiral grazing trace close to Rotundusichnium zumayensis Gómez de Llarena, which is widely distributed in Alpine flysch deposits.
Phycodes noa from the Valongo Formation occurs as quite large, horizontally flabellate structure with up to 10 diverging passages. Specimens from the Canelas quarry (Arouca) are commonly infilled by pellets (Tomaculum), and are preserved flattened and tectonically expanded.
Giant Rotundusichnium-like forms are exclusive from the Canelas quarry and consist of ?concentric to tightly spiral traces with a large elliptical outline (major axis up to 130 cm long), showing endichnial ribbons inclined to the centre of the structure. These are associated with imploded fragmocones of nautiloids preserved under them, and the trace maker harvested the microbial proliferation around them in tight centrifugal coils.
The third remarkable trace corresponds to bite marks preserved in large trilobite carapaces. They have a consistent acute V-shaped outline and represent marginal breakage, usually placed in the right pygidial pleural border of asaphids, in diverse margins of calymenaceans or in semi-infaunal molluscs. These triangular bite marks are attributed to large nautiloid predators or scavengers, sometimes attacking freshly-molted giant trilobites.

This research is a contribution to the projects CGL2012-39471 of the Spanish MINECO and IGCP-591 (IUGS-UNESCO).

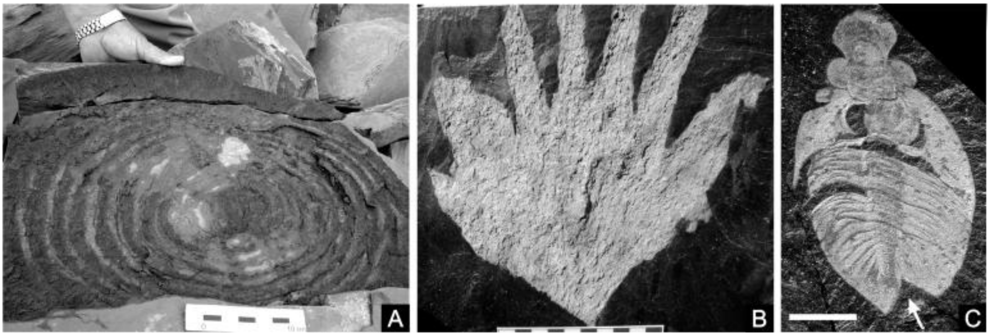

Figure 1- Feeding burrows (A, "Rotundusichnium" isp. nov.; B, Phycodes noa) and example of bioerosion (C, trilobite exuvium with triangular bite mark – arrowed; scale bar = 2 cm) from the Valongo Formation, Arouca.

Bedding-plane assemblage of "Catenichnus" in the Santa Justa Formation (Lower Ordovician, N Portugal)

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Keywords: Ordovician, trace fossils, Central Iberian Zone, Valongo, Portugal

The Santa Justa Formation (Armorican Quartzite facies) is named after the Santa Justa hill in the vicinity of Valongo (East of Oporto, N Portugal). This locality is a touristic place and along the path from the St. Sabinus chapel to the St. Justa chapel there is an outcrop of thick beds of quartzite, which corresponds to the upper part of the formation (Sá et al., 2011). A large bedding plane facing the path is crowded by shallow, elongate depressions, not preferentially oriented, which represents large "Catenichnus" (ca. 20 cm long) in epirelief preservation. The best samples show a U-shape burrow with divergent arms and a fairly uniform diameter within each structure up to 10 mm. The presence of a thick-mud lining differentiate the studied specimens from "Catenichnus" contentus McCarthy and ichnospecies of the genera Catenarichnus and Arenicolites. The weathering of the mud lining favoured the removal of the internal U-shaped cylinder, so that many specimens resemble "bath-tube" epireliefs without any internal detail.
Occurrences of similar shaped "Catenichnus" have been recently described from the Pochico Formation (Arenigian) of Sierra Morena, Spain (Rodríguez-Tovar et al., 2014). Two new Spanish records with similar characteristics are also here reported from the Armorican Quartzite of the Cabañeros National Park and the Agudo Syncline, in the Province of Ciudad Real.

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References

Rodríguez-Tovar, F.J., Stachacz, M., Uchman, A. & Reolid, M. (2014). Lower Ordovician (Arenig) shallow-marine trace fossils of the Pochico Formation, southern Spain: palaeoenvironmental and palaeogeographic implications at the Gondwanan and peri-Gondwanan realm. Journal of Iberian Geology, 40, 539-555.

Sá, A.A., Piçarra, J., Vaz, N., Sequeira, A. & Gutiérrez-Marco (2011). Ordovician of Portugal. 11th International Symposium on the Ordovician System (ICS/IUGS/UNESCO), Pre-Conference Field Trip Guide. UTAD – CSIC – IGME, Vila Real, 79 p.

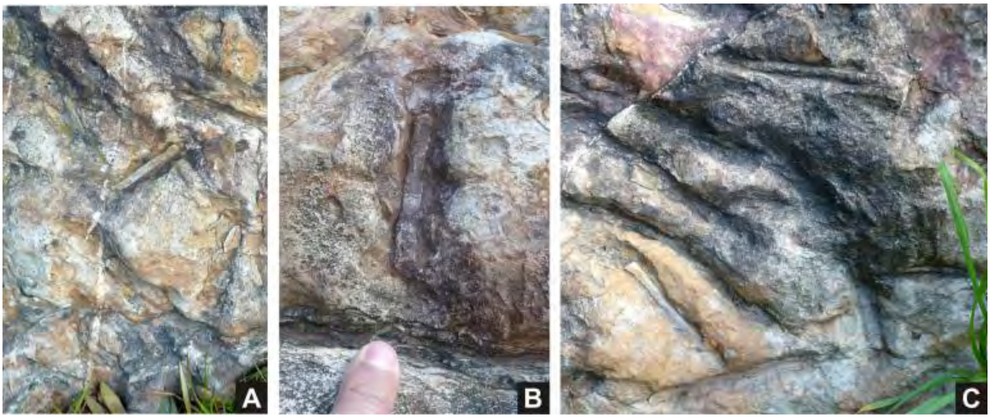

Fig. 1 – Different specimens of "Catenichnus" isp. from the Santa Justa Formation.

Teichichnus duplex Schlirf and Bromley, 2007 and its relationships to the ichnogenus *Cruziana* d'Orbigny, 1842

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Keywords: Teichichnus, *Cruziana*, arthropods, burrowing

Teichichnus duplex Schlirf and Bromley, 2007 is a bilobated trace fossil with double gutter-shaped spreites and occasionally scratch traces, so far described from the Cambrian of Sweden and the Triassic of Germany. Similar Paleozoic trace fossils were earlier assigned to Scolicia isp. (e.g., Orlowski, 1989) and Cruziana roaulti or C. tenella (e.g., Rodríguez-Tovar et al., 2014). Lately, *Teichichnus duplex* was recognized in the Cambrian Ocieseki Formation, Poland, and in the Ordovician Pochico Formation, Spain, where it occurs as endichnial, straight or curved, sand-filled, wall-like structures, visible as smooth bilobate ridge on the lower bedding plane, or spreite structures in cross sections. The Ordovician specimens are deeper than the Cambrian examples and they show steeply inclined spreite laminae.
The described trace fossil resembles the deep *Cruziana furcifera* from the Ordovician Pochico Formation (Stachacz et al., 2015). However, the latter displays only indistinct internal lamination or a massive filling and distinct scratch traces on the surface of the bilobate ridge. However, absence of the scratch traces can depend on their preservation potential. Moreover, a part of the original specimens of *Teichichnus duplex* shows some bioglyphs interpreted as irregular scratch traces (Schlirf and Bromley, 2007), suggesting arthropods as the tracemakers, similarly to Cruziana. Therefore, the deep *Cruziana* and *Teichichnus duplex* may represent the same behavior of arthropods feeding deeply in sands.

References

Orlowski, S. 1989. Trace fossils in the Lower Cambrian sequence in the Swietokrzyskie Mountains, Central Poland. Acta Palaeontologica Polonica, 34: 211–231.

Rodríguez-Tovar, F.J., Stachacz, M., Uchman, A. & Reolid, M. 2014. Lower/Middle Ordovician (Arenigian) shallow-marine trace fossils of the Pochico Formation, southern Spain: palaeoenvironmental and palaeogeographic implications at the Gondwanan and peri-Gondwanan realm. Journal of Iberian Geology, 40: 539–555.

Schlirf, M. & Bromley, R.G. 2007. Teichichnus duplex n. isp., new trace fossil from the Cambrian and Triassic. Beringeria, 37: 133–141.

Stachacz, M., Rodríguez-Tovar, F.J., Uchman, A. & Reolid, M. 2015. Deep endichnial Cruziana from the Lower-Middle Ordovician of Spain: a unique trace fossil record of trilobitomorph deep burrowing behavior. Ichnos, 22: 12–18.

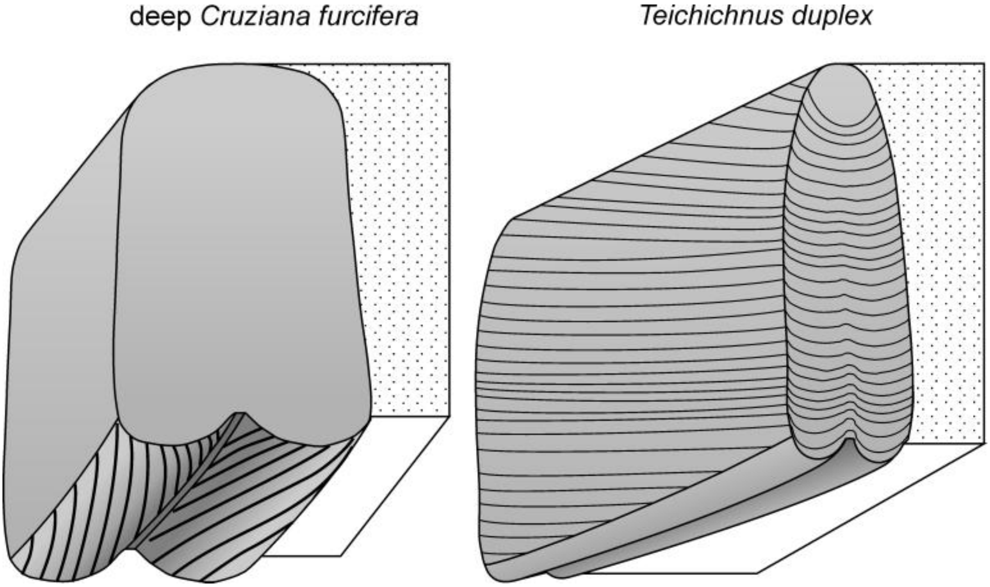

Fig. 1. Sketch-draw of *Cruziana furcifera* and *Teichichnus duplex* with their similarities and differences.

Ant nests from the Palaeogene and Quaternary of Uruguay

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Keywords: ant nests, paleosols, Palaeogene, Quaternary, Uruguay.

We report two Cenozoic cases of trace fossils from paleosols, attributable to ants in Uruguay, South America. The first one corresponds to the nests located below the limit between the Mercedes Formation (late K) and the Asencio Formation (Palaeogene, probably early Eocene) in southern Uruguay. These trace fossils were produced during the Asencio times, but penetrate into the Mercedes Fm. together with other trace fossils and physical structures. The nests consist of piled up, planar, horizontally oriented chambers (5 mm in height, 15 mm in width), connected by a vertical shaft (Fig. 1). Krausichnus isp. is perhaps the most accurate identification, although there are some differences with the known ichnospecies. The chambers of the Uruguayan material are not so numerous and tend to be more planar and irregular. The second case occurs in paleosols of the Sopas Formation (Late Pleistocene), in northern Uruguay, where only scarce remains of chamber infills were found. An AMS ^{14}C age of 12,502 ± 55 years BP (cal. BP 14,234 – 15,001) (AA104912, shell of Cyanocyclas sp.) is available taken from an underlying level. Associated mammalian fauna includes extinct medium to large ground-sloths, glyptodonts and deers, some of them related to open environments. Despite the scarcity of the material the kidney-shaped morphology of the chambers surrounding the vertical shaft (Fig. 2) suggests that these trace fossils correspond to Daimoniobarax cf. nephroides.

Fig. 1. Ant nest preserved in full relief from the Asencio Fm. (Palaeogene, probably early Eocene), Colonia County, Uruguay. Note the piled up flat chambers stained in red. Scale divisions in cm.

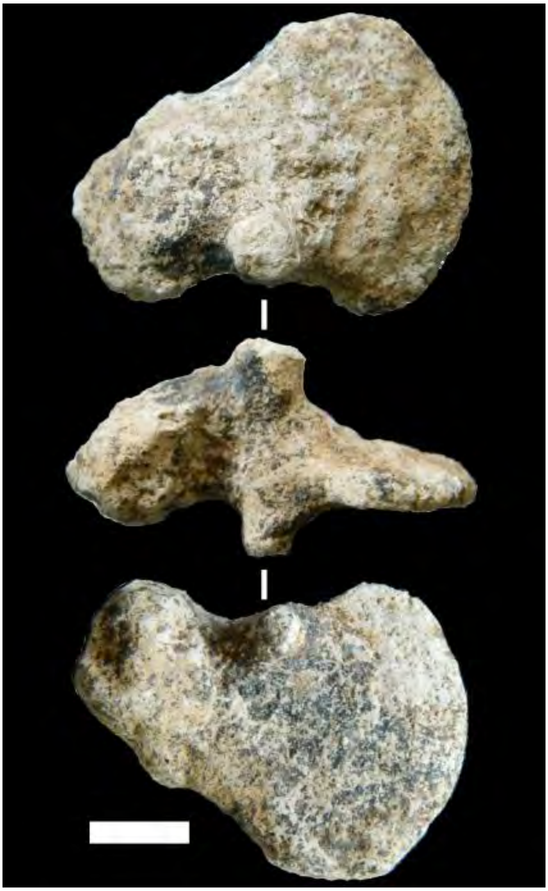

Fig. 2. One ant nest chamber preserved as a carbonate cast, from the Sopas Fm. (Late Pleistocene), Río Negro County, Uruguay. Plan view (above), side view (center) and lower side view (below). Scale bar: 1 cm.

On the findings of trilobite trace fossils of Cruziana ichnofacies in the Lower Ordovician deposits of Transbaikalia

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Keywords. Transbaikalia, Ordovician, suite, trace fossils, ichnofacies

Ordovician deposits are exposed in the Upper-Kalar Graben (North of Transbaikalia), where they are included in the Vendian-Ordovician Upper-Kalar series (about 2 500 m). The Ordovician part of the section (520 m) contains three suites (upward): Vorotninskaya (O_1vr), Naledninskaya (O_2nl) and Ustnaledninskaya (O_{2-3}un) (State...82).
Various trilobite trace fossils were found in the deposits of Vorotninskaya suite which are composed of terrigenous cyclites with the interbeds of limestones. The icnofossils are represented by: *Rusophycus didymus* Salter (fig. A) – small coffee-bean shaped traces with midline furrow and scratch marks V-angle as 60-90^0; *Cruziana* cf. *semiplicata* Salter (fig. A) – bilobate traces with circular path, which have well developed internal scratch marks, forming a V-angle 75-90°, and weakly expressed marginal lines; *Cruziana* cf. *rugosa* d'Orbigny – has more straight path with rough ridges; *Diplichnites gouldi* Bradshaw (fig. B) – the trace of two parallel rows of small grooves; *Dimorphichnus* cf. *obliquus* Seilacher (fig. C) – with series of double slightly curved ridges and *Monomorphichnus lineatus* Crimes, Legg, Marcos & Arboleya – as single inclined parallel ridges. Ichnofossils are preserved horizontally and usually in the form of convex hyporelief on the soles of greenish or brownish fine-grained sandstones.
The complex of trace fossils demonstrates various behavioral patterns of their producers-trilobites: resting (*Rusophycus*), movement in the upper part of the sediment in search of food (*Cruziana*), on its surface (*Diplichnites*) and grazing (*Dimorphichnus*, *Monomorphychnus*). The ichnocoenoses confirm the Early Ordovician age of surrounding rocks (MacNaughton 138), characterize the Cruziana ichnofacies (Seilacher 204-05) and indicate shallow marine conditions.

References

State geological map of the Russian Federation. Scale: 1000000 (third generation). Aldan–Transbaikal Series. Explanatory note. St. Petersburg: Cartographic factory, 2010. Print.

MacNaughton, Robert B. “The Application of Trace Fossils to Biostratigraphy.” Trace Fossils: Concepts, Problems, Prospects. Ed. William Miller. Amsterdam: Elsevier, 2007. 135–48. Print.

Seilacher, Adolf. Trace fossils analysis. Berlin: Springer, 2007. Print.

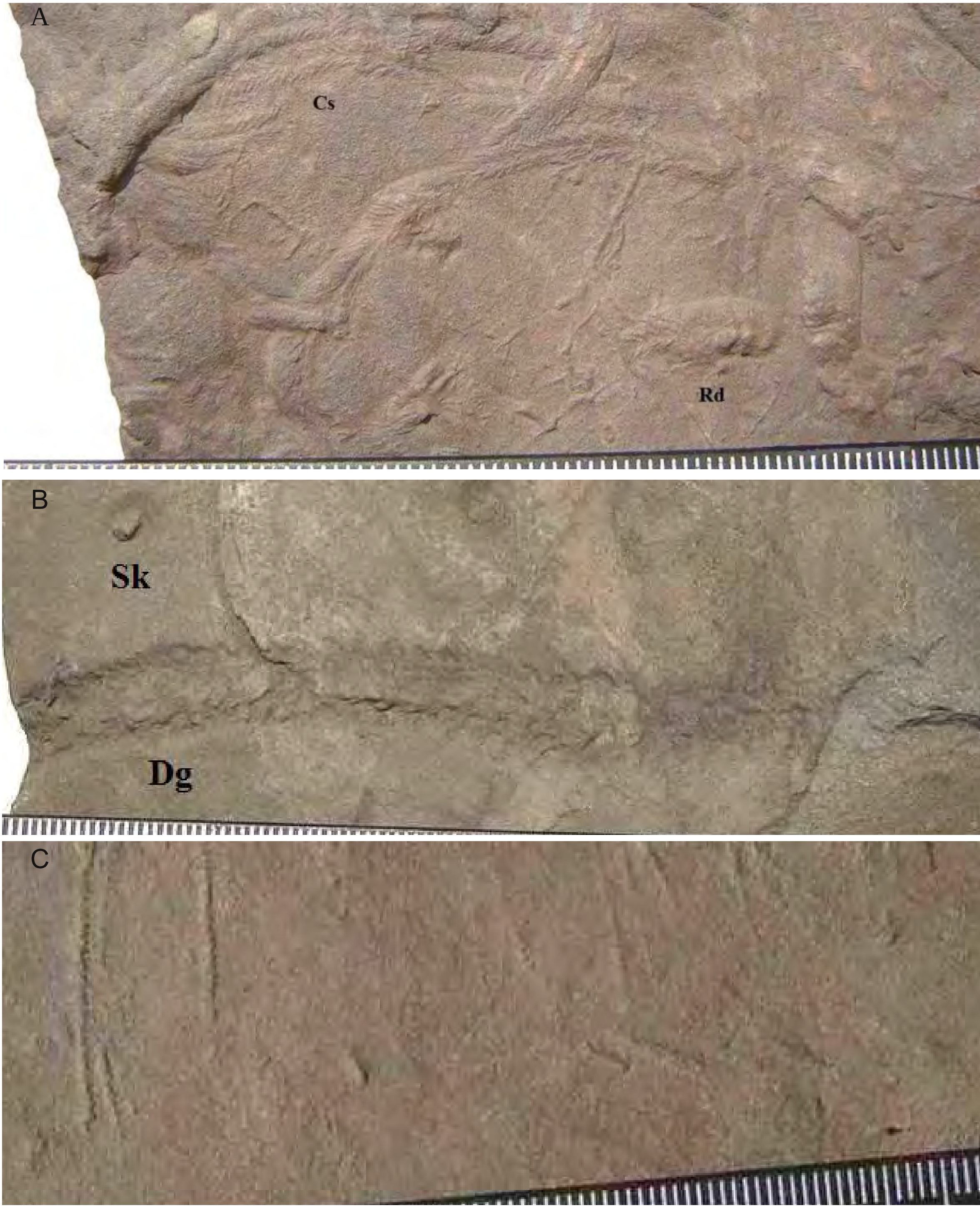

Fig. 1. Trace fossils reported from the Vorotninskaya (O1vr) suite, Upper-Kalar series, Upper-Kalar Graben, Transbaikalia: A. Trilobite trace fossils: *Cruziana semiplicata* (Cs), *Rusophycus didymus* (Rd); B. View of *Diplichnites gouldi* (Dg), Skolithos (Sk); C. View of *Dimorphichnus* cf. *obliquus* (Dob)

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Ichnofabrics

Megaporous Ichnofabrics and Associated Focused Groundwater Flow in Carbonate Platforms

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Keywords: Ichnology, carbonates, porosity, permeability, aquifers

Thalassinideans, plant roots, and perhaps thalassinidean-like crustaceans have produced megaporous and high-permeability ichnofabrics in Cretaceous-to-Pleistocene shallow-marine carbonate platform rocks that contribute to widespread zones of focused groundwater flow in carbonate aquifers. Examples from outcrop and subsurface carbonate platforms in Texas, Florida, Bahamas, and Spain indicate that this ichnofabric-related megaporosity can develop into a highly transmissive, fabric-selective, stratiform, dual-porosity system.

Ichnofabric-associated, dissolution-enlarged megaporosity has been identified within rhizolith-dominated *Psilonichnus* Ichnofacies, *Ophiomorpha*-dominated *Skolithos* Ichnofacies, *Thalassinoides*-dominated *Cruziana* Ichnofacies, and *Thalassinoides*-dominated *Glossifungites* Ichnofacies. Measured centimeter-scale megaporosity, associated with thalassinidean-generated ichnofabrics examined in the Lower Cretaceous of Texas (fig. 1) and Pleistocene of Florida, is as high as 78%. Lattice-Boltzmann determined permeability of the same Texas and Florida samples can exceed the upper range measured with laboratory permeameter (Cunningham et al., 2012). In some cases, extreme dissolution of the Texas *Thalassinoides*- and Florida *Ophiomorpha*-dominated ichnofacies, promotes the formation of karst collapse structures. Mixing-zone dissolution plausibly produced *Thalassinoides*-related megaporosity in Paleocene carbonate rocks in Spain (fig. 2, Baceta et al., 2007), as invoked for Triassic peritidal carbonate rocks in Sicily (Torado et al., 2016). Borehole flowmeter data from carbonate aquifers in the Lower Cretaceous of Texas and the Eocene, Oligocene, Pliocene, and Pleistocene of Florida provide examples where ichnofabric-linked megaporosity produces focused groundwater flow. In the subsurface of southeast Florida, mangrove and other types of root molds contribute to dissolution-enlarged pore and permeability systems capping Eocene carbonate peritidal cycles (fig. 3). Megaporous Pleistocene Bahamian *Ophiomorpha*-dominated Ichnofacies are comparable to examples in southeast Florida.

References

Baceta, Juan Ignacio, V. Paul Wright, Simon J. Beavington-Penney, and Victoriano Pujalte. "Palaeohydrogeological Control of Palaeokarst Macro-porosity Genesis during a Major Sea-level Lowstand: Danian of the Urbasa–Andia Plateau, Navarra, North Spain." Sedimentary Geology 199.3-4 (2007): 141-69.

Cunningham, Kevin J., Michael J. Sukop, and H. Allen Curran. "Chapter 28 - Carbonate Aquifers." Developments in Sedimentology–Trace Fossils as Indicators of Sedimentary Environments. Eds. Knaust, Dirk, and R.G. Bromley. Vol. 64. Amsterdam, Elsevier (2012): 869-96.

Todaro, S., C. Hollis, and P. Di Stefano. "Spongy-like Porosity in Peritidal Carbonates: An Interaction of Cyclic Sea-level Oscillations, Fresh Water Supply and Sediment Texture." Sedimentary Geology 333 (2016): 70-83.

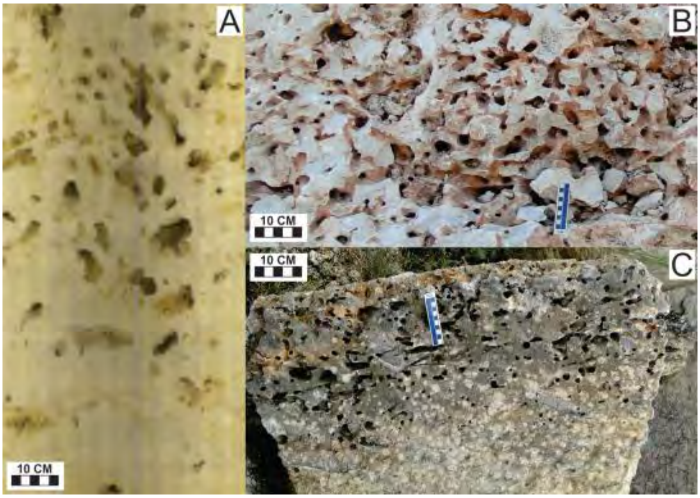

Fig. 1. Examples of dissolution-enlarged Thalassinoides- and Ophiomorpha-related megaporosity exhibited in Lower Cretaceous shallow-marine platform carbonate rocks in the subsurface and outcrops of Central Texas, USA. (A) Solution-enlarged permeable megaporosity formed by Thalassinoides or Ophiomorpha in the Glen Rose Formation that contributes to a groundwater production zone in a water well at depths below the surface between 93 and 94.2 m. (B) Solution-enlarged Thalassinoides that forms fabric-selective megaporosity in a lime packstone matrix (Thalassinoides-dominated Cruziana Ichnofacies) within of the Burrowed Member of the Fort Terrett Formation that crops out near Leakey, Texas. (C) Solution-enlarged Ophiomorpha that forms fabric-selective megaporosity in a lime grainstone matrix (Ophiomorpha-dominated Skolithos Ichnofacies) of the Glen Rose Formation that crops out at the Canyon Lake Spillway in Comal County, Texas.

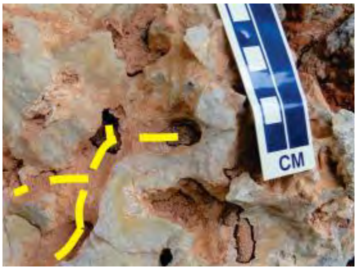

Fig. 2. Dissolution-enlarged megaporosity in a Thalassinoides-dominated lime packstone (Thalassinoides-dominated Cruziana Ichnofacies) within lagoonal platform carbonate rocks of Paleocene age at Monte Baio, northeastern Spain. The dashed yellow line emphasizes the hallmark branching morphology of the Thalassinoides. This megapore system has apparently resulted from overprinting of mixing-zone dissolution (Baceta et al., 2007) over a Thalassinoides-dominated ichnofabric. It is considered analogous to the interaction between mixing-zone dissolution and bioturbated strata presented by Todaro et al. (2016) for Triassic peritidal carbonate rocks in Sicily.

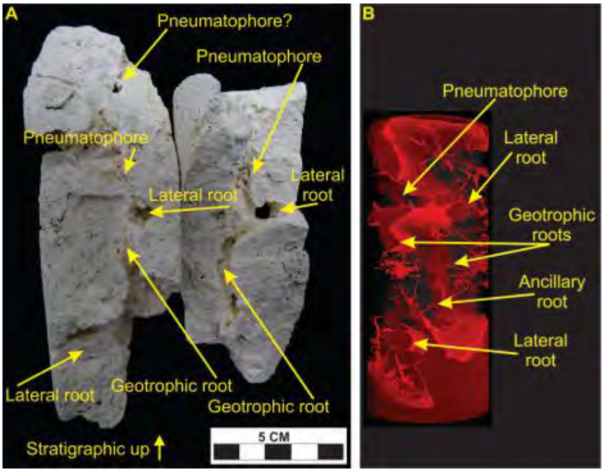

Fig. 3. Photograph (A) and rendering of X-ray computed tomography scans (B) of a rhizolith-dominated Psilonichnus Ichnofacies in a limestone core specimen acquired from a depth of 1175.1 m (top of specimen) below the surface in the G-2984 test corehole located in southeastern Florida, USA. (A) Dissolution-enlarged mangrove-root molds dominate the megaporosity of core specimen of middle Eocene tidal-flat benthic-foraminifer wackestone and packstone that caps a carbonate peritidal high-frequency cycle. This megaporosity type is a major contributor to groundwater flow detected by a borehole-fluid flowmeter. (B) Three-dimensional volume of X-ray computed tomography slices of core specimen in A. Acquisition and volume rendering of computed tomography data conducted at the University of Texas High-Resolution X-ray Computed Tomography Facility.

Ichnofabrics in tide-influenced meander loop deposits: Underscoring the geometry of the colonization window

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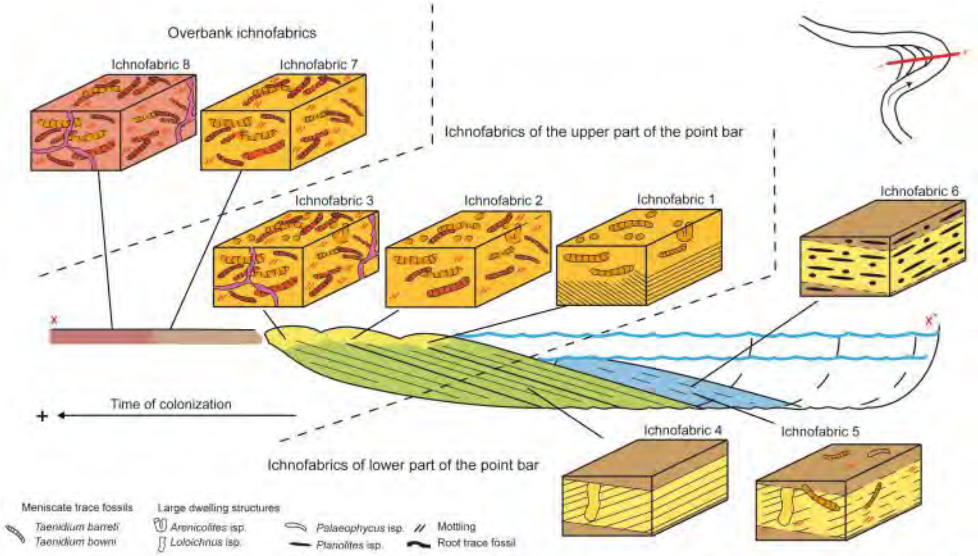
Keywords: Ichnofabric approach, bioturbation controls, tide-influenced meander loop, colonization window

Studies dealing with the colonization window typically emphasize two major features, duration (short vs long time) and frequency (episodic vs continuous colonization). However, our understanding of tide-influenced meander loops requires considering an additional feature, the geometry of the colonization window. Tide-influenced meandering channels show an heterogeneous ichnofaunal distribution that reflects the variety of processes operating along the point bar and overbank surfaces. Ichnofabric analysis of tide-influenced meander loop deposit from the Upper Cretaceous Tremp Formation (Pyrenees, Spain) provides valuable insights to better understand the dynamic and ichnology of these marginal marine systems and to evaluate the importance of their paleomorphology controlling the colonization window. Eight ichnofabrics are identified in the point bar and associated overbank deposits. The ichnofabrics differ in bioturbation index (higher in upper part of point bars), preservation of primary sedimentary fabric (typically preserved in lower part of point bars), inferred behaviour and trophic types (dominance of dwelling or feeding structures in the lower and upper parts of point bars, respectively), depth of penetration, ichnotaxonomic composition (e.g. freshwater vs brackish water suites), presence or absence of root traces and/or mottling, and the number of superimposed suites. Moreover, the colonization windows inferred differ in duration, frequency and geometry (e.g. inclined vs horizontal). The key environmental factor controlling the nature and distribution of ichnofabrics is the paleomorphology of the point bar lateral accretion surfaces, which is directly linked to the geometry of the colonization window. Factors of subordinate importance are: helicoidal flow, water level changes, time of meander loop development, salinity fluctuations and early diagenesis (shallow dissolution and/or cementation).



Facies	Lithologies	Body fossils	Sedimentologic features	Other features	Depositional environment	
Non-channelized deposits	Yellowish sandy-marly mudstone	Fragments of mollusc shell, planktonic foraminifera and calcispheres	Commonly massive Locally lenticular bedding Glauconite grains and locally authigenic glauconite	Ichnofabric 7	Proximal	Overbank mudflats
	Reddish sandy-marly mudstone	Commonly ostracods and charophytes	Massive	Ichnofabric 8 Locally carbonate nodules and paleosols	Distal	
Paleochannel deposits	Hybrid arenite	Fragments of bivalve shell and planktonic and benthonic foraminifera and calcispheres	Commonly massive	Ichnofabrics 1, 2, 3	Upper point bar	Tide-influenced meander loops
	Hybrid arenite and sandy-marly mudstone	Plant remains, including palm tree leaves Locally fragments of echinoderm and red algae and charophytes, ostracods, and vertebrate bones and eggshells	Inclined heterolithic stratification (IHS) with erosional and no erosional reactivation surfaces. Large- and small-scale cross-bedding, climbing-ripple cross bedding, flaser bedding and parallel lamination Locally diffuse IHS and sedimentary structures	Ichnofabrics 4, 5, 6	Lower point bar	

Fig. 1. Ichnofabrics identified in tide-influenced meander loops of Tremp Formation (South-Central Pyrenees, Spain). The geometry of deposition of point bars controls, firstly, the ichnofaunal distribution.

Ichnological and sedimentological features of the Hongguleleng Formation (Devonian–Carboniferous transition) from the western Junggar, NW China

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Keywords: Trace fossil, Late Devonian, Volcanic arc, Event sedimentation, Western Junggar

Two sections of the Late Devonian to Early Carboniferous Hongguleleng Formation in the Sha'erbuerti and Xiemisitai mountains of western Junggar, NW China were logged in detail. It is composed essentially of marginal- to shallow-marine deposits formed in a volcanic arc-related setting. Trace fossils include indeterminate ellipsoid structures, indeterminate shallow-pit structures, *Chondrites intricatus*, *Chondrites targionii*, *Chondrites* isp., *Dolopichnus gulosus*,?*Multina* isp., *Nereites missouriensis*, *Nereites* isp., *Palaeophycus tubularis*, ?*Phycosiphon* isp., ?*Phymatoderma* isp., *Rhizocorallium commune*, *Rosselia* cf. *socialis*, *Teichichnus rectus*, *Teichichnus* ispp., *Thalassinoides* isp., and *Zoophycos* ispp. These ichnofossils and related bioturbation structures constitute five distinct groups of ichnofabrics: *Chondrites*–?*Phymatoderma*, *Rhizocorallium commune*, anemone dwelling/burrowing, *Teichichnus*, and *Zoophycos* ichnofabrics, conforming to an upward trend from the *Cruziana* to *Zoophycos* ichnofacies. The volcanic arc setting provides a natural laboratory to investigate the colonisation styles of benthic faunas in event influenced strata during the Devonian. Simple and composite ichnofabrics have been distinguished. The simple ichnofabrics are typified by the indeterminate ellipsoid "ichnofabric" made by sea anemones, representing short colonisation event and in situ death and burial resulted from relatively high sedimentation rates even during the periods between volcanic explosions. The composite ichnofabrics are characterised by the *Chondrites*–?*Phymatoderma*, ?*Multina*–*Zoophycos* and multi-tier *Zoophycos* ichnofabrics, representing vertical migration of benthic faunas in pace with either distal event deposition or steadily accreted sea floor. The colonisation window in the arc-related setting is closely related to sedimentation rates and frequency of depositional events, determining the completeness of burrow system structure and maturity of benthic communities.

References

Aigner, T. "Calcareous Tempestites: Storm-Dominated Stratification in Upper Muschelkalk Limestones (Middle Trias, SW-Germany)." Cyclic and Event Stratification. Eds. Einsele, Gerhard and Adolf Seilacher: Springer Berlin Heidelberg, 1982. 180–98. Print.

Ávila, Sérgio P., et al. "Palaeoecology, Taphonomy, and Preservation of a Lower Pliocene Shell Bed (Coquina) from a Volcanic Oceanic Island (Santa Maria Island, Azores)." Palaeogeography, Palaeoclimatology, Palaeoecology 430 (2015): 57–73. Print.

Hou, Hongfei, et al. "Discovery of a New Famennian Echinoderm Fauna from the Hongguleleng Formation of Xinjiang, with Redefinition of the Formation." Stratigraphy and Paleontology of China 2 (1993): 1–18. Print.

Mángano, María Gabriela, and Luis Alberto Buatois. "Shallow Marine Event Sedimentation in a Volcanic Arc-Related Setting: The Ordovician Suri Formation, Famatina Range, Northwest Argentina." Sedimentary Geology 105.1–2 (1996): 63–90. Print.

Seilacher, Adolf. " General Remarks about Event Deposits. " Cyclic and Event Stratification. Eds. Einsele, Gerhard and Adolf Seilacher: Springer Berlin Heidelberg, 1982. 161–74. Print.

Seilacher, Adolf. "Towards an Evolutionary Stratigraphy." Acta geológica hispánica 16.1 (1981): 39–44. Print.

Suttner, Thomas J., et al. "Stratigraphy and Facies Development of the Marine Late Devonian near the Boulongour Reservoir, Northwest Xinjiang, China." Journal of Asian Earth Sciences 80 (2014): 101–18. Print.

Xiao, Wenjiao, et al. "Middle Cambrian to Permian Subduction-Related Accretioary Orogenesis of Northern Xinjiang, Nw China: Implications for the Tectonic Evolution of Central Asia." Journal of Asian Earth Sciences 32.2–4 (2008): 102–17. Print.

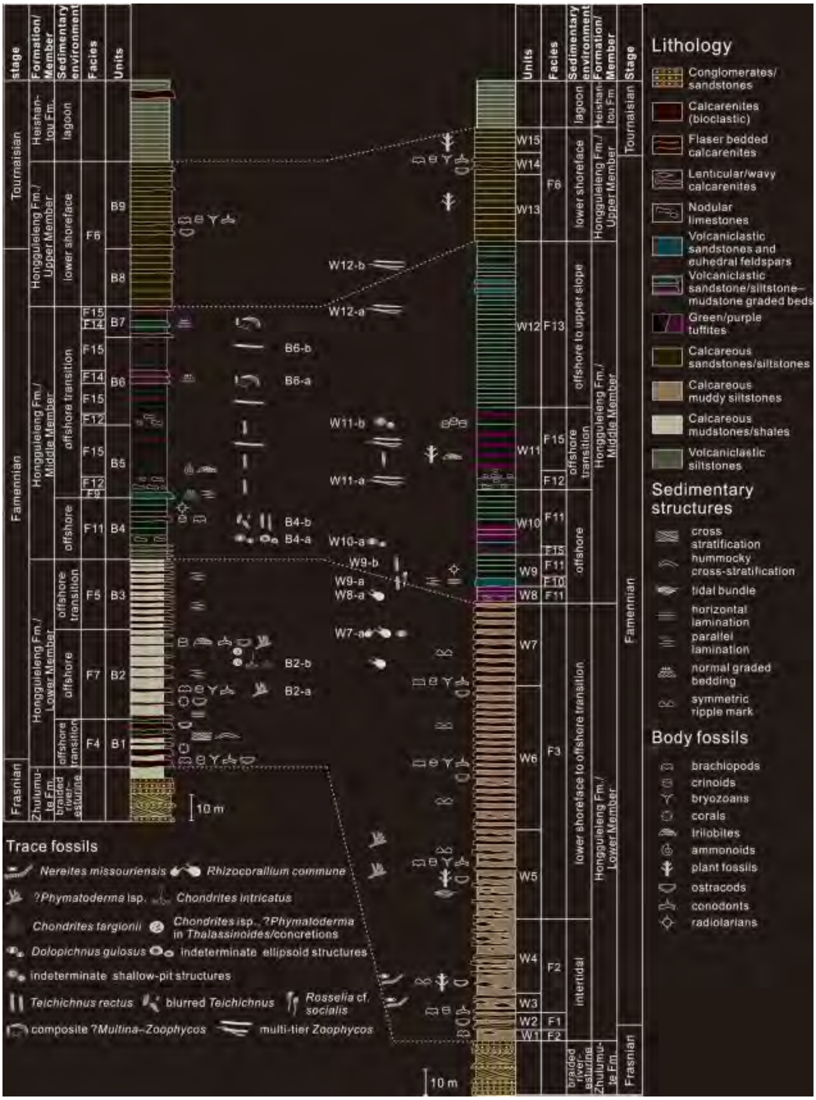

Fig. 1. Sedimentary columns of the Bulongguoer (left) and Wulankeshun (right) sections in western Junggar, recording sedimentary structures, body and trace fossils and their facies interpretations.

Stacking pattern analysis constrained by ichnofabrics

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Keywords: ichnofabrics, stacking-pattern, depositional environment interpretation, correlation

Detailed description including physical and biogenic sedimentary structures is mandatory to achieve comprehensive facies analysis of reservoirs in exploration projects complemented by the integration of all sort of data at different scales (petrography, biostratigraphy, chemostratigraphy, wireline log and seismic).

Identification of ichnotaxa and their grouping into ichnofabrics coupled with the analysis of physical sedimentary structures supports the recognition of half regressive and half transgressive cycles (Gérard and Bromley, 2008). Identification of the cyclicity from bed scale to bedset scale to parasequence scale (Campbell, 1967) is essential to identify the geologically significant surfaces bounding flow units at reservoir scale and sequences at the basin scale.

Recognition of the stacking pattern supports sequence analysis to achieve correlation of depositional sequences and geological surfaces between wells. Detailed stratigraphic analysis is essential for describing and understanding the reservoir architecture and more importantly for prediction of changes in reservoir architecture and quality in response to lateral facies changes as proposed by the Walther´s law.

A series of case studies will exemplify the importance of combining physical sedimentary structures and biogenic structures to identify sequences and interpret depositional environments. Recurring ichnofabrics from classical prograding storm-dominated shelfs will be presented, but also incised valley fills and prograding river-dominated deltas controlled by floods where ichnofauna is sensitive to fresh water input will show the importance of recognition of the fining-upward and coarsening-upward cycles (1-5m) in defining the architectural elements and their correlation between wells.

References

Campbell C.V. Lamina, laminaset, bed and bedset. Sedimentology, 8, p7-26, 1967.
Gérard J.R.F. and Bromley R.G.B. Ichnofabrics in clastic sediments. Madrid. 100p. 2008.

Permeability and porosity characteristics of ichnofabrics and lithofacies from the Early Cretaceous Hibernia Formation, offshore Newfoundland, Canada

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Keywords: Early Cretaceous, Hibernia Formation, ichnofabric, permeability, porosity

The Early Cretaceous, upper Hibernia Formation in the southern Jeanne d'Arc Basin (Fig. 1), offshore Newfoundland in Canada is interpreted as a wave-influenced delta. Facies analyses show a transition from offshore marine in the Hebron area to more proximal shoreface and deltaic facies in the West Bonne Bay region. Hydrocarbon discoveries in the Hibernia Formation make it a potential target for the petroleum industry though little research has been conducted on the upper Hibernia Formation in the southern Jeanne d'Arc Basin. This study utilizes core samples taken through the Hebron Member, of the upper Hibernia Zone in the southern Jeanne d'Arc Basin to assess facies-specific trends in permeability and porosity related to the presence or absence of bioturbation. Minipermeametry analyses of slabbed core faces show a difference of 300 mD between mud-lined burrows and surrounding clean sandstones within the same 19 cm long core section (Fig. 2). Comparisons between thinly bedded sandstones and their cryptobioturbated equivalents display a difference in permeability of up to 20 mD. Core plug data indicates that parallel laminated storm-generated sandstone beds display higher permeability and porosity values than bioturbated fair-weather facies. Coarse-grained, cross-bedded sandstones with rare *Ophiomorpha* in the Hibernia Formation (Fig. 2) display the greatest permeability values (up to 900 mD), but bioturbated mudstones and very fine-grained sandstones containing *Phycosiphon* isp. are demonstrated, by petrography and core plug analyses, to have increased porosity and permeability. Facies distribution of isolated sandstone lenses and *Phycosiphon*-containing fair-weather deposits therefore strongly influence the potential for reservoir connectivity and thus should be factored into well planning.

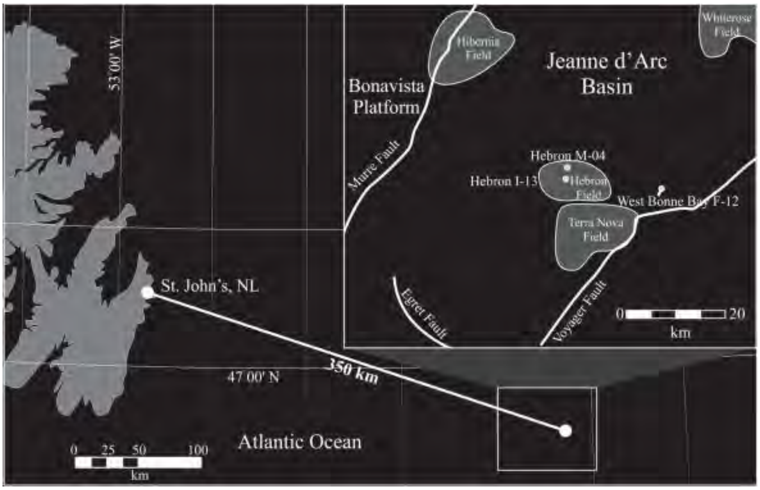

Figure 1. Geographic map indicating the location of the studied wells and nearby oil fields in the Atlantic offshore of Newfoundland, Canada.

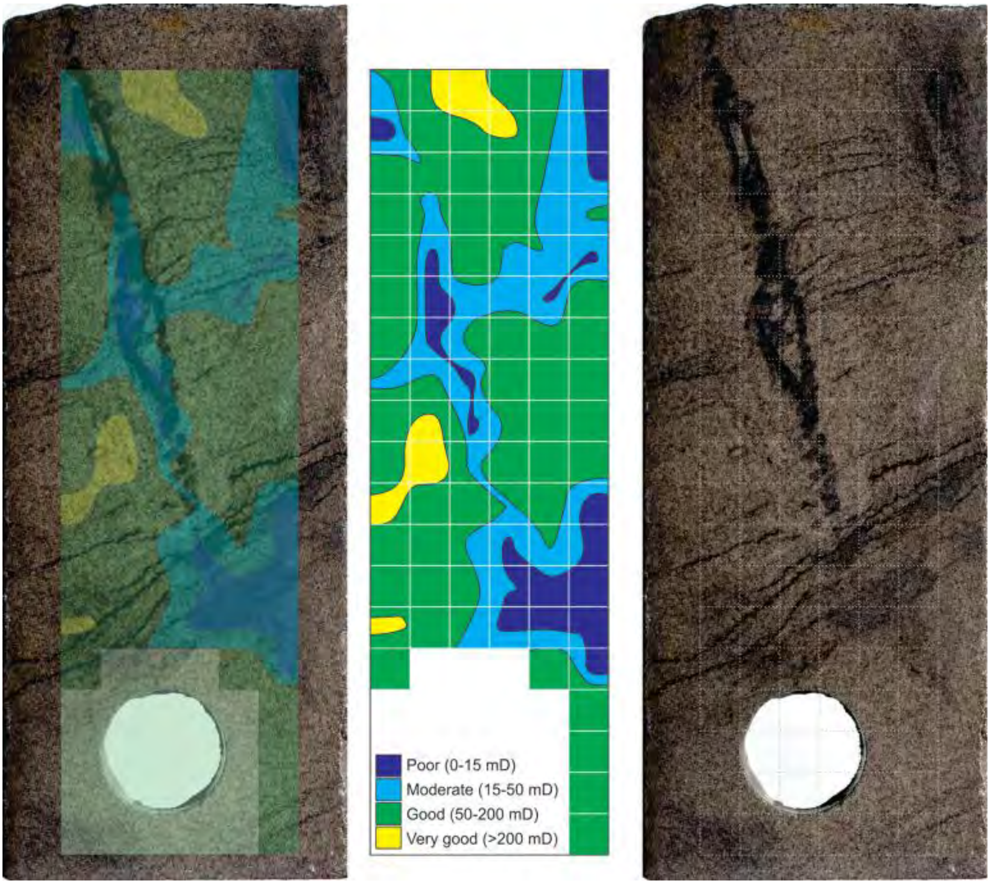

Figure 2. A contour map illustration of mini-permeametry results of sampling conducted on a slabbed core face from the West Bonne Bay F-12 core. Note the permeability difference between the Ophiomorpha burrow lining and the surrounding medium- to coarse-grained cross-bedded sandstone. Sampling grid is 6 cm by 19 cm.

Integration of ichnofabrics in depositional environment interpretation and sequence analysis

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Keywords: ichnofabrics, sequence analysis, depositional environment interpretation;

Ichnology provides useful information on the environmental conditions that prevailed during or shortly after sediment deposition. As such, recognition and interpretation of trace fossils are now integrated in advanced sedimentological studies. Like most other laboratory or field techniques, ichnology should not be used as a stand-alone tool. Ichnofabric information is best used in the full context of the sedimentary framework. Only then can ichnology provide detailed environmental information that can be related to depositional processes, relative palaeobathymetry, sequence stratigraphy and correlation.

The use of "ichnofabrics" has increased steadily since the ichnofabric concept was first developed by Bromley and Ekdale in 1984: "Ichnofabrics: all aspects of the texture and internal structure of a sediment that result from bioturbation at all scales". Globally recurring trace fossil associations or ichnofabrics are interpreted to be characteristic of bathymetric zones and/or depositional environments passing from onshore to deep offshore settings although the suite of ichnofabrics consists of a broad spectrum of palaeobathymetry with subtle but real changes of trace fossil associations along the depositional profile in response to local physical and chemical changes.

Identification of ichnotaxa and their grouping leads to the understanding of the vertical distribution of the endobenthic community in the sediment along a tiering profile which is mainly controlled by sediment grain size, texture, oxygenic content and redox boundary. Sediment aggradation results in an overprint of the shallow tier by the medium and deep tier. Therefore, the analysis of the cross-cutting relationship between tiers provides a key to the understanding of the relative adjustment of the endofauna to sediment aggradation with time although absolute duration cannot be assessed. Although identification of all ichnotaxa is not always achievable where the degree of bioturbation is high, ichnofabric technique helps splitting the stratigraphic record in recurring associations organized in half-transgressive and half-regressive cycles bounded by correlative geological surfaces.

In the case of low aggradation rate and even erosion associated to transgressive ravinement events, physical and chemical conditions prevailing for a fair amount of time lead to changes of the substrate and texture of the underlying sediments. Then, the sea floor is generally colonized by new ichnofauna more adapted to a firmer substrate. The analysis of ichnotaxa below this colonisation surface and the degree of bioturbation of the sediment provide additional constraints to the identification of significant geological surfaces of the stratigraphic record.

In fact ichnofabric techniques bear a fair potential for high resolution sequence analysis, as the sedimentologist can split the sequences observed in core particularly or possibly in a section in the field too, in a series of recurring ichnofabrics. Ichnofabrics allow not only large third-order cycle recognition, but can also identify and correlate higher-frequency cycles by comparing the ichnofabric cycles and their vertical stacking. Furthermore, the stacking pattern of ichnofabrics leads to the identification of correlative bounding surfaces that are essential to understand the stratigraphy at basin scale or achieving description, correlation and prediction of reservoir architecture to constrain ultimately reservoir modelling.

Grain size? No issue for burrowing! An example from the Eocene of Kachchh, India

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Keywords: Fulra Limestone Formation, Foraminiferal limestone, bioturbation, Upper Eocene

Kachchh Basin, located in the western margin of Peninsular India is a rift basin holding an excellent record of sediments from Mesozoic to Recent. The Paleogene sediments are classified into five formations *viz*., Matanomadh, Naredi, Harudi, Fulra Limestone and Maniyara Fort in ascending order. The current study encompasses Fulra Limestone Formation. This formation is more or less uniform in lithology and consists of thickly bedded, white to buff or ochreous yellow coloured biomicrite or biosparite, bearing abundant large saddle-shaped benthic foraminifera *Discocyclina* and ellipsoidal *Alveolina* bestowing a very coarse grained nature. The maximum grain size is to the order of 5 cm. The formation is bioturbated almost throughout its thickness, except for a few beds towards the base. The ichnoassemblage consists mainly of *Thalassinoides,* forming horizontal networks and mazes. *Bichordites* and *Planolites* occur occasionally. The burrows have been emplaced by tunneling through the coarse grained substrate, resulting in reorganisation of grains of the larger foraminifera. They have been arranged perpendicular to the length of the burrow thus modifying the original fabric. The present example rather deviates from the ichnological concept that traces are usually preserved in medium to fine grained clastics.The construction of burrows appear to be similar to the recent *Diopatra* tubes but the absence of wall and masonary work rules out the possibility of any comparison.

Fig. 1. Outcrop of Fulra Limestone Formation. Note highly bioturbated horizons within the limestone giving nodular appearance to the surface.

Fig. 2. *Thalassinoides*, wall showing presence of tests of larger benthic foraminfera.

Fig. 3. Burrow wall showing arrangement of tests of larger benthic foraminifera perpendicular to the length of burrow.

Ichnofabrics of Devonian shales: a case study from Paraná Basin, southern Brazil

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Keywords: Devonian shales, Gondwana, anoxic events.

Six ichnofabrics present in Devonian shales from Ponta Grossa Formation (sensu Grahn et al., 2013) were analyzed in Tibagi region (Brazil, Fig. 1). The composite *Planolites-Palaeophycus* ichnofabric (Fig.2) reflects feeding behavior of detritivorous organisms in dysoxic upper offshore settings. The composite *Asterosoma-Teichichnus* is dominated by feeding burrows of detritivorous organisms but burrows produced by suspension-feeders are also present. It characterizes the relict preservation of the shallow tiers in the historical layer zone, representing optimum ecological conditions in lower shoreface to offshore transition zones. The composites *Asterosoma-Zoophycos* and *Asterosoma-Chondrites* ichnofabrics are dominated by feeding burrows that reflect activity of preferentially detritivorous and decomposers and represent colonization of dysoxic substrates to in offshore settings. The *Chondrites* ichnofabric shows the prevalence of decomposing activity and suggests abundant organic-rich content into oxygen-deficient offshore substrates. These ichnofabrics characterizes a fair-weather trace fossil assemblage of the distal *Cruziana* Ichnofacies, suggesting deposition below wave base affected by storms. *Skolithos* ichnofabric shows simple vertical burrows that express prevalence of suspension feeding behavior, represents the opportunistic colonization of the substrate during higher-energy events and characterizes the Skolithos Ichnofacies (Fig. 3). Uchman and Wetzel (2011) pointed that bioturbation is absent when organic carbon content is high (Corg >2%) and correlated beds express Corg near to 2%. *Chondrites* and *Planolites* are post-depostional burrowers and its presence at the top of the shale bed suggests that the substrate became hospitable for chemosymbiont animals after the reactivation of the bottom currents. Unbioturbed black shale beds reflects prevalence of anoxic conditions into the substrate.

References

Grahn, C.Y., Mendlowicz-Mauller, P., Bergamaschi, S., Bosetti, E.P., 2013. Palynology and sequence stratigraphy of three Devonian rock units in the Apucarana Sub-basin (Paraná Basin, south Brazil): additional data and correlation. Review of Palaeobotany and Palynology 198, 27–44.

Reineck, H.-E., 1963. Sedimentgefüge im Bereich der südlichen Nordsee. Abhandlungen der senckenbergischen naturforschenden Gesellschaft, v. 505, p. 1-138.

Uchman, A., Wetzel, A., 2011. Deep-sea ichnology: the relationships between depositional environment and endobenthic organisms. In: Hüneke, H., Mulder, T. (eds.), Deep-Sea Sediments. Elsevier, Amsterdam, Developments in Sedimentology 63, pp. 517–556.

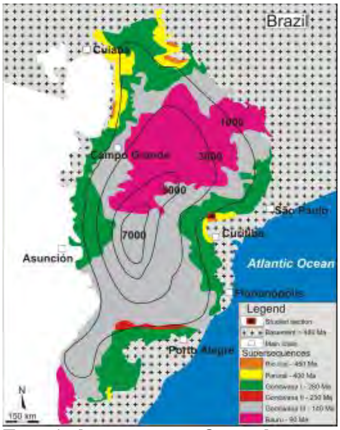


Fig. 1. Location of study area in the Paraná Supersequence, S Brazil.

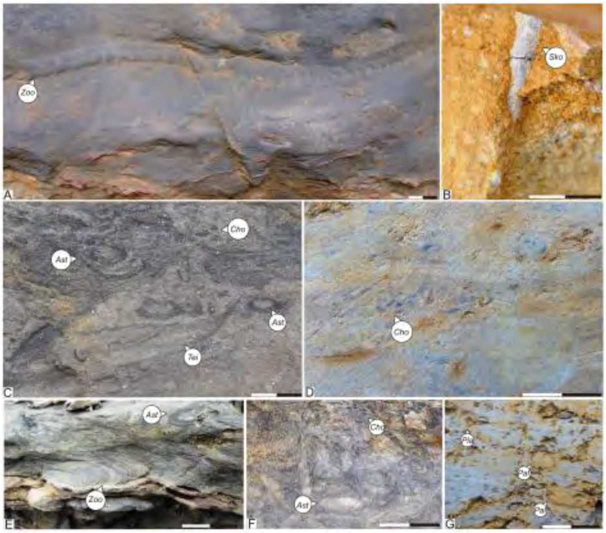


Fig.2. Ichnofabrics from the study area. A. *Zoophycos* ichnofabric. B. *Skolithos* ichnofabric. C. Composite ichnofabric of *Asterosoma-Teichichnus* with *Chondrites*. D. *Chondrites* ichnofabric. E. Composite ichnofabric of *Asterosoma -Zoophycos*. F. Composite ichnofabric of *Asterosoma - Chondrites*. G. Composite ichnofabric of *Planolites - Palaeophycus*. Scale bar 2 cm.

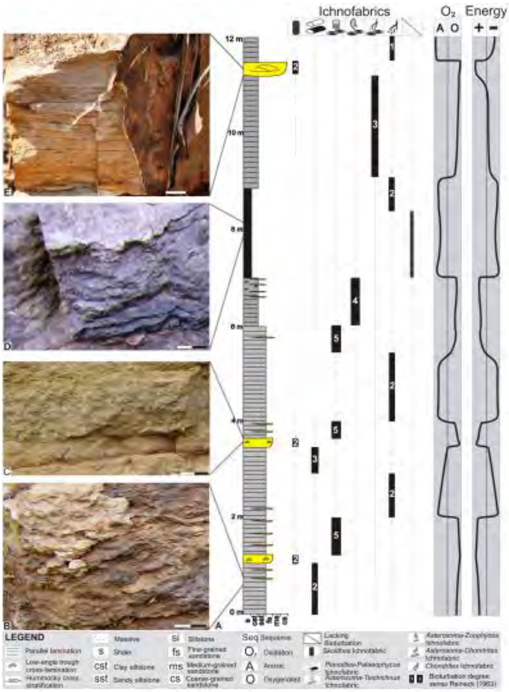
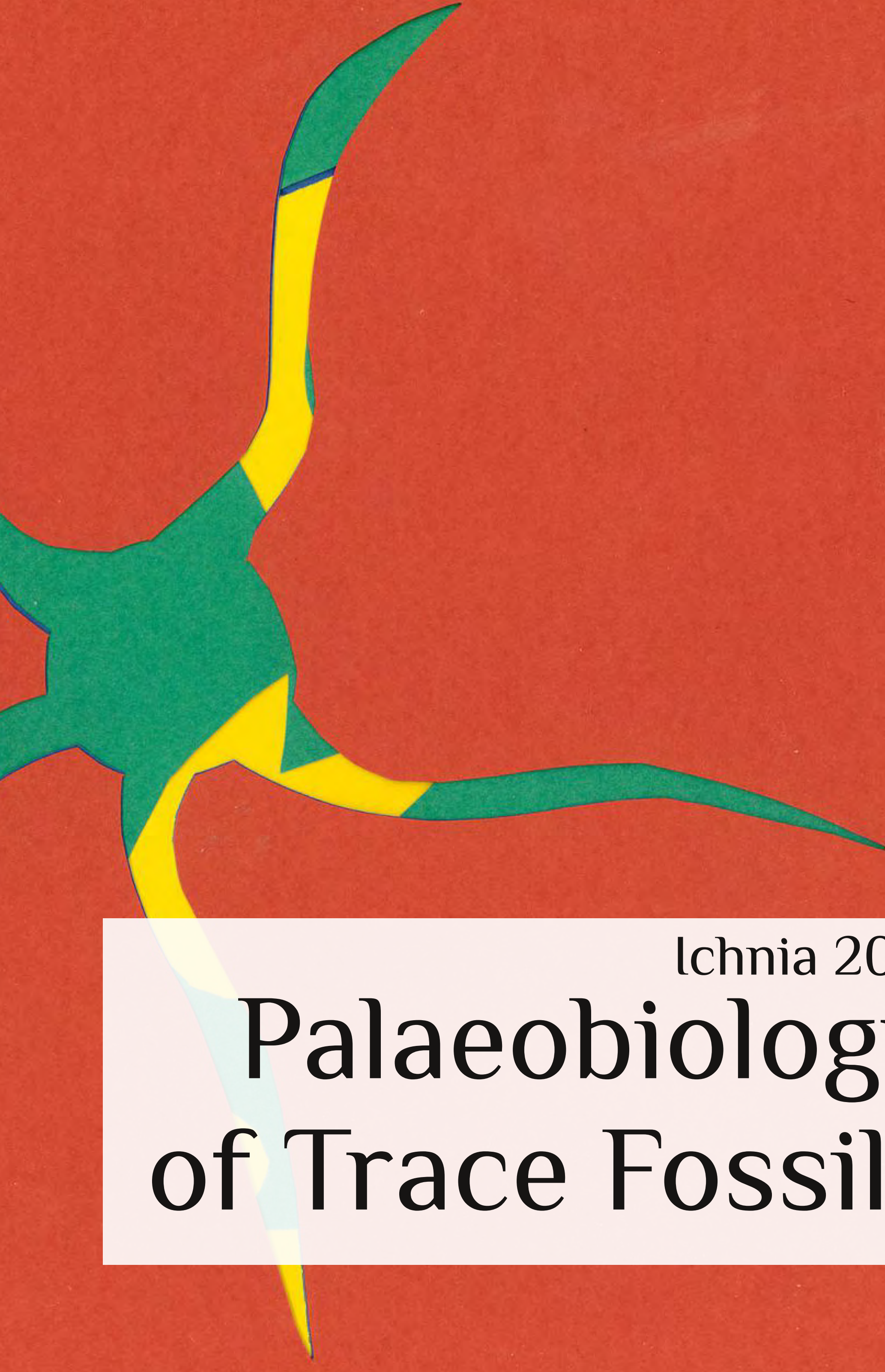


Fig. 3. Geological section of Ponta Grossa Formation at Tibagi region. A. Schematic profile, distribution of ichnofabrics and inferred paleoenvironments parameters of the study area. B. Sandy siltstones with parallel lamination interrupted by fine-grained sandstone lenses. C. Fine-grained sandstone beds with wavy ripples. D. Pyritiferous black shales. E. Medium to coarse-grained sandstone with hummocky cross stratification. Scale bar 2 cm.



Ichnia 2016
Palaeobiology of Trace Fossils

A doomed expedition? Exploring the concept of doomed pioneers using an annular flume tank and the polychaete, *Alitta virens*

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Keywords: Doomed pioneers, annular flume tank, *Alitta virens*, turbulent transport, allochthonous

Trace fossils provide *in situ* evidence for organisms and their activities and are widely applied as palaeoenvironmental indicators. But what if the organisms are allochthonous to the depositional environment? This is the concept behind the"doomed pioneers" hypothesis (Föllmi and Grimm, 1990); that organisms living in a well-oxygenated environment could be caught up in a turbulent flow and transported to a different, oxygen deficient, environment. These organisms are then able to colonize and create trace fossils in anoxic sediment, at least for a short time, before eventually succumbing. The feasibility of this occurring has important implications for interpreting trace-fossil material in deep-marine settings.

Using an annular flume tank, ethically-approved experiments have been designed to explore the survivorship potential and viability of the polychaete, *Alitta virens*, after being subjected to a turbulent transport regime (Fig-1). In a matched-pairs experimental design, the ability and time taken to burrow, is compared between polychaetes that have been subject to turbulent transport and those that have not. From these observations we can begin to constrain survivorship potential and quantify just how functional an organism is after undergoing turbulent transport and the likelihood of it forming any traces from its doomed expedition. Results from these experiments are discussed here.

References

Föllmi, K.B. & Grimm, K.A. 1990. Doomed pioneers: Gravity-flow deposition and bioturbation in marine oxygen-deficient environments. Geology, **18**, 1069-1072.

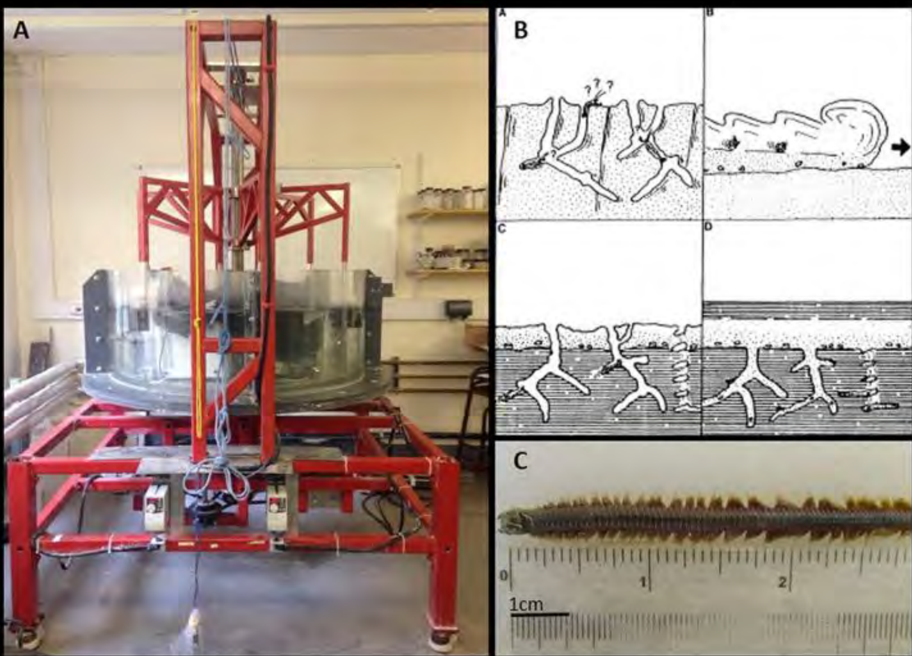

Fig. 1. A) Annular Flume tank utilized for these experiments B) An illustration of the doomed pioneer hypothesis (after Föllmi and Grimm 1990) and C) the polychaete, *Alitta Virens*.

Run, rabbit, run: Ichnodisparity and ichnodiversity trajectories during evolutionary radiations

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Keywords: evolutionary radiations, ecospace colonization, ichnodiversity, ichnodisparity, trace fossils

Organisms and their behaviors are in constant change as a result of colonization of new ecospace, environmental fluctuations, and extinctions. In order to explore the ichnologic record of evolutionary radiations, we compile changes in ichnodiversity and ichnodisparity of invertebrate trace fossils through time. Occurrences were compiled on a case-by-case basis, therefore summarizing actual occurrences. However, ichnodiversity and ichnodisparity curves were plotted as “range-through” data, and therefore they are based on lower and upper appearances for each ichnogenus/category of architectural design and then extrapolating their presence through any intervening gap in the continuity of its record. Comparison of the ichnologic record during the Cambrian Explosion, the Great Ordovician Biodiversification Event and the Mesozoic Marine Revolution as well as of events in the continental realm indicates that evolutionary radiations are invariably associated with an ichnodiversity increase. Analysis of ichnodiversity changes through geologic time supports Sepkoski’s three-phase kinetic model, which was originally based on analysis of marine body fossils. In contrast, increases in ichnodisparity are not linked to evolutionary radiations *per se*, but to the colonization of empty ecospace, as illustrated by the Cambrian Explosion for softground colonization, the Great Ordovician Biodiversification Event for colonization of hardgrounds, and the colonization of paleosols by the end of the Mesozoic. This pattern supports analysis based on body fossils that indicates a “first disparity, then diversity” scenario. In spite of potential limitations of ichnodiversity and ichnodisparity, our study indicates that ichnologic information is highly useful as an independent line of evidence to understand paleobiologic megatrends.

Neoichnology of the blue land crab *(Cardisoma guanhumi)*: indicative meaning of a Bahamian landscape engineer

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Keywords: Supratidal, Sea Level, Decapod, Georadar, Eleuthera, San Salvador

Neoichnological research in the Bahamas (Eleuthera, San Salvador; Fig. 1) demonstrates that the blue land crab (*Cardisoma guanhumi*) acts as a pervasive tracemaker in a number of transitional supratidal habitats. Open-ground and root/rock-sheltered large (entrance diameter >10 cm) and medium (5-10 cm) burrows occurr at densities of up to 4-5/m^2. Accompanied by massive spoil piles of sediment excavated from their *Macanopsis*-like shaft-tunnel-chamber systems (total length >1 aerial photography and geophysics (georadar). The substrate composition is modified with the introduction of organic matter by these semi-terrestrial omnivorous brachyurans, along with discarded exoskeletons from >50 moult cycles (triple of most land crab species) and exotic clasts (relict mollusc shells, artifacts). A sandy washover from a recent storm was devoid of bioturbation but contained rarely observed trackways of *C. guanhumi*, with tapered footprints identical to those on the floor of a chamber cast. In contrast to relatively steep J-shaped shafts through a thick mangrove peat, burrows at lower elevations exhibit gentler gradients, both designed to terminate just below the local groundwater table to sustain a shallow hydration pool. Proximity of the water table to tidal levels, high preservation potential of domichnia with habitat shift, and the radiocarbon-dating utility of enclosed vegetation remains, make blue crab burrows a prospective sea-level indicator. To complement their Neogene body fossil record, the identification of fossil *Cardisoma* sp. burrows and galleries will offer a valuable benchmark for paleoenvironmnetal reconstruction of Atlantic and Indo-Pacific supratidal successions.

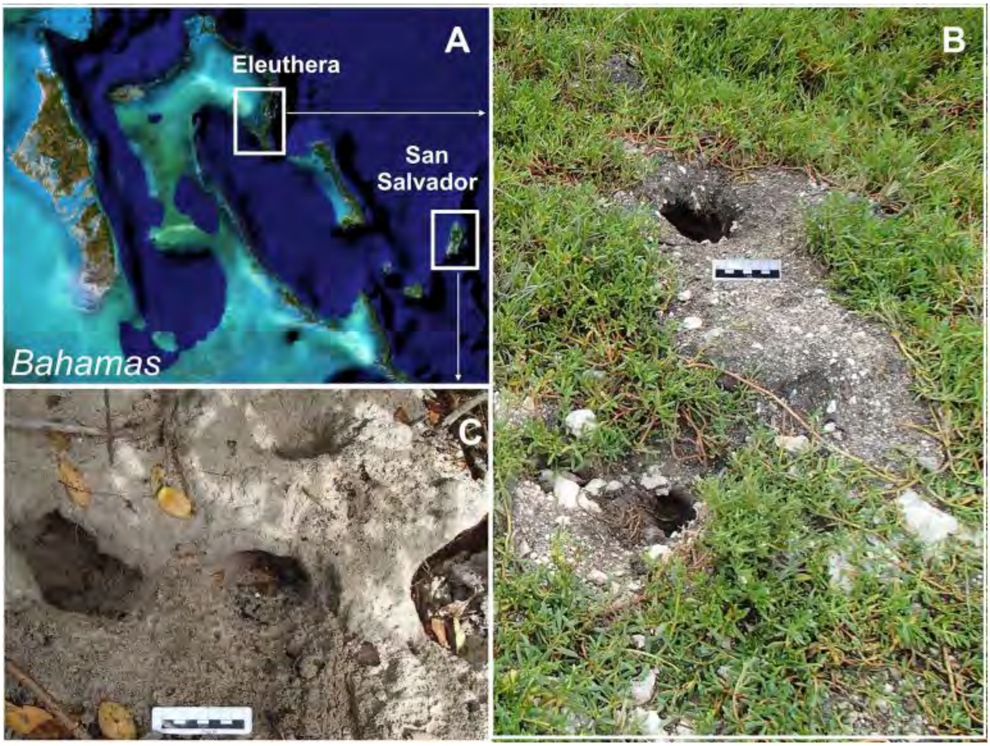

Figure 1. Field sites along the two islands in the Bahamian Archipelago (A) exhibit extensive bioturbation by the blue land crab in mangrove-fringe (B) and backdune (C) supratidal settings.

Mammal and avian tracksites from the Lower Oligocene in the North of Ebro Basin (Aragón, Spain)

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Keywords: Artiodactyl, Avian, footprints, continental facies, Cenozoic, Spain

The record of Oligocene vertebrate ichnites in the Iberian Peninsula is especially interesting because the fossils from this epoch are scarce worldwide (McDonald et al., 2007). In Aragón (NE of Spain), Hernández-Pacheco (1929) reported the first Cenozoic tracksite ("Playa Fósil", Peralta de la Sal locality, Peralta Formation) in the Iberian Peninsula. The author described two different morphotypes of avian footprints: one with, and another one without interdigital membrane. Later, Canudo et al., (2007) made a preliminary description of the Fondota tracksite (Abiego locality, "Calizas de Peraltilla Formation") where they distinguished 3 different morphotypes of artiodactyl tracks (*Anoplotheriipus*-like, Ellenberger, 1980). During last year, new fieldwork was carried out in these localities in order to obtain high spatial resolution point clouds with Terrestrial Laser Scanning (TLS, LiDAR technology) and photogrammetry techniques. Moreover stratigraphic profiles were made for providing a sedimentological interpretation of the deposits. A close-up examination of the ichnites and the photogrammetric models of the "Playa Fósil" tracksite allow to suggest that the described avian morphotypes might be produced by a single trackmaker walking in a detrital substrate with different water content. This is coherent in an environment like a shallow lake shoreline reached by detrital supplies or in a ponded area located in a flood plain. The TLS data and the photogrammetric models of "Fondota" tracksite allow us to characterize better the morphology of the three previous described morphotypes and distinguishing 26 lineations that represent individual trackways produced by the artiodactyls walking subperpendicular to the a lake shoreline.

References

Canudo, J. I., Barco, J. L., Cuenca-Bescós, G., & Rubio, J. (2007). Icnitas de Abiego. Prames. 24 pp.

Ellenberger, Paul. Sur les empreintes de pas de gros mammiféres de l'Eocène supérieur de Garrigues-Ste-Eulalie (Gard). Paleovertebrata, Mémoire Jubilé R. Lavocat (1980): 37-78.

Hernández-Pacheco, Francisco. Pistas de aves fósiles en el Oligoceno de Peralta de la Sal (Lérida). Memorias de la Real Sociedad Española de Historia Natural, XV (1929): 379-382.

McDonald, H. Gregory, et al. An indexed bibliography of Cenozoic vertebrate tracks. Cenozoic vertebrate tracks and traces. New Mexico Museum of Natural History and Science Bulletin, 42 (2007): 275-302.

Fig. 1.Pictures of parts of the outcrops from the Playa fósil tracksite (A) and the Fondota tracksite (B) from the Lower Oligocene of the North of Ebro Basin (Aragón, Spain).

A stromatoporoid trace fossil from the Upper Ordovician of the Siberian Platform

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Keywords: Stromatoporoids, trace fossils, Upper Ordovician, Siberia.

Numerous specimens of a conical-shaped trace fossil similar to *Conichnus conicus* Männil, 1966 but usually larger (10–35 cm high and about 7–20 cm in diameter) were found in the Upper Ordovician (Katian) cool-water carbonate succession of the Tungus Basin in the Siberian Platform (Fig.1). The trace fossils are represented by vertically oriented conical or bulbous accumulations of bioclastic material (bioclastic packstone) surrounded by mudstone or wackestone with much lower concentrations of bioclasts. In several conical detrital accumulations, calcite tubes of stromatoporoid *Aulacera tenuipunctata* Yavorsky, 1955 were found in the axial or slightly tilted (axis-off) position in the cones (Fig. 2). During 2014, outcrops yielding numerous large tubes of *Aulacera tenuipunctata* were studied in detail. Where *in situ* the lower end of the tube is vertically oriented and surrounded by a detritic envelope of the conical shape. Detritic cones are thus closely connected with the calcite tubes and represent a trace fossil for which the aulaceratid stromatoporoids were the trace makers. It seems that the aulaceratid stromatoporoids could accumulate bioclastic debris around them as well as to penetrate into the sediment for at least 35 cm, probably by means of their weight and vibrations caused by hydrodynamic activity. Bioclastic debris probably passively filled an open space created by this vibration between the stromatoporoid tube wall and the firm surrounding sediment. They formed a kind of anchor, which prevented the animal from being plucked out by storms. In this respect, the trace fossils under consideration could be attributed to fixation/anchoring traces or the category fixichnia (Gibert et al., 2004).

References

Gibert J.M. de, Doménech R., Martinell J. “An ethological framework for animal bioerosion trace fossils upon mineral substrates with proposal for new class, fixichnia.” *Lethaia* 37 (2004): 429–437.

Fig. 1. Conical-shaped trace fossils produced by the stromatoporoid *Aulacera tenuipunctata* Yavorsky, 1955; Moyerokan River valley; Dzherom Formation. Upper Ordovician of the Siberian Platform.

Fig. 2. Calcite tube of the stromatoporoid *Aulacera tenuipunctata* Yavorsky, 1955 within the conical detrital accumulation; Moyerokan River valley; Dzherom Formation. Upper Ordovician of the Siberian Platform.

Cruziana, Rusophycus and the record of arthropod limb evolution

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Keywords: Cruziana, Rusophycus, Gondwana, trace formation

The most iconic of all trace fossils, *Cruziana* and *Rusophycus,* have intrigued generations of ichnologists. While their stratigraphic significance and species diversity has been thoroughly documented (Seilacher, 1994), their modes of formation are still far from clear. The research community is divided in two regarding the formation of *Cruziana*. Major issues are the position of the organism in relation to the benthos and the limbs or parts thereof participating in the formation of the trace. The position of the trace maker as an epi- or endo- benthic organism is a crucial aspect for understanding the formation of *Cruziana* and *Rusophycus*. Here we discuss the mode of formation of *Cruziana* through interpretation of material from the Ordovician Sajir formation of Saudi Arabia. The material interpreted here indicates that Ordovician forms from Gondwanan outcrops did not have a differentiated endopod into an excavating mechanism and that it was retained as a relatively simple structure. Other specimens from the same locality indicate that the formation of the trace could not have been anything but at the interface between sand-mud layers, as overlapping traces could not be produced in an open burrow due to the absence of the casting substrate in the larger lobes of excavated sediment. In this report we wish to illustrate the difficulty of working with aspects of trace fossil formation and the importance of taphonomical processes in the preservation of trace fossil material and whether the evolution of arthropod limbs could be documented by the ornament of associated trace fossils.

References

Seilacher, A. “How Valid Is Cruziana stratigraphy?” *Geologische Rundschau Geol Rundsch 83.4* (1994)

Goldring, R. “The Formation of the Trace Fossil Cruziana.” *Geological Magazine Geol. Mag.* 122.01 (1985): 65

Life and death on the continental shelf 20 Ma: the interaction between predator and prey as reflected in trace fossils

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Keywords: Schaubcylindrichnus, *Ophiomorpha*, *Piscichnus waitemata*, Miocene, Taiwan

Before Taiwan formed in the late Miocene-Pliocene through the collision of a volcanic arc on the Philippine Sea Plate with the continental shelf of the Eurasian Continent, the environment was characterized by a wide shelf where cyclic deposits of offshore to deltaic sediment were laid down. Today these sand- and siltstones are exquisitely exposed along the northeast coast of Taiwan, allowing detailed observations on the relationship between the different organisms that inhabited the benthic environment. In particular, *Piscichnus waitemata* (stingray feeding traces) often contain broken pieces of wall material from *Ophiomorpha* and *Schaubcylindrichnus,* suggesting that the shrimps and worms constructing these borrow systems belonged to the favorite food of the stingrays. These observations are of special interest for our understanding of the trace fossil *Schaubcylindrichnus*. Is the sequential construction of lined tubes in the typical sheaves or bundles of wide, U-shaped tubes in *Schaubcylindrichnus* a response to attacks by stingrays?

Here data from two well exposed areas along the NE Coast of Taiwan are evaluated to determine whether there is a statistical correlation between the abundance of *P. waitemata* and the number of tubes in the *Schaubcylindrichnus* sheaves. The hypothesis being that increased predation pressure by stingrays would lead to more *Schaubcylindrichnus* systems being partly destroyed, in its turn resulting in higher numbers of repaired systems, as reflected by the number of tubes per sheaf.

Terror at the beach: huge theropod tracks on the Jura carbonate platform (Late Jurassic, Switzerland)

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Keywords: Dinosaur track, tridactyl, Theropoda, 'Megalosaurids', Jura Mountains

Excavations along Highway A16 (NW Switzerland) in Kimmeridgian tidal-flat deposits of the Jura carbonate platform revealed > 650 sauropod and tridactyl (mostly theropod) trackways with different morphologies and size classes. All trackways were carefully documented and partially collected and/or casted constituting a huge track collection and database. Several huge (pes length > 50 cm) tridactyl trackways were discovered. Some of these tracks are well preserved and morphologically distinct, characterized by a slightly larger pes length than width, a very small anterior triangle, weak mesaxony, three blunt ('fleshy') digits (II-III-IV) with pronounced claw marks of equilateral triangle-shape, and occasionally with heel impression. Some of these features are typical of very large theropod tracks. The blunt digits and sheer size of the largest tracks, some of which amongst the largest worldwide, suggests a 'megalosaurid' theropod as a trackmaker. The frequent presence of huge theropod tracks in tidal-flat deposits of the Jura carbonate platform and in (close) association with tiny to large sauropod tracks and minute to large tridactyl tracks, has important palaeoecological implications for the dinosaur population. Also this evidence is important for palaeo(bio)geographical reconstructions, as theropod tracks larger than 50 cm in length (and some of which of similar morphology) are also known from of the Late Jurassic of Northern Germany (Kaever & Lapparent, 1974), France (Cariou et al., 2014), Spain (Cobos et al., 2014), and Morocco, and tracks of similar morphology are also known from the Middle Jurassic of Portugal (under study).

References

Cariou Elsa, Olivier, Nicolas, Pittet, Bernard, Mazin, Jean-Michel, and Hantzpergue, Pierre. "Dinosaur track record on a shallow carbonate-dominated ramp (Loulle section, Late Jurassic, French Jura)." *Facies*. 60 (2014): 229-253.

Cobos, Alberto, Lockley, Martin. G., Gascó, Francisco, Royo-Torres, Rafael and Alcala, Luis. "Megatheropods as apex predators in the typically Jurassic ecosystems of the Villar del Arzobispo Formation (Iberian Range, Spain)." *Palaeogeography, Palaeoclimatology, Palaeoecology*. 399 (2014): 31-41.

Kaever, Mathias and de Lapparent, Albert F. "Les traces de pas de dinosaures du Jurassique de Barkhausen (Basse Saxe, Allemagne).", Bulletin de la Société Géologique de France. 7.16 (1974): 516-525.

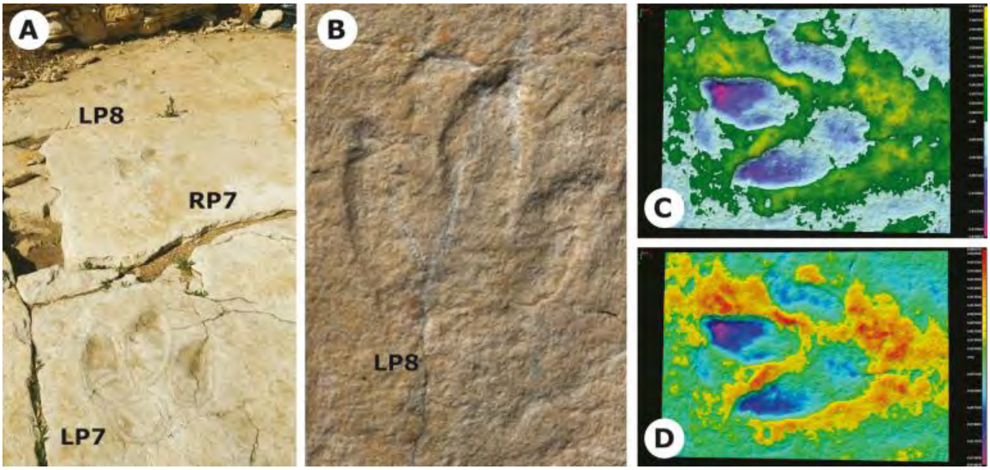

Figure 1: Trackway T1 from level 1500 of the Courtedoux—Sur Combe Ronde tracksite near Porrentruy (Jura Canton, NW Switzerland). These tracks are clearly different from other Late Jurassic huge theropod tracks and it is under currently under study. A: Overview photo of tracks LP7, RP7 and LP8. B: Photogrammetric 3D-model of track LP8 in a low angle view. C & D: Depth map of track LP8 with two different color keys.

Communal therapsid burrows from interdune facies of the Lower Jurassic Navajo Sandstone, southern Utah, USA

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Keywords: tetrapod burrow, desert deposits, trytilodont, bilobed bottom.

Tetrapod burrows with a bilobed bottom are reported from outcrops of the lower part of the Navajo Sandstone in southern Utah. The structures were identified in two close localities (38° 1.433' N, 110° 32.759'W), southeast of Hanksville. The Navajo Sandstone contains thin lacustrine carbonate lenses embedded in eolian dune cross-strata. The carbonate lenses are composed of dark micritic limestone with mudcracks, rhizoliths and invertebrate burrows. The burrow casts with bilobed bottoms occur in a set of wind-ripple cross strata overlying a bleached zone composed of calcite cemented sandstone (Fig. 1), which is laterally correlative to a carbonate lens. The burrows are shallowly penetrating (average 17°), lack enlargements and display a curved path in plan view. The burrow casts correspond to two size classes: 33-72 mm (the most common) and 128-159 mm. Burrow widths roughly match *Brasilichnium* trackway widths from correlative deposits. Burrow cross sections are roughly kidney-shaped, with a convex roof and bilobed bottom (Fig. 2), and vertically flattened (average burrow width/burrow height ratio= 2.1). The bottom is divided by a central depression that accounts for 1/3 of the burrow width (Fig. 3). Burrow fill is massive and mostly smooth with faint chevron-like ridges. The cross-sections suggest open burrows with a protracted occupation by scratch-digging tetrapods (probably trytilodonts). Compaction produced by the repeated passage of the occupant produced bilobed bottom, which was preferentially cemented because of excrements. Estimated body mass of the producer is 12-40 g (smaller burrows) and 324-780 g (larger burrows).

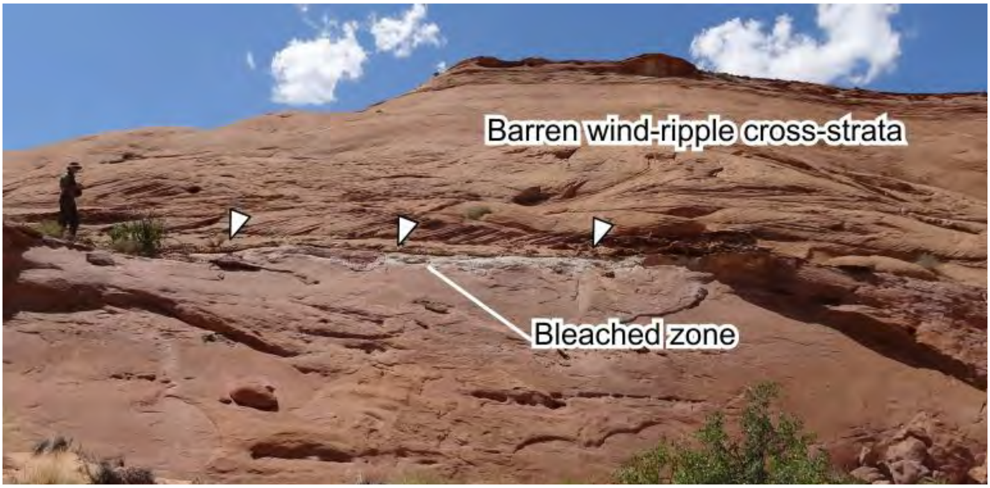

Fig. 1. Field view of the studied stratigraphic interval showing the bleached zone and overlying bed with bilobed burrow casts (white arrows).

Fig. 2. Cross-section of therapsid burrow cast with convex-upward roof and bilobed bottom.

Fig. 3. Loose therapsid burrow cast with smooth bilobed bottom.

A Carboniferous chiton (Mollusca, Polyplacophora) at the end of its trail: a unique find from the Czech Republic

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Keywords: Visean, Czech Republic, Culm Facies, chitons, locomotion traces

An exceptional find of a chiton preserved at the end of its locomotion trace comes from the Culm Facies, i.e. turbidity-controlled dark shales, greywackes and sandstones. The chiton trace is a smooth, rather indistinct, 7 8 mm wide bilobate ridge (convex epirelief), forming an incompletely preserved loop of estimated extent 5 × 8 cm. At its end is preserved a completely articulated chiton *Proleptochiton* sp., 4.0 mm wide and 11.5 mm long, oriented congruently with the trace. The neighbouring strata provide relatively frequent ichnofossils, e.g., *Chondrites* isp., *Planolites* isp., *Dictyodora liebeana* (Geinitz) and *Diplocraterion* isp.

The chiton trace fossil corresponds to ichnotaxa that have historically been compared to modern gastropod trails. The gastropods are well-known for two different monotaxic locomotion techniques, one for hard substrates such as glass, and another for soft substrates, where the animals move through muscular waves of much higher amplitude than observed on glass. Thereby, adhesion useable for the movement on the hard surface is functionally replaced with friction. Loosening of the sediment by rapid moves of foot muscles is the cause of the structure's convexity, i.e. increasing volume. Similar behaviour is documented in chitons.

The studied specimen is the first locomotion trace fossil attributed to polyplacophorans.

The find documents the burrowing technique of chitons in deep-marine, turbidity-influenced soft substrate during the Viséan (330 Ma). It demonstrates the similarity of chiton and some gastropod traces in soft substrates, and adds to the lengthening list of animals that were fossilized within their traces.

Fig. 1. *Proleptochiton* sp. at the end of its trail; lower left, *Chondrites* isp. Lhotka locality, Visean, Czech Republic. Bar = 1 cm.

Ichnology in the Paleobiology Database

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Keywords: database, paleobiology, paleobiodiversity, ichnotaxa

The Paleobiology Database (PBDB, paleobiodb.org) is an open resource of global paleontological data on all types of fossil organisms through all time periods. Data types include bibliographic references; taxonomic names, taxonomic opinions and classifications; primary fossil collection data; taxonomic occurrences; and geologic time scales all stored in a relational database. PBDB currently contains over 1.28 million occurrences of over 333,000 fossil taxa from nearly 176,000 collections. It is expanding every day as over 385 researchers from around the world continuously contribute data. Hundreds of studies have been published that use data derived from the Paleobiology Database, including 247 official publications. Numerous tools are available for analyzing aspects of the fossil record, such as diversity history, ecological distribution, or geographic patterns. Unfortunately, ichnology is woefully underrepresented in the database. Prior to January 2014, all ichnotaxa were listed simple as “Metazoa” At that time, a new higher category of “Ichnofossil” was created and seeded with the ichnogenera from the Treatise on Invertebrate Paleontology. As of Jan. 1, 2016, 294 ichnogenera and 75 ichnospecies were in the database, coming from less than 1000 individual fossil collections. The most common ichnogenera are *Planolites, Zoophycos, Chondrites, Thalassinoides,* and *Palaeophycus.* In order to take advantage of the many analytical tools in the database, ichnologists will need to enter both taxonomic and collections data. They will also need to advise the PBDB leadership on changes to the database data entry forms that will best serve the needs of the ichnological community.

Ichnology and Paleoecology of Carbonate Boring habit in the Development of Marine Algae

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Keywords: Bioerosion, trace fossils, bangial rhodophytes, paleobathymetric indicators

Traces of microorganisms that penetrate carbonate substrates conform closely to the outlines of their makers and produce "instant fossils" that have an unusually high preservation potential. The habit of penetrating relatively soluble substrates such as carbonates and phosphates evolved among prokaryotic cyanobacteria and eukaryotic rhodophytes, chlorophytes and fungi that occupy the euendolithic ecological niche since the Mesoproterozoic times. They are well represented throughout the Phanerozoic, with the euendolithic developmental phases called Conchocelis represent most of the fossil record of otherwise soft-bodied Bangial rhodophytes. Organically preserved fossil Conchocelis stages have been described as *Palaeoconchocelis starmachii* Campbell, Kazmierczak et Golubic 1979, however, the formal description of its trace has been only recently submitted for publication (Radtke et al., in press).

We review the presently available record of fossil Conchocelis occurrences, discuss the morphological properties of this traces in comparison with traces of euendolithic chlorophytes, cyanobacteria and fungi, their value as paleobathymetric indicators as well as the ecological role of the boring habit in marine bioerosion processes and in the development and generation alternation of modern and ancient marine algae.

References

Campbell SE, Kazmierczak J, Golubic S 1979. Palaeoconchocelis starmachii gen. n., sp. n., an endolithic Rhodophyte (Bangiaceae) from the Silurian of Poland. *Acta Palaeontologica Polonica* 24: 405–408.

Radtke G, Campbell SE, Golubic S in press. *Conchocelichnus seilacheri* igen. and isp. nov., a complex microboring trace of Bangialean rhodophytes. *Ichnos* (Mem. Seilacher-Vol.).

Cyanobacterial origin and morphology of the Volkhov hardgrounds (Dapingian, Middle Ordovician) of the St. Petersburg Region (Russia)

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Keywords: Hardground, cyanobacterial mat, mineralization, Ordovician, Baltica

Hardgrounds are widespread at several stratigraphic levels in the Volkhov Regional Stage (Dapingian, Middle Ordovician) in the Leningrad Region and northern Estonia. Until recently they were assumed to be of inorganic origin (Vinn et al., 2015). However, our research has shown two typical hardgrounds to be of cyanobacterial origin. A typical Volkhov hardground is composed of fine-grained compact yellowish limestone with an irregular base and a smooth upper surface encrusted with holdfasts of various crinoids, eocrinoids *Ripidocystis*, several species of bryozoan, and numerous *Trypanites* borings (figs. 1, 2). The thickness of the hardground varies from several mm to several cm. In places this hardground is abruptly thickened to form ring-like bioherm structures surrounding a clay core. We have studied hardgrounds of the boundary between Billingen and Volkhov regional stages, so-called "steklo" beds, and a hardground in the middle of the Volkhov at the top of the "Bordyur" bed. The smooth surface of the "steklo" hardgrounds from the Babino Quarry has a few small (1--3 cm) "windows" with jagged edges, filled with coarse-grained carbonate with a considerable amount of glauconite. Although the surface of the hardground is completely flush with the surface of the window holes, the original surface of the latter was evidently soft as it lacks traces of attachment structures or borings. The origin of these window holes was clarified by SEM studies of the naturally prepared hardground surface from the "bordyur" bed (fig. 1). This hardground has revealed structure and dolomitization typical of mineralized cyanobacterial films. The uneven margins of the holes are slightly raised over the surface of the hardground, suggesting that in these places, a slightly mineralized cyanobacterial film was lifted and torn off the substrate by a gas bulb, possibly oxygen. The rest of the hardground was completely mineralized and partly dolomitized, and was consolidated due to precipitating fine carbonate material interacting with the exopolymeric substances constituting the microbial mats, as was shown for some recent microbial mats (Bontognali et al., 2010). After the decline of the cyanobacterial community, its mineralized remains formed an ideal hardground with pockets of soft substrate resulting from ruptures during the life-time of the cyanobacterial films.

References.

Vinn Olev et al. Bioerosion of Inorganoc Hard Substrates in the Ordovician of Estonia (Baltica). *PLoS ONE* 10(7) (2015): e0134279. Doi: 10.1371/journal.pone.0134279

Bontognali Tomaso R.R. et al. Dolomite formation within microbial mats in the coastal sabkha of Abu Dhabi (United Arab Emirates). *Sedimentology* 57 (2010): 824-844. Doi: 10.1111/j.1365-3091.2009.01121.x

Fig. 1. Hardground surface with prepared windows of soft ground. Specimen PIN4125/926. Middle Volkhov (Dapingian). Leningrad region, quarry Babino.

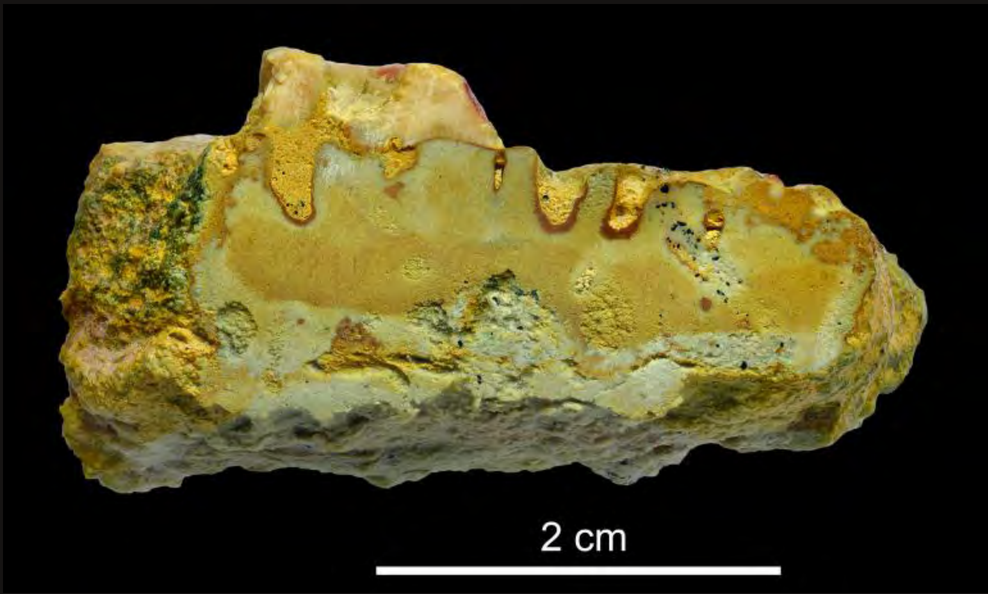

Fig. 2. Section of a hardground fragment with attached crinoid holdfast and *Trypanites* borings. Specimen 4125/817. Distal part of a ring-like bioherm. Middle Volkhov (Dapingian). Leningrad region. Volkhov river near Simonkovo.

A *Zoophycos* carnival: crowded *Zoophycos* ichnofabric reflecting tolerance behavior in early Phanerozoic beds

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Keywords: crowded *Zoophycos* ichnofabric, tolerance behavior,.maximum flooding surface biomarker.

Zoophycos is common in Devonian mudstones from the Paraná Basin (southern Brazil), which compose three stratigraphic sequences named B to D (Grahn *et al.* 2013; Fig.1). It normally occurs in clayish siltstones and claystones interbedded with very fine-grained sandstones with swaley cross-stratification, in association with *Asterosoma, Chondrites, Gordia, Lockeia, Planolites, Rhizocorallium, Teichichnus* and few other ichnogenera, forming a composite ichnofabric. The bioturbation degree is high (BD 5-6) and the ichnofabric represents a climax suite of the Cruziana Ichnofacies. In the Sequence C (Emsian-Eifelian; Fig.1), the climax Cruziana Ichnofacies suite is suddenly overlain by a highly bioturbated (BD 5-6) monospecific *Zoophycos* suite, forming a dense ichnofabric that covers completely the host bed. The presence of *Zoophycos* in both suites and the maintenance of a high bioturbation degree suggest that the monospecific character of the *Zoophycos* suite results from the sudden disappearing of the other tracemakers. The presence of a meter-thick black shale bed with taphonomic signatures of anoxia in the upper portion of the Sequence C suggests that O_2 depicting impacted the substrate and shifted the resident community. *Zoophycos* producers, otherwise, being able to support such conditions, remained burrowing in the clayey substrate. The absence of other burrows favored the exceptional preservation of *Zoophycos*, forming a crowded *Zoophycos* ichnofabric (CZI). The CZI demarks the maximum flooding surface of the Emsian-Eifelian sequence in the Paraná Basin and reinforces the adoption of ecological tolerance behavior (*sensu* Vermej, 1978) by marine invertebrates since the early Phanerozoic.

References

Grahn, C.Y., Mendlowicz-Mauller, P., Bergamaschi, S., Bosetti, E.P., 2013. Palynology and sequence stratigraphy of three Devonian rock units in the Apucarana Sub-basin (Paraná Basin, south Brazil): additional data and correlation. Review of Palaeobotany and Palynology 198, 27 – 44.

Vermeij, G..J., 1978. Biogeography and Adaptation: Patterns of Marine Life. Harvard University Press, Cambridge, Massachusetts.

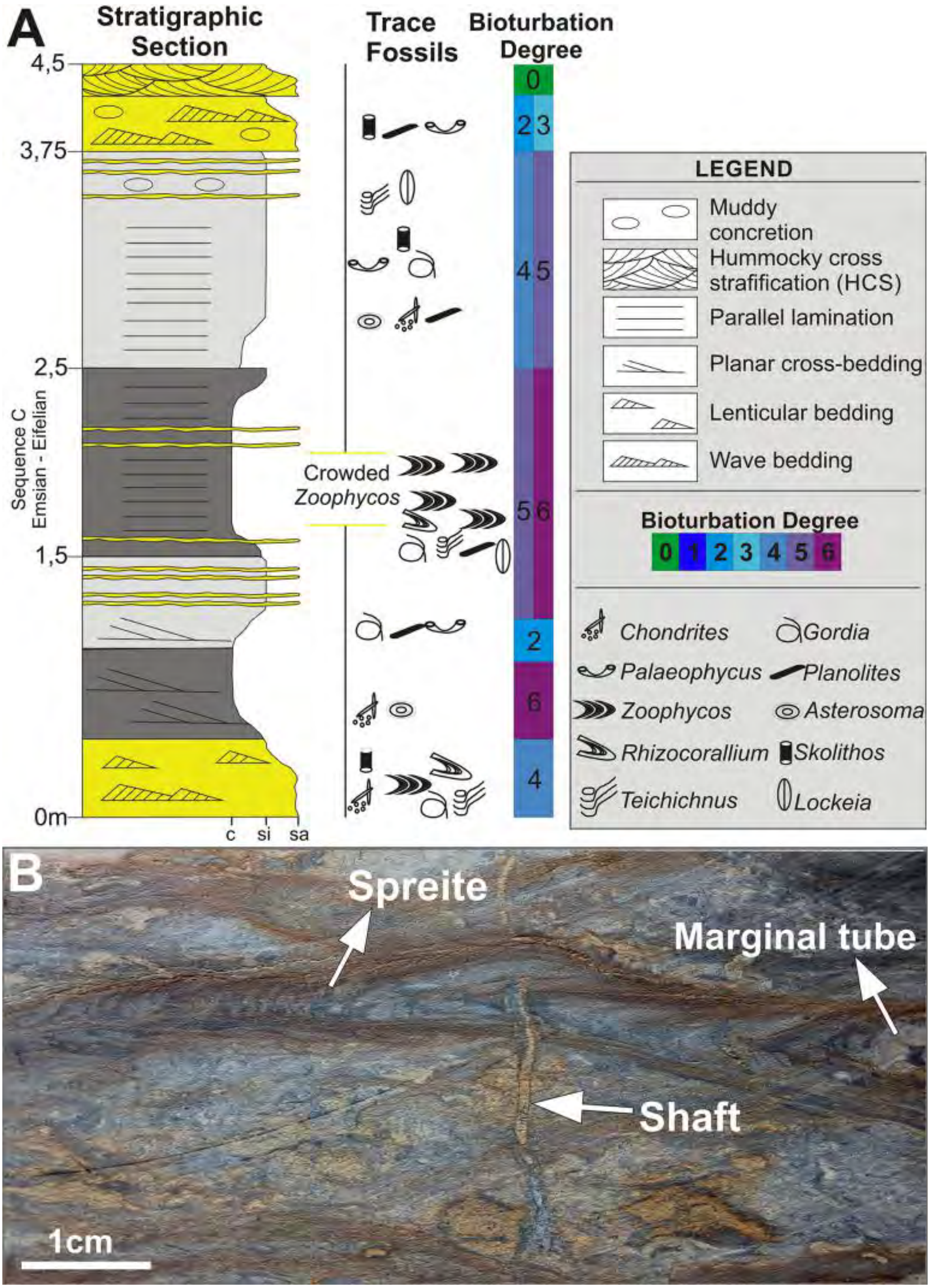

Fig. 1. Study area diagram. A. Geological section and ichnological distribution. B. Detail of *Zoophycos* ichnofabric.

Macaronichnus in Devonian beds: paleobiological and paleoecological implications

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Keywords: Macaronichnus, Middle Devonian, shoreline signatures, polychaete ancestral behavior.

Macaronichnus is recorded in Middle Devonian beds of the Paraná Basin (latest Silurian–Frasnian Paraná Supersequence, Brazil, Fig. 1). It occurs as ichnofabric (bioturbation degree 2-3) in fine to medium-grained quartz sandstone beds with very low-angle trough cross-lamination and parallel lamination that indicate high-energy shallow shoreface settings. *Macaronichnus* occurs in the basal beds of the Late Eifelian sequence (*sensu* Grahn et al., 2013) in association with *Lingulichnus, Rosselia* and *Cylindrichnus*, and in the upper beds of the Early Givetian sequence, forming a monospecific assemblage (Fig. 2). The record of *Macaronichnus* has been mostly restricted to post-Paleozoic deposits and opheliid polychaetes are assumed as tracemakers (Clifton and Thompson, 1978). Based in the latitudinal distribution of *Euzonus*, *Macaronichnus* has being used as indicator of cold waters and medium to high paleolatitudes (Quiroz et al., 2010). Biostratigraphic, sedimentological, paleogeographical and paleoclimatological data indicates that the Devonian beds that contain *Macaronichnus* in Paraná Basin were deposited under fully marine conditions and cool temperate climate, between paleolatitude 60° and 80°S (Blakey, 2008). Vagile epibenthic annelids similar to opheliid polychaetes are present in the fossil record since the Early Cambrian but infaunal polychaetes apparently diversified much later than the vagile forms (Dzik, 2004). Considering that opheliid or opheliid-like polychaetes might be the producer of early Paleozoic *Macaronichnus*, this new record (i) reinforces the preferential preservation of *Macaronichnus* in high-energy shallow marine settings, (ii) suggests that the trace fossil record of infaunal polychaetes precedes its fossil record and (iii) indicates that the paleolatitudinal constraint might reflect a strategic behavior present in opheliid and opheliid-like polychaetes biological program since the early Phanerozoic.

References

Blakey, R. C. (2008). Gondwana paleogeography from assembly to breakup - a 500 m.y. odyssey. Geological Society of America Special Paper, 441, 1-28.

Clifton and Thompson (1978). *Macaronichnus segregatis*: a feeding structure of shallow marine polychaetes. Journal of Sedimentary Petrology, 48.

Dzik, J. (2004). Anatomy and relationships of the Early Cambrian worm Myoscolex. Zoologica Scripta 33, 57–69.

Grahn, C.Y., Mendlowicz-Mauller, P., Bergamaschi, S., Bosetti, E.P. (2013). Palynology and sequence stratigraphy of three Devonian rock units in the Apucarana Sub-basin (Paraná Basin, south Brazil): additional data and correlation. Review of Palaeobotany and Palynology 198, 27–44.

Quiroz et al. (2010). Is the trace fossil *Macaronichnus* an indicator of temperate to cold waters? Exploring the paradox of its occurrence in tropical coasts. Geology 7.

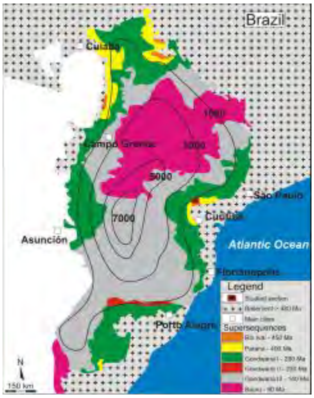

Fig. 1. Location of *Macaronichnus* occurrences in the Paraná Supersequence.

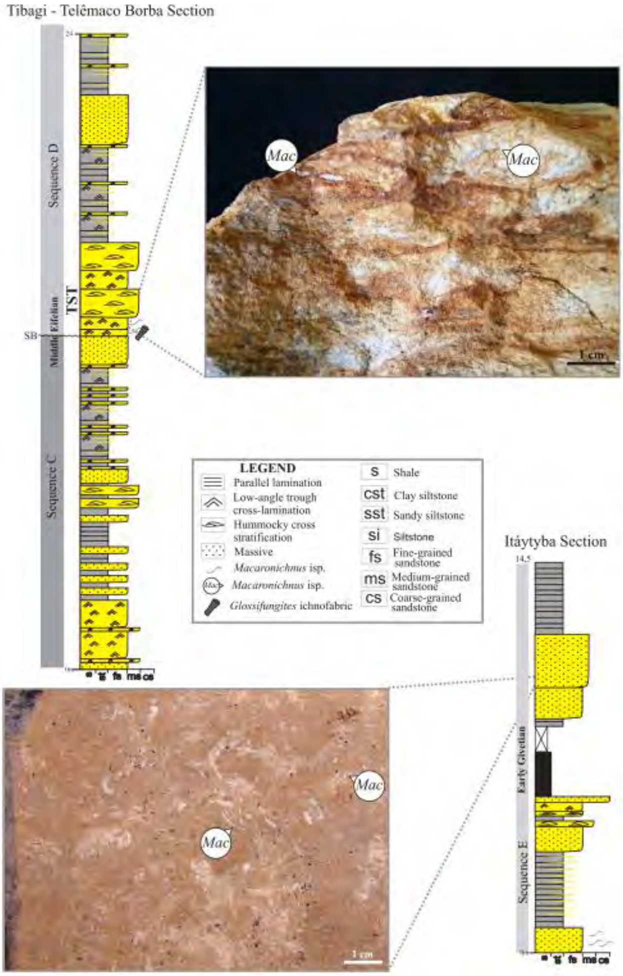

Fig.2. Schematic profile of Late Efeilian (sequence C) and Early Givetian (sequence D) sequences from the Paraná Supersequence (Paraná Basin) with *Macaronichnus* ichnofabric distribution as observed in Tibagi-Telêmaco Borba and Itáytyba sections (Paraná State, S Brazil).

Avian wing loading, aspect ratio, area and span are related to tracks

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Keywords: track morhpology, wing loading,aspect ratio, multiple regression analysis,habitat type

Avian wings designed for flying may be related to tracks made by walking, another form of locomotion. Modern avian wing area and span and bodyweight data were collected and analysed to examine how the wings might be related to tracks. A discriminant analysis showed that avian wings can be divided into three groups, similar to tracks, which are divided morphologically into three groups corresponding to habitat type. Multiple regression analyses revealed that the avian wing loading and aspect ratio were closely correlated to the parameters of track shape, expressed by a simple equation. These results may reflect the adaptation of avian locomotion to habitat. The regression analyses revealed that wing area and span were related to track area. The relationship provides a method for estimating the wing area and wingspan from the fossil track area. Using this method, the wingspan and area were estimated from three tracks of extinct Cretaceous avian taxa. The estimated values suggest that *Archaeornithipus meijidei*, *Hwangsanipes choughi* and *Yacoraitichnus avis* had bodies similar to herons (or grus), large sandpipers (or small sea birds) and medium-sized gulls, respectively. The ecology of avian flight based on aerodynamics suggests that birds are divided by their wing aspect ratio into the two groups of “transport aircraft” and “fighter aircraft”. The former includes sea birds and wading birds. The latter includes song birds, birds of prey and pheasants.

Sequestrichnia – a new ethological category of trace fossils in oligotrophic deep-sea environments

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Keywords: behavior, nutritional strategy, cache, seasonality, deep sea

Nutrition strategies of deep-sea burrowers can be deciphered from the morphology, filling and tiering position of the resultant trace fossils. In Cretaceous-Palaeogene beds composed of organic-poor turbiditic marls covered by organic-rich "background" mud some trace fossils occur in middle- to deep-tier position, but they were actively filled by the material from above, for instance *Zoophycos*, *Phymatoderma*, *Cladichnus*, *Polykampton* or "*Ophiomorpha*" *recta*. Their filling can be arranged in pellets, spreites, meniscae or their mixture. The active introduction of mud to deeper tiers can be explained by a distinct feeding strategy: Ingest nutritional mud at the surface, especially after fresh arrival, deposit it at depth beyond the range of shallowly burrowing sediment-feeders and within oxygen-deficient host sediment, and feed on such sequestered material during starvation times. Thus, the burrow fill represents a nutritional cache (similarly to the *Zoophycos* model of Bromley, 1991), which can be exploited indirectly, probably by solutions and ectoenzymes, or directly by repeated reworking. Microbial activity within the filling is likely, but not easy to prove. This feeding strategy is a good response to seasonal oligotrophy in the deep-sea floor, where nutritional quality of freshly-deposited mud deteriorates quickly by oxygenation and microbial decomposition. Modern examples from South China Sea point to an intensive use of seasonally supplied organic-rich sediments as a food source sequestered in burrows. Trace fossils referred to the described way of feeding can be distinguished as the sequestrichnia – a new ethological category.

Zoophycos macroevolution since 541 Mas and its ichnotaxonomy

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Keywords: Zoophycos, macroevolution, morphology, *Spirophyton*

Zoophycos is one of the most complex and enigmatic trace fossils recorded in marine strata from Cambrian to Quaternary worldwide, which is invaluable for the study of Phanerozoic development of organism–environment interactions. The genus *Zoophycos* is here systematically revised based on the systematic research of the literatures with detailed description and plates, from 1855 to 2015. The ichnogenus *Zoophycos* is revised into 9 ichnospecies: they include *Zoophycos cauda-galli* (Vanuxem, 1842), *Zoophycos curtain* (Vanuxem, 1842), *Zoophycos velum* (Vanuxem, 1842), *Zoophycos brianteus* Massalongo, 1855, *Zoophycos villae* Massalongo, 1855, *Zoophycos liasinus* (Fischer-Ooster, 1858), *Zoophycos flabelliformis* (Fischer-Ooster, 1858), *Zoophycos insignis* (Squinabol, 1890), *Zoophycos rhodensis* Bromley and Hanken, 2003. The ichnogenus *Spirophyton* is composed of *Spirophyton typum* Hall, 1863 and *Spirophyton eifeliense* Kayser, 1872. The *Zoophycos* and *Spirophyton* are grouped into *Zoophycos* Group.

Here we address and demonstrate the macroevolution of Phanerozoic *Zoophycos* by assembling 448 points in constructing the Phanerozoic *Zoophycos* database based on 291 papers from 1821 to 2015 and 180 specimens from Cambrian to Palaeogene. The comprehensive dataset reveals, for the first time, five peaks and six depressions in Phanerozoic *Zoophycos* occurrence frequency. Secondly, the palaeogeographical distribution of *Zoophycos* is closely associated with the supercontinent Pangaea shifting. Our data also attest that the bathymetrical shift of *Zoophycos* from the littoral–neritic to bathyal environments is synchronized with the tiering shift from shallow to deeper. By detailed comparison with body fossils, geochemical and palaeogeographical records, we conclude that the macroevolution of Phanerozoic *Zoophycos* is multi-affected by the global biodiversity expansion, benthic nutrient enhancement, and the biotic macroevolution of the *Zoophycos*-producers. The macroevolution of development evidenced by the morphological changes of *Zoophycos* and other trace fossils, may have great implications on the behavioural and physiological adaptation of ancient animals to the environments.

References

Olivero, D. “Early Jurassic to Late Cretaceous evolution of Zoophycos in the French Subalpine Basin (southeastern France)”. Palaeogeogr. Palaeoclimatol. Palaeoecol. 192, 59–78 (2003).

Löwemark, L. & Schäfer, P. “Ethological implications from a detailed X–ray radiograph and 14C study of the modern deep–sea Zoophycos”. Palaeogeogr. Palaeoclimatol. Palaeoecol. 192, 101–121 (2003).

Knaust, D. “The oldest Mesozoic nearshore Zoophycos: evidence from the German Triassic”. Lethaia 37, 297–306 (2004).

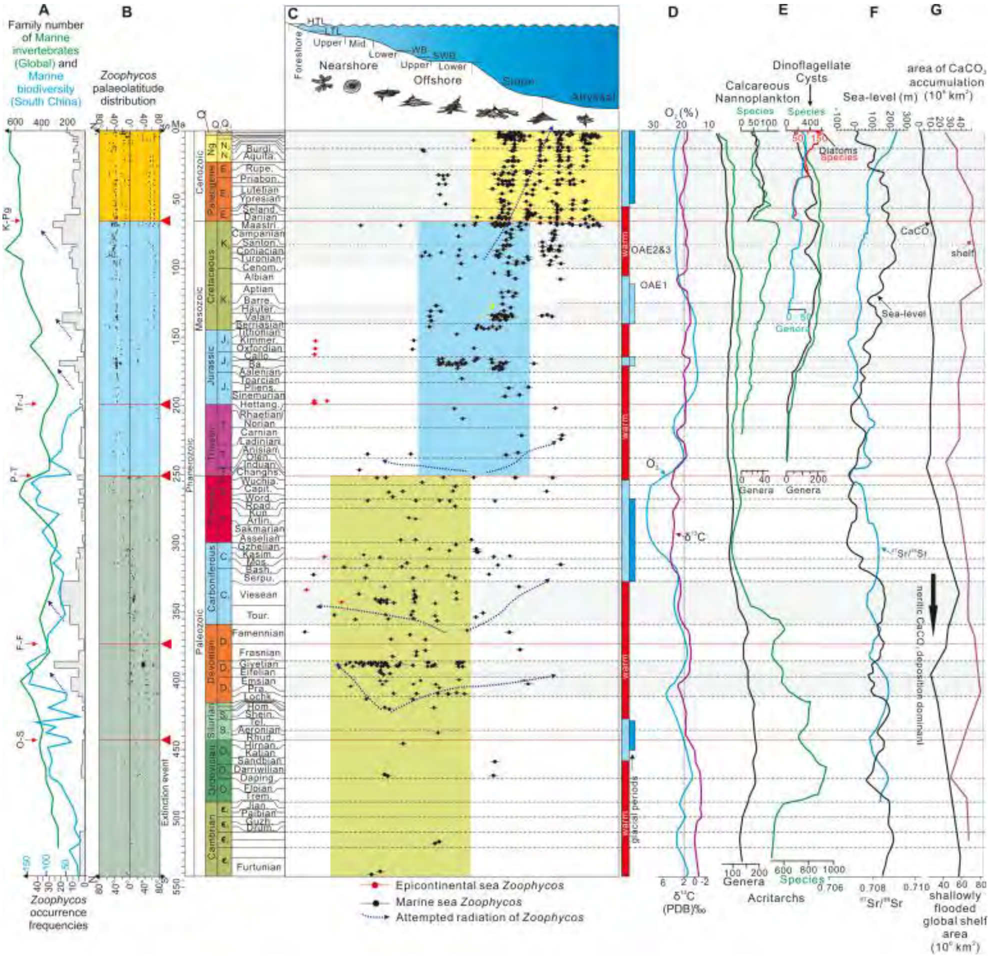

Fig. 1. Spatiotemporal distribution of Phanerozoic *Zoophycos* and its bio-environmental background. (a), Curves of global family number of marine invertebrates and marine biodiversity from South China. (b), Palaeolatitudinal distribution of *Zoophycos*. (c), Bathymetrical distribution of *Zoophycos*, the *Zoophycos* sketches redrawn from previous studies1,2,3, the green, blue, yellow column represent the main *Zoophycos* distribution areas in the Palaeozoic, Mesozoic and Cenozoic, respectively. (d), Column recording climate changes and glacial periods, curves for atmospheric oxygen7 and δ13C. (e), Acritarchs, calcareous nanoplankton (genera, species), dinoflagellate cysts (genera, species) , and diatoms (genera, species) diversity curves. (f), Curves of sea-level changes and 87Sr/86Sr ratios. (g), Curves of areas of $_3$ accumulation and shallowly flooded global shelf area. Abbreviation: HTL = high-tide line, LTL = low-tide line, WB = wave base, and SWB = storm wave base. The grayish sections in the figure represent the five peaks of Phanerozoic *Zoophycos*.

A peculiar reworking of *Ophiomorpha* shafts in the Miocene Nangan Formation, Taiwan

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Keywords: Miocene, Ophiomorpha nodosa, shoreface, offshore, Taiwan.

Abundant trace fossils are preserved in the Miocene sandstones of the Nangan Formation in the northeast coast of Taiwan. The depositional setting of this unit is interpreted as a wave-dominated shallow marine environment. In particular, upper offshore to lower shoreface deposits have been identified in the Fanziao section. The lower shoreface comprises both fair-weather and storm-related trace-fossil suites. A peculiar reworking of vertical *Ophiomorpha* shafts was observed (Löwemark et al., 2015). The reworking consists of an inner, lined tube positioned in the center of the shaft. Both outer and inner tube walls were constructed by small sub-pellet, indicating a crustacean origin, instead of commensal organisms such as worms. Interestingly, abundance of these shafts and the distinct difference of sub-pellet size of walls between shafts and *Ophiomorpha nodosa* mazes found in the same beds suggest the specific purpose of constructing these shafts. In addition, the similarities in sub-pellets indicate that they likely were constructed by different generations of the same crustacean species. Due to the absence of brooding chambers, we suggest that the vertical shafts were constructed to encourage juvenile shrimp to resettle in the parental burrows after they had completed their pelagic larval stages.

References

Löwemark, Ludvig, Yu-Chen Zheng, Subarna Das, Chung-Ping Yeh, and Tzu-Tung Chen. "A Peculiar Reworking of Ophiomorpha Shafts in the Miocene Nangang Formation, Taiwan." Geodinamica Acta 28.1-2 (2015): 71-85. Web.

Figure 1. Photos of *Ophiomorpha* shafts with their inner tubes from different points of view.

Crustacean burrows (*Ophiomorpha irregulaire*, *Gyrolithes* isp.) with pellets covered by plant debris (Lajas Formation, Neuquén Basin, Argentina; Jurassic: Bajocian-Bathonian).

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Keywords: Crustacean burrows, Ophiomorpha, Gyrolithes, Delta, Jurassic

Well-preserved crustacean burrows (*Ophiomorpha irregulaire, Gyrolithes* isp.) lined by pellets with plant debris are reported from the Lajas Formation (Bajocian-Bathonian, Middle Jurassic, Neuquén Basin, Southwest Argentina) (Boyd, *et al*., 2012). This formation is attributed to a deltaic environment (Canale *et al*., 2015) and it constitutes an important gas reservoir (Giusiano, *et al*, 2011).

The studied crustacean burrows have been recognized in outcrops and core (YPF.Nq.Laj.a-8), being associated with poorly preserved *Dactyloidites ottoi* and *Skolithos* isp.

This ichnoassociation is characterized by high bioturbation degree (BI 4-5) and developed on deltaic bars on a delta front, in middle to distal shoreface situation

Ophiomorpha irregulaire and *Gyrolithes* isp. are lined by pellets having a sand core covered by coalified vegetal debris. The burrows have a circular to ovoidal section, of small size (70-130 mm) Fig, 1, Fig. 2, and the pellets are ovoidal, sometimes exibiting difuse lining due to deformation of the plant debris Fig. 3

The producers are interpreted to have made an active search for the plant debris, probably for feeding and to mechanically reinforce burrows. In the low energy periods, fine grain sediments bearing phytodetrita deposit. The latter are deformed by pressure and associated with pyrite as a result of organic matter anaerobic decay. The phytodetrita that present the greatest degree of deformation are those with parenchymal tissue, while those with wooden tissues mantain a more recognizable structure.

References

Boyd, C., D. Mcilroy, L. G. Herringshaw, and M. Leaman. "The Recognition of *Ophiomorpha irregulaire* on the Basis of Pellet Morphology: Restudy of Material from the Type Locality." Ichnos 19.4 (2012): 185-89. Web.

Canale, N., Ponce, J.J., Carmona, N.B., Drittanti, D., Olivera, D.E., Martïnez, M.A., and Bournoud, N.A. "Sedimentología E Icnología De Deltas Fluvio-dominados Afectados Por Descargas Hiperpícnicas De La Formación Lajas (Jurásico Medio), Cuenca Neuquina, Argentina." Andgeo Andean Geology 42.1 (2015). Web.

Giusiano, A., Mendiberri, H., and Carbone, O., “Introducción a los Recursos Hidrocarburíferos”, in Leanza, H.A., Arregui, C., Carbone, O., Danieli, J.C., and Vallés, J.M., eds., Geología y Recursos Naturales de la Provincia de Neuquén: XVIII Congreso Geológico Argentino, (2011): p. 639–644.

Fig. 1. *Ophiomorpha irregulaire* in outcrop, Arroyo Carreri

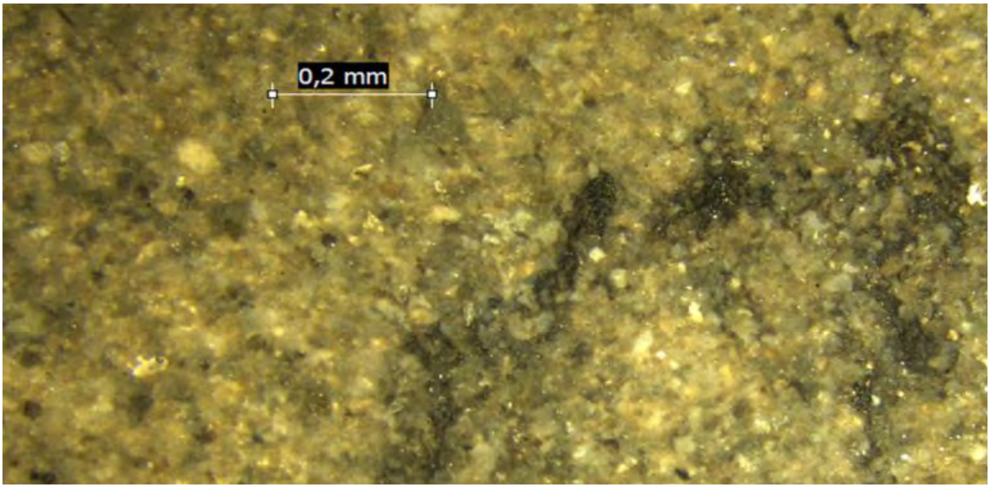

Fig. 2. *Ophiomorpha irregulaire* in core, (YPF.Nq.Laj.a-8)

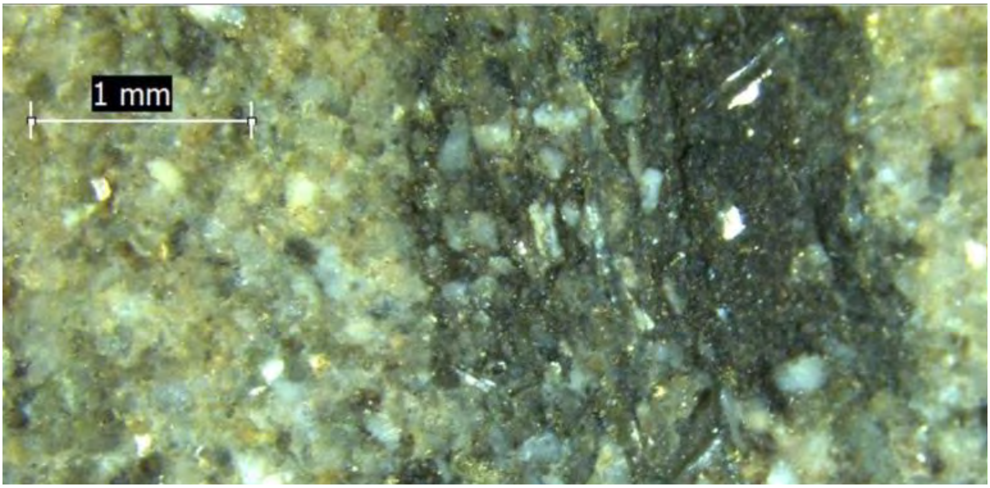

Fig. 3. Detail of a pellet from *Ophiomorpha irregulaire* in core, (YPF.Nq.Laj.a-8).

Amphipod and callianassid shrimp burrows in the Piedras Estuary (Lepe, Huelva, SW Spain)

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Keywords: Amphipoda, Callinassidae, Bioturbation, Neoichnology, Lepe

The estuary of the Piedras river, located in the coast of Lepe (Huelva, SW Spain), constitutes a lagoon bounded on its marine side by a 12 km-long spit (known as Flecha de Nueva Umbria or Flecha de El Rompido) that runs parallel to the coast and extends to the east due to littoral drift. Several neoichnological studies have been carried out during the last years (e.g. Belaústegui et al., 2015; Gibert et al., 2013; Muñiz et al., 2015).

In particular, the burrowing activity of three species of crustaceans has been studied: a) *Talitrus saltator* (Amphipoda: Talitridae); b) *Corophium volutator* (Amphipoda: Corophiidae); and c) *Pestarella thyrrena* (Decapoda: Callianassidae). Neoichnological studies were carried out along the supra- and intertidal zones (mean tide range around 2 m) of this estuary, both in the salt marshes (secondary and tertiary channels) as in the main channel (inner part of the spit); either by direct observation in the field, simple excavation and/or resin casting.

Burrowing activity of the sand hopper *T. saltator* is restricted to the supratidal sandy areas of the main channel, and consists of simple unlined shafts (diameter up to 50 mm; *Skolithos*-like). By contrast, *C. volutator* has only been observed in the muddy secondary and tertiary channels of the salt marshes, excavating simple U-shaped burrows (up to 3 mm in diameter and 50 mm depth; *Arenicolites*-like). Finally, *P. tyrrhena* burrows have been observed in both studied areas (salt marshes and main channel), distinguishing two main morphologies: a) vertical burrows with horizontal blind and rounded chambers and b) irregular U-shaped galleries (comparable to ichnogenera *Thalassinoides* and *Parmaichnus*); in both cases, with thin vertical shafts (exhalant tubes).

References

Belaústegui, Zain, Fernando Muñiz, Rosa Domènech, and Jordi Martinell. " Ichnology of the Lepe Area (Huelva, SW Spain): Comparison between Modern and Fossil Ichnofabrics." Ed. Masakazu Nara. Abstract Book - 13th International Ichnofabric Workshop, Kochi, Japan, 2015. 48-49.

Gibert, Jordi M. de, Fernando Muñiz, Zain Belaústegui, and Matúš Hyžný. "Fossil and modern fiddler crabs (Uca tangeri: Ocypodidae) and their burrows from SW Spain: ichnologic and biogeographic implications." Journal of Crustacean Biology 33 (2013): 537-551.

Muñiz, Fernando, Zain Belaústegui, Carolina Cárcamo, Rosa Domènech, and Jordi Martinell. "Cruziana- and Rusophycus-like Traces of Recent Sparidae Fish in the Estuary of the Piedras River (Lepe, Huelva, SW Spain)." Palaeogeography, Palaeoclimatology, Palaeoecology 439 (2015): 176-83.

Large mammal burrows in late Miocene calcareous paleosols from central Argentina

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Keywords: tetrapod burrow, Notoungulata, Xenarthra, body mass

Laminated burrow fills occurring in calcareous paleosols of the late Miocene Cerro Azul Formation of Argentina (Fig. 1) are described and interpreted. A total of 111 fossil burrows were studied from two localities: Salinas Grandes de Hidalgo and near Carhué (La Pampa and Buenos Aires provinces, respectively). The burrow fills are mostly composed of laminated claystone and siltstone that contrast with the structureless hosting siltstone or sandstone (Fig. 2). They exhibit a horizontal diameter ranging from 0.15 m to 1.50 m and a maximum preserved length of 8 m. Most burrow cross-sections are elliptical and the remaining are subcircular or plano-convex (Fig. 3). In plan view, burrow fills are slightly curved to sinusoidal and rarely U-shaped. Average angle of inclination is 8° (range= ≈0°-27°) and burrow openings were mainly facing west, similar to burrow orientation in extant armadillos. Frequency distribution of burrow horizontal diameter suggests a normal distribution with three subpopulations: 0.15-0.34 m (8%, body mass <10 kg), 0.39-0.98 m (84%, body mass=37-438 kg), and 1.05-1.50 m (8%, body mass=0.7-1.6 tons). Body mass was estimated using allometry (White, 2005). Although *Eosclerocalyptus* and other indeterminate Glyptodontidae (Xenarthra) are the most abundant fossil remains found within the burrow fills, Notoungulata (indeterminate Mesotheriinae and Hegetotheriidae: *Paedotherium*), and other Xenarthra (Dasypodidae: *Doellotatus* and Mylodontidae: *Proscelidodon*) were also recorded. These structures are the result of passive and episodic infilling of open burrows and were probably produced or reoccupied by *Paedotherium*, *Doellotatus* and *Lagostomus* (smaller burrows), and large Dasypodidae, Glyptodontidae, Mylodontidae and Mesotheriinae (larger burrows).

Reference

White, Craig R. "The Allometry of Burrow Geometry." J. Zoology 265.4 (2005): 395-403.

Fig. 1. Field view of laminated fill of fossil mammal burrow (arrowed).

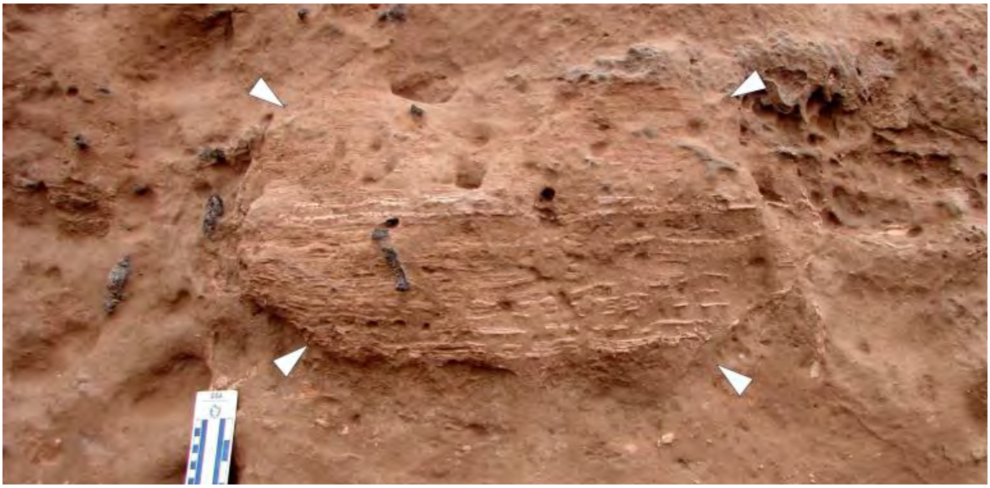

Fig. 2. Cross-section of mammal burrow fill showing laminated structure (arrowed). Scale= 10 cm.

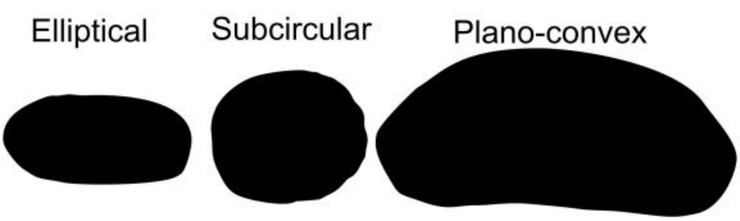

Fig. 3. Silhouette of representative cross-sections of mammal burrows.

The early evolution of trace fossils and bioturbation in the Villuercas-Ibores-Jara UNESCO Global Geopark, Spain

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Keywords: Villuerca-Ibores-Jara UNESCO Global Geopark, trace fossils, Ediacaran, Cambrian, Ordovician

Trace fossils provide the earliest widely accepted evidence for bilaterian animals, from about 560 Ma onwards. The appearance of trails, burrows and other types of animal-sediment interactions (bioturbation) had far-reaching impact on sediment properties and benthic ecology and has been considered an early example of ecosystem engineering.

The Villuercas-Ibores-Jara UNESCO Global Geopark provides an unique opportunity to follow the rise and early diversification of infaunal activity, from the late Ediacaran to the Ordovician (ca. 550 to 470 Ma): (a) Late Ediacaran sedimentary rocks yield rare simple horizontal trace fossils in sandstone and mudstone in the lower and middle Ibor Group; they are superficial (a few millimetres into the sediment) and there is no real evidence for bioturbation, so they are difficult to differentiate from three-dimensionally preserved filamentous organism (e.g. vendotaenids). (b) In rocks of Cambrian age, (younger than ca 542 Ma) infaunal activity is more prominent, with more complex burrow systems, vertically orientated burrows and relatively large trace fossils, some more than one centimetre wide, which appear in sandstones overlying *Cloudina*-bearing carbonates of the Ibor Group, including *Treptichnus pedum*, a Cambrian index fossil. (c) In Ordovician rocks trace fossils often are visually striking objects and the disruption of depositional sedimentary structures can be extensive; *Skolithos*, *Cruziana* (*C. furcifera* and *C. goldfussi*) and *Daedalus* are common fossils in the Armorican Quartzite within the geopark.

Fig. 1. Trace fossils from the Villuercas-Ibores-Jara UNESCO Global Geopark. (A) Ediacaran trace fossils; simple horizontal irregularly meandering t burrows made near the sediment surface. (B) Cambrian trace fossils; base of sandstone bed with several different types of trace fossils, including burrows with simple or branching patterns. (C) Ordovician trace fossils; *Cruziana furcifera* on bed sole, most probably made by a trilobite but there remains uncertainties as to how exactly the trace was produced.

Crab burrows from the Oligocene of Kachchh, Gujarat, India

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Keywords: Thalassinoides, Crabs, Carpiliidae, India

The youngest among the Paleogene sequence of Kachchh basin, Gujarat, India, is the Maniyara Fort Formation. This formation is subdivided into four members viz., Basal, Lumpy Clay, Coral Limestone and Bermoti Member. The Coral Limestone Member is composed of hard limestone with frequent coral bioherms. Within the foraminiferal limestone long networks and mazes of large diameter *Thalassinoides horizontalis* and *T. suevicus* are present. A high energy open shelf environment is suggested for this member. Within these burrows are present well preserved body fossils of crabs belonging to the family Carpiliidae. Interestingly, reburrowing by small *Thalassinoides* and at places by *Palaeophycus* is also seen, indicating gap in sedimentation along with change in environment. Despite a cessation in sedimentation the unindurated burrow fills were colonised by the next generation of burrowing organisms. These facts are indicative of availability of nutrient material helping in the reestablishment of a burrowing fauna; though the organisms may have been other than Carpiliidae. Based on sedimentological and ichnological data, two events are suggested that led to entrapment of the producers of these burrows.

References

Vega, Francisco, and Sunil Bajpai. "Additions to *Palaeocarpilius rugifer* Stoliczka from the Oligocene of Kutch, Western India." Bulletin of the Mizunami Fossil Museum 36 (2010): 45–49. Print.

Biswas, S K. "Tertiary stratigraphy of Kachchh". Journal of Palaeontological Society of India. 37 (1992): 1-29. Print.

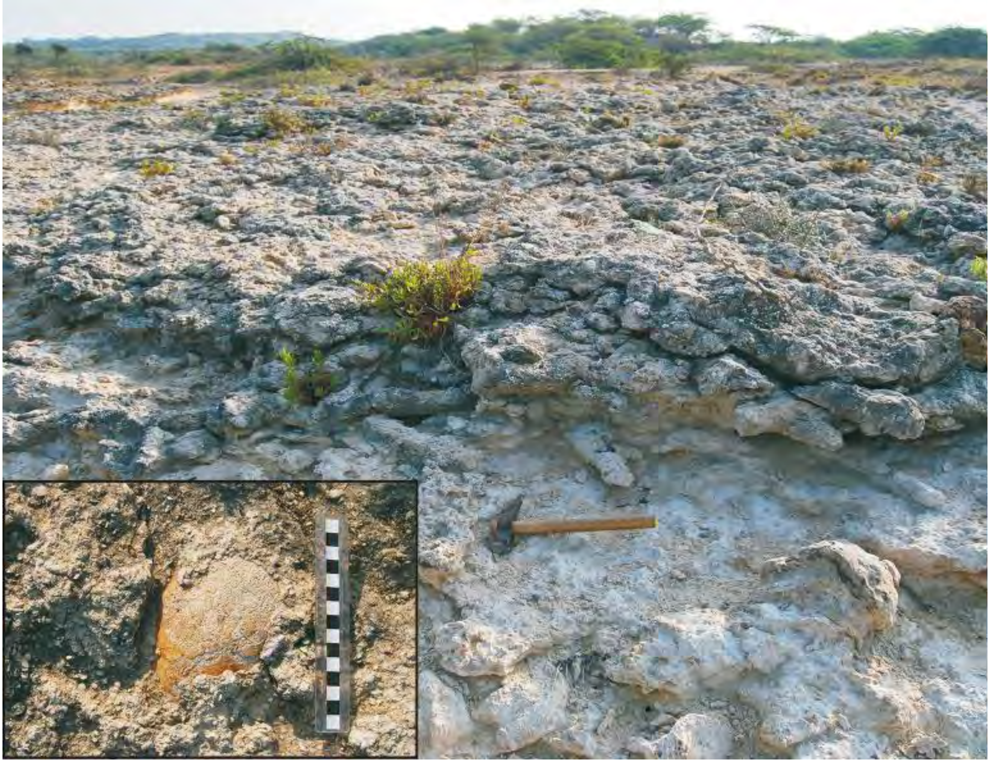

Fig. 1. Network of *Thalassinoides* within the Coral Limestone Member, Maniyara Fort Formation. Inset shows presence of crab within the burrow.

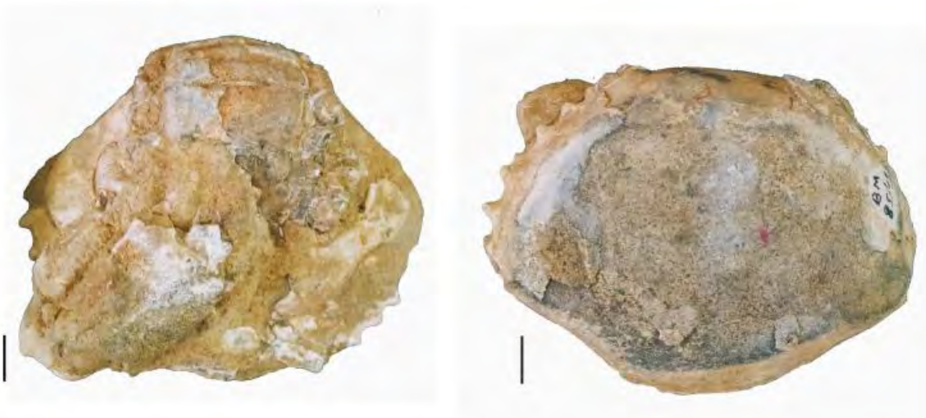

Fig. 2. Crab carapaces exhibiting excellent morphological characters.

Ichnological analysis of the Cretaceous-Paleogene boundary deposits in the Agost section, Spain

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Keywords: K-Pg boundary, trace fossils, Lilliput effect, Agost, Spain

The Agost section (Betic Cordillera, south-eastern Spain) is one of a few places worldwide with the complete sedimentary record across the Cretaceous-Palaeogene (K-Pg) boundary. It is composed of the uppermost Maastrichtian greenish grey marls intercalated with marly limestones, overlain by the lowermost Danian dark boundary clay, white marls and rose marly limestones; a 2 mm-thick rusty layer at the base of the boundary clay marks the K-Pg boundary. Below the boundary, beside the light–filled Maastrichtian trace fossils (Chondrites ?targionii, Planolites isp., Thalassinoides isp., Zoophycos isp.), the same but dark-coloured Early Danian ichnotaxa and dark coloured Chondrites affinis, Pilichnus isp., ?Teichichnus isp. occur. The Late Maastrichtian and Early Danian ichnotaxa are almost the same, supporting insignificant mortality of macrobenthic ichnofauna after the K-Pg event, similarly to other K-Pg sections (Rodríguez-Tovar and Uchman 2006, 2008; Monaco et al. 2015). However, significantly in the Agost section, Thalassinoides, ?Planolites and Chondrites from the lowermost Danian boundary clay (light and dark filled; colonization surface at least partly above the boundary clay) are distinctly smaller than in the underlying uppermost Maastrichtian sediments (the Lilliput effect). Initially, the mass mortality of plankton caused favourable nutritional conditions for their tracemaker, but after collapse of the primary production, the shortage of food resulted in environmental stress reflected in the dwarfism. Therefore, the reaction of ichnofauna to the K-Pg boundary event was delayed comparing to changes in other groups of organisms.

References

Monaco, P., Rodríguez-Tovar, F.J., Uchman, A., 2015. A delayed response of the trace fossil community at the Cretaceous-Paleogene boundary in the Bottaccione section, Gubbio, central Italy. Geobios 48, 137–145.

Rodríguez-Tovar, F.J., Uchman, A., 2006. Ichnological analysis of the Cretaceous–Palaeogene boundary interval at the Caravaca section, SE Spain. Palaeogeography, Palaeoclimatology, Palaeoecology 242, 313–325.

Rodríguez-Tovar, F.J., Uchman, A., 2008. Bioturbational disturbance of the Cretaceous– Palaeogene (K–Pg) boundary layer: implications for the interpretation of the K–Pg boundary impact event. Geobios 41, 661–667.

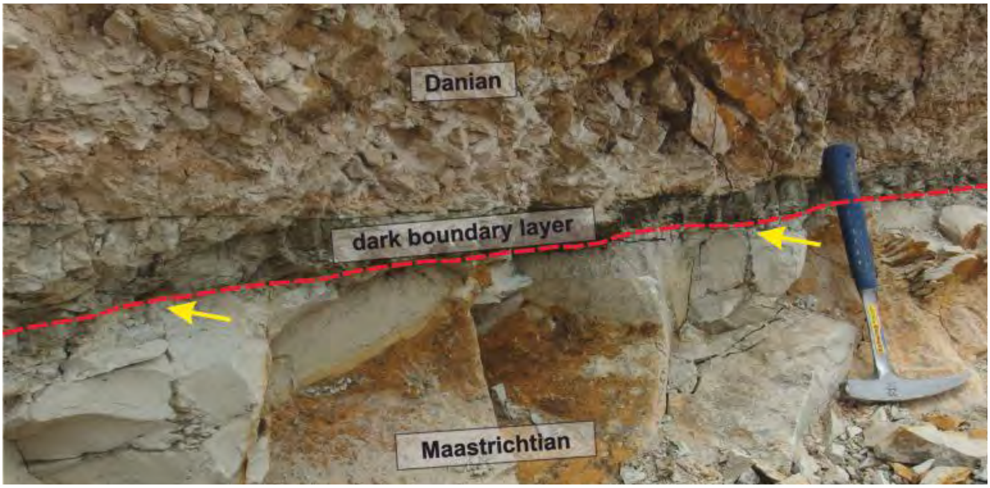

Fig. 1. The Cretaceous-Paleogene boundary section at Agost. Yellow arrows indicate Zoophycos ispp. from dark boundary clay layer disturbing the rusty layer and plunging in the uppermost Maastrichtian marly limestone. The dash line marks the K-Pg boundary. The hammer is 23 cm long.

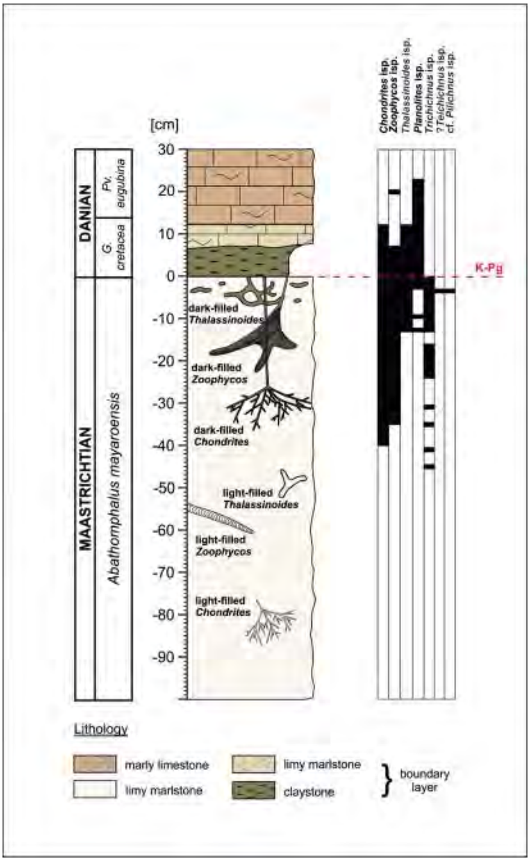

Fig. 2. Vertical distribution of trace fossils at the Agost K-Pg boundary section and their principle cross-cutting relationship.

Endemic bioturbation: distinctive Neogene eolian trace fossil assemblages dominated by large meniscate burrows from Patagonia, Argentina

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Keywords: tetrapod burrows, eolian dune, interdune, armadillo burrows, Santa Cruz Formation

Eolian trace fossil assemblages dominated by large meniscate burrows (ichnogenus *Nagtuichnus*) have been reported from late Miocene-early Pliocene damp and dry interdune deposits of coastal dunes and Holocene dry interdune sediments of a marginal lacustrine eolian system (Melchor et al. 2012). *Nagtuichnus* producer are fossil relatives of the extant pink fairy armadillo (Dasypodidae, Chlamyphorinae), which developed subterranean habits between 32 and 17 Ma. Here we present a further example from the eolian section of the middle Miocene (Langhian) Santa Cruz Formation near Comodoro Rivadavia, Chubut province. Logged sections are Pico Salamanca (45° 34.432′S, 67° 20.328′W) and Cañadón Ferrais (45° 38.994′ S, 67°39.296′ W). Both sections are interpreted as a dune field composed of transverse dunes with dry (sandflat) and wet (lacustrine and fluvial) interdune areas. The dominant trace fossil in dune and dry interdune deposits are *Nagtuichnus* isp. (Fig. 1), which occurs preferentially above and below the lower bounding surface of crossbeds (Fig. 2), with variable orientation. These are unbranched, cylindrical burrows with a uniform meniscate filling (average meniscus thickness= 13 mm, n= 23) that range in width from 44 to 82 mm. Diagnostic features of *Nagtuichnus* found in these burrows are a filling composed of a discontinuous, outer massive layer (Fig. 3) and a central meniscate core. Occurrence at the lower bounding surface of cross-strata suggests colonization of toesets of migrating dunes and underlying moister sediments. As chlamyphorines are restricted to southern South America, these examples can represent a case of Neogene endemism for the ichnogenus *Nagtuichnus*.

Reference

Melchor, Ricardo N., Jorge F. Genise, Aldo M. Umazano, and Mariella Superina. "Pink Fairy Armadillo Meniscate Burrows and Ichnofabrics from Miocene and Holocene Interdune Deposits of Argentina: Palaeoenvironmental and Palaeoecological Significance." Palaeogeography, Palaeoclimatology, Palaeoecology 350-352 (2012): 149-70.

Fig. 1. Horizontal *Nagtuichnus* isp. cutting wind-ripple cross-strata. Coin is 23 mm.

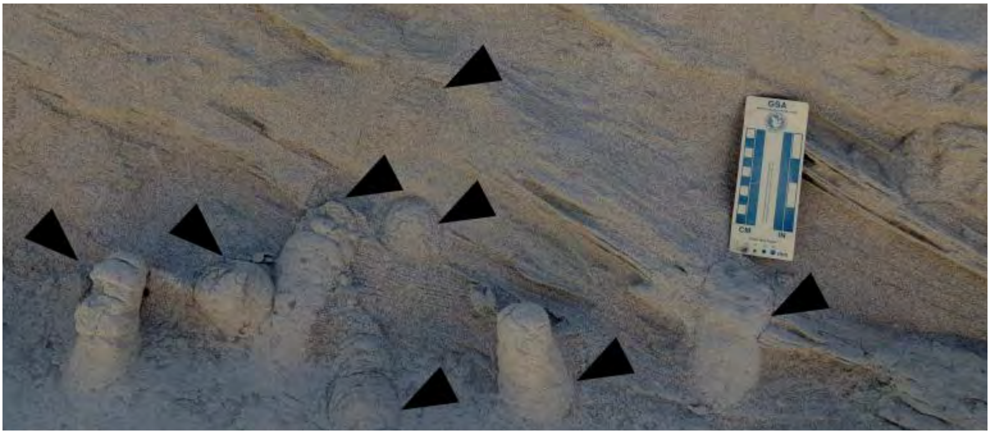

Fig. 2. Several *Nagtuichnus* isp. (arrowed) in the lower part of a tangential cross-bed. Scale= 100 mm.

Fig. 3. Specimen of *Nagtuichnus* isp. showing the marginal massive zone (white arrows). Scale= 100 mm.

Skin impressions on dinosaur footprints in the floodplain deposits of the Early Cretaceous Haman Formation, Korea: preservation and paleoenvironmental implications

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Keywords: dinosaur, skin impressions, Cretaceous, Haman Formation, paleoenvironment

The occurrences and features of skin impressions on dinosaur footprints from the Early Cretaceous Haman Formation (Albian), Korea, are described and their preservation and paleoenvironmental implications are interpreted. The skin imression-bearing deposits are unconfined flow deposits on a floodplain under semi-arid climate with alternating wet and dry periods, and various types of dinosaur tracks including sauropods, ornithopods, and theropods and webbed bird footprints occur in these deposits. Diverse types of skin impressions on dinosaur footprints are observed in these floodplain deposits, from impression on an entire heel pad about 30 cm in diameter of a sauropod footprint (Fig. 1) to partial impressions on footprints, and from distinctive polygons to diffuse polygons. The large distinctive impression on a sauropod footprint is preserved on mudstone film in interlaminated purple fine-grained sandstone to siltstone and mudstone, and partial diffuse impressions are preserved on purple shaly mudstone. Some of the impressions found around the large impression have diffuse polygons. The distinctiveness of impressions is usually decreasing toward margins of the footprints. In addition polygonal texture resembling skin impression on flat surface without footprint traces is also observed in these deposits.
The diverse occurrences of the skin impressions observed in this study can provide insight into why skin impressions on dinosaur footprints are very rare despite countless dinosaur tracks in the Mesozoic deposits. It is suggested that the preservation of skin impressions on dinosaur footprints can be used to understand specific paleoenvironmental conditions and paleobiology of dinosaurs.

Fig. 1. Cast of skin impression on the heel pad of a sauropod footprint preserved in the Cretaceous Haman Formation, Korea.

Beaver manuports in glacial landscapes

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Keywords: trace fossils, beaver, paleontology, paleoecology

Construction of tunnels and channels in stony sediments involves a transport of rock fragments. In moraine landscapes, these rock fragments can be from gravel to boulder size, the possibility of their displacement varying greatly for different groups of fossorials.
The surface of drained beaver ponds in moraine/postglacial landscapes is commonly covered with a scatter of rock fragments, mainly of a cobble size. The cobbles are often clustered along the active channels, but can also be found as sublinear alignments, presumably associated with the beaver channels that were abandoned and filled-in. The cobbles are bedded atop the organic sediments that were accumulated at the bottom of the beaver pond and are therefore displaced from their original bedding in the glacial till. Sections across the beaver channels showed that the rock fragments larger than 20cm were left in situ forming “shape imperfections” at the bottom and sides of the channels. Size distribution of displaced rock fragments shows a majority of fragments ranging from 7 to 18 cm, with a median at 12 to 15cm. The weight of the displaced cobbles varied from 0.2 to 3.5kg, indicating that the size, not the weight was a discriminating factor of the rock transport. The presence of both the lower and upper size limits reflects the differential manual transport of the fragments, unlike the unsorted mixtures pushed out from the terrestrial burrows by other mammals. In the latter case, the maximum size of fragments is defined by the diameter of a burrow, and is weight-sensitive.

Fig. 1. Rock scatter at the bottom of a drained beaver pond, Gatineau Park, Canada

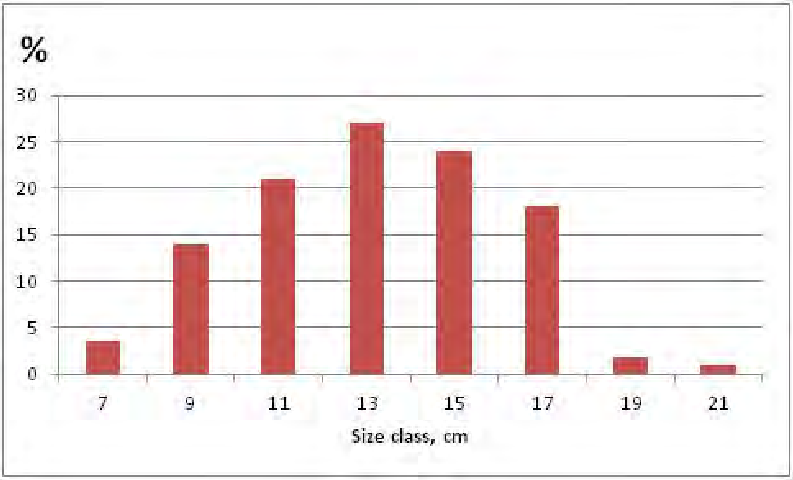

Fig. 2. Size distribution of beaver manuports.

Bird trackway crossing a slope: neoichnological analysis and morphological biases

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Keywords: neoichnology, photogrammetry, 3-D, slopes, biomechanics

Neoichnological studies are important for the understanding of different factors controlling the morphology and preservation of tetrapod footprints. Here we present the trackways of a small living bird, probably a plover-like taxon, recorded in the inner part of a river bank bordering the dried out portion of the Issene river in the Argana Basin (western High Atlas, Morocco). Main object is a longer trackway segment with seventeen successive pes imprints recorded perpendicular to the slope. Contour lines and colour map from a photogrammetric 3-D model show that the slope surface is wavy and that right and left tracks almost consistently lack digits IV and II impressions, respectively. Gait and substrate related parameters are reflecting changes that result from the summation between the 45° slope of the surface and the wavy topography underlying the trackway, perpendicular to the main slope.
From quantitative and qualitative data, three factors are recognized as main biases in the morphological preservation of the trackway: a) the wavy nature of the crossed slope surface affecting trackway parameters and depths registered in accordance to the change in topography; b) the presence of water level marks subparallel to the trackway mid-line suggesting that water activity was erasing both digit II of left tracks and digit IV of right tracks, being nearly aligned along the narrow gauge bird trackway; c) the different weight distribution when walking along the slope, with emphasis on the inner and outer digits, respectively.

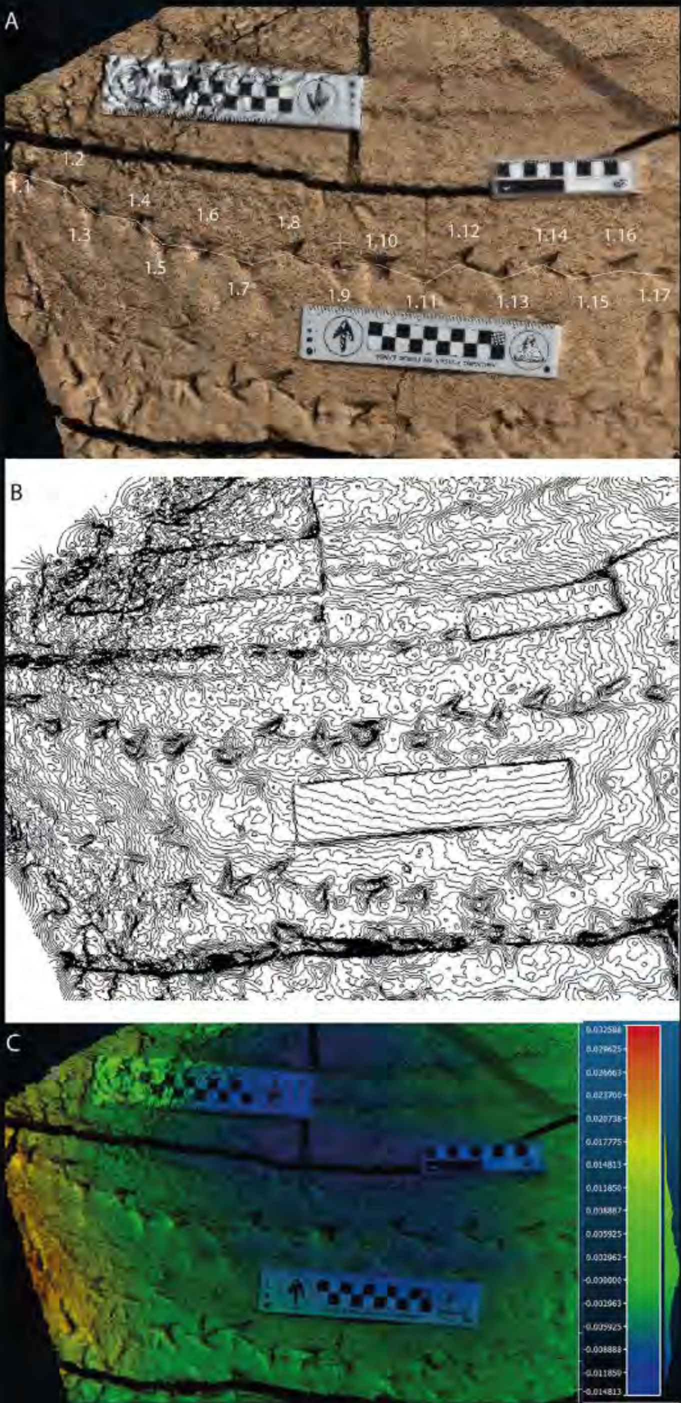

Fig. 1. Bird trackway from the Argana Basin in A) 3-D photogrammetry model in CloudCompare free software, with tracks numbered from 1.1 to 1.17 and water level marks above, B) Contour lines model in Paraview free software showing topography of sloping surface; C) Colour map in CloudCompare free software showing the gradient of sloping and wavy surface. Scale bars 18 cm.

First evidence of sauropod tracks in the Lower Cretaceous of the Algarve Basin (Portugal)

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Keywords: Sauropoda, tracks, Praia dos Arrifes, Albufeira, Portugal.

The Lower Cretaceous of the Algarve Basin (South Portugal) consists mainly of carbonate and mixed facies from inner shelf and transitional environments, sometimes with excellent conditions for the occurrence of dinosaur tracks. This is the case of the shoreline exposures located between Ponta da Baleeira and Praia dos Arrifes, near Albufeira, where cliffs are cut in vertical sandstone, claystone, marl and limestone beds of Valanginian age (Manuppella, 1992). The high potential of this area to find palaeontological evidences was revealed during fieldwork in Praia dos Arrifes, when several dinosaur tracks preserved as natural casts were found.

On the lower surface of a sandstone bed, at least two sauropod trackways and tridactyl footprints were recognized. They became exposed due to erosion of the underneath greyish mudstone layer that left a space between levels. These tracks were produced when the dinosaurs crossed sandy and chalky sediments highly bioturbated, and sunk in the underneath muddy layer. They testify the existence of sauropods and biped dinosaurs, possibly theropods, living near a shallow and restricted inner shelf palaeoenvironment of a littoral plain.

Previously, Early Cretaceous dinosaur tracksites in the Algarve Basin were recognized only near Vila do Bispo, 17 km to the west of Lagos, where iguanodontian footprints were described for the first time in Portugal, showing that this group was well-represented in the Iberian Peninsula and Southwestern Europe (Santos *et al*., 2000, 2013). This new tracksite yields the first evidence of Early Cretaceous sauropods in the Algarve Basin and the ongoing study will provide more information to increase the palaeobiogeographical data available for this group in the Iberian Peninsula.

References

Manuppella, G. 1992. Mesozóico. *In*: Oliveira, J.T. (Coord.), Notícia Explicativa da folha 8, Carta Geológica de Portugal 1/200000. *Serviços Geológicos de Portugal (Lisboa)*: pp. 51-63.

Santos, V.F., Callapez, P.M., and Rodrigues, N.P.C. 2013. Dinosaur Footprints from the Lower Cretaceous of the Algarve Basin (Portugal): New Data on the Ornithopod Palaeoecology and Palaeobiogeography of the Iberian Peninsula. *Cretaceous Research* 40: 158-69.

Santos, V.F., Dantas, P., Moratalla, J., Terrinha, P., Coke, C., Agostinho, M., and Galopim de Carvalho, A.M. 2000. Primeiros vestígios de dinossáurios na Orla Mesozóica Algarvia, Portugal. *In*: Diez, J.B. & Balbino, A.C. (Eds.), *Resumos do I Congresso Ibérico de Paleontologia e XVI Jornadas de la Sociedad Española de Paleontología*, *Universidade de Évora (Évora)*: pp. 20-21.

First report of elasmobranch foraging-resting activity on the Upper Miocene of S Spain (Guadalquivir basin)

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Keywords: Piscichnus, Feeding traces, Praedichnia, Upper Miocene, Spain.

In present marine environments traces left by the activity of foraging and/or resting marine rays are well known. In the fossil record these structures are known as *Piscichnus* (Fiebel, 1987), and only a few examples of stingray feeding pits have been described. The oldest are from the Late Cretaceous in Utah (EEUU, Howard et al., 1977), Antarctica (Scasso et al., 1991) and NE Spain (Martinell et al., 2001). In the Tertiary, *Piscichnus* is limited to the Western Pacific Miocene of New Zealand (Gregory, 1991), Japan (Kotake, 2007), and Taiwan (Löwermark, 2015), the Western Atlantic Pleistocene of Florida, Georgia and North Carolina (EEUU, Howard et al., 1977), and the Western Indian Plio-Pleistocene of Kenya (Fiebel, 1987). The Hornachuelos upper Miocene site, in South Spain, is one of these few localities where is possible to see the direct foraging activity by batoid elasmobranchs.
The study area is located in the place named Cortijo de Los Nublos (37º49'25.00''N; 5º12'15.00''W), at 3,5 km East of Hornachuelos (Cordoba) with a total area of 9,8 ha. The bioturbated substratum corresponds to a detritic-carbonated formation from the Upper Tortonian.
The aim of this study is to investigate in detail the trace fossil assemblage of Los Nublos and the spatial and sequential relationships of its components, in order to interpret the biotic interactions of the substratum biota recorded. For this, a total of 407 pits have been studied and measured (size, direction), together with all the trace fossils present.

References

Fiebel C.S. "Fossil Fish Nests from the Koobi Fora Formation (Plio-Pleistocene) of Northern Kenya." Journal of Paleontology 61 (1987): 130-34.

Gregory M.R. "New Trace Fossils from the Miocene of Northland, New Zealand, Rosschachichnus amoeba and Piscichnus waitemata." Ichnos 1 (1991): 195-206.

Howard J.D., Mayou T.V., and Heard R.W. "Biogenic Sedimentary Structures Formed by Rays." Journal of Sedimentary Petrology 47 (1977): 339-46.

Martinell J., Gibert J.M. de, Domènech R., Ekdale A.A., and Steen P.P. "Cretaceous Ray Traces?: An Alternative Interpretation for the Alleged Dinosaur Tracks of La Posa, Isona, NE Spain." Palaios 16 (2011): 409-16

Scasso R.A., Olivero E.B., and Buatois L.A. "Lithofacies, Biofacies and Ichnoassemblage Evolution of a Shallow Submarine Volcaniclastic Fan-shelf Depositional System (Upper Cretaceous, James Ross Island, Antarctica)." *Journal of South American Earth Sciences* 4 (1991): 239-60.

Kotake N. "*Macaronichnus* isp. associated with *Piscichnus waitemata* in the Miocene of Yonaguni-jima Island, Southwest Japan." *Trace Fossil: Concepts, Problems, Prospects*. Ed. Miller W. III. Amsterdam: Elsevier, 2007. 492-501.

Löwemark L. "Evidence for Targeted Elasmobranch Predation on Thalassinidean Shrimp in the Miocene Taliao Formation, NE Taiwan." *Lethaia* 48 (2015): 227-34.

Fig. 1. Plan view of *Pischichnus* isp.(black arrow) together with *Bichordites* isp. (white arrows) on Upper Tortonian limestone from Los Nublos (S Spain). Scale bar. 20 cm.

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Conceptual Tools and Methods

Ichnofacies: a network perspective

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Keywords: network theory, ichnofacies, complex systems

Several systems can be described as networks, that are sets of nodes and links. For instance, food webs consist of species connected by trophic interactions; social networks are made by people connected by relations; the World Wide Web is formed by webpages connected by hyperlinks. Similarly, ichnological systems can be conceived as sets of ichnotaxa connected by association relationships (Baucon and Felletti, 2013; Baucon et al. 2014). The goal of this study is to see the ichnofacies model in the network perspective.
The ichnofacies model synthesizes the environmental significance of traces, and, as such, it has been one of the most influential concepts in ichnology since its introduction. The ichnofacies model was developed by Adolf Seilacher on the basis of empirical observation of several ichnoassociations (Buatois and Mángano, 2011; MacEachern et al., 2012; Seilacher, 1967). The observations on which the ichnofacies model is based have been recorded as a table that describes the ichnofaunal composition of several ichnosites (Seilacher, 1978, p. 176). The table has been recently presented in Seilacher (2007), pag. 205, and is herein referred to as 'ichnofacies table'.
The ichnofacies table can be modelled as a network by representing ichnotaxa as nodes, and association relationships as links. In other words, the rule for translating the ichnofacies table into an ichnonetwork is 'connect with a link those ichnotaxa that co-occur in the same ichnosite'.
The resulting network (Fig. 1) is characterized by two cohesive subgroups that correspond to the typical ichnotaxa of the Nereites and the Cruziana ichnofacies. These subgroups are connected by nodes with high betweenness, that is, nodes that is a topological metric that measures how nodes are embedded within the whole system. High betweenness nodes are topological bridges between different structural areas of the network. Intriguingly, high betweenness nodes corresponds to those ichnotaxa that are characteristically described as 'facies-crossing ichnogenera' in the ichnofacies model.

References

Baucon, A., Felletti, F., 2013. The IchnoGIS method: Network science and geostatistics in ichnology. Theory and application (Grado lagoon, Italy). Palaeogeogr. Palaeoclimatol. Palaeoecol. 375, 83–111. doi:10.1016/j.palaeo.2013.02.016

Baucon, A., Ronchi, A., Felletti, F., Neto de Carvalho, C., 2014. Evolution of Crustaceans at the edge of the end-Permian crisis: ichnonetwork analysis of the fluvial succession of Nurra (Permian-Triassic, Sardinia, Italy). Palaeogeogr. Palaeoclimatol. Palaeoecol. 410, 74–103.

Buatois, L.A., Mángano, M.G., 2011. Ichnology: Organism-Substrate Interactions in Space and Time. Cambridge University Press, Cambridge / New York.

MacEachern, J.A., Bann, K.L., Gingras, M.K., Zonneveld, J.-P., Dashtgard, S.E., Pemberton, S.G., 2012. The Ichnofacies Paradigm, in: Knaust, D., Bromley, R.G. (Eds.), Trace Fossils as Indicators of Sedimentary Environments. Developments in Sedimentology 64. Elsevier, Amsterdam, pp. 103–138.

Seilacher, A., 1967. Bathymetry of trace fossils. Mar. Geol. 5, 413–428.

Seilacher, A., 1978. Use of trace fossil assemblages for recognizing depositional environments, in: Basan, P.B. (Ed.), Trace Fossil Concepts - SEPM Short Course No. 5. pp. 167–181.

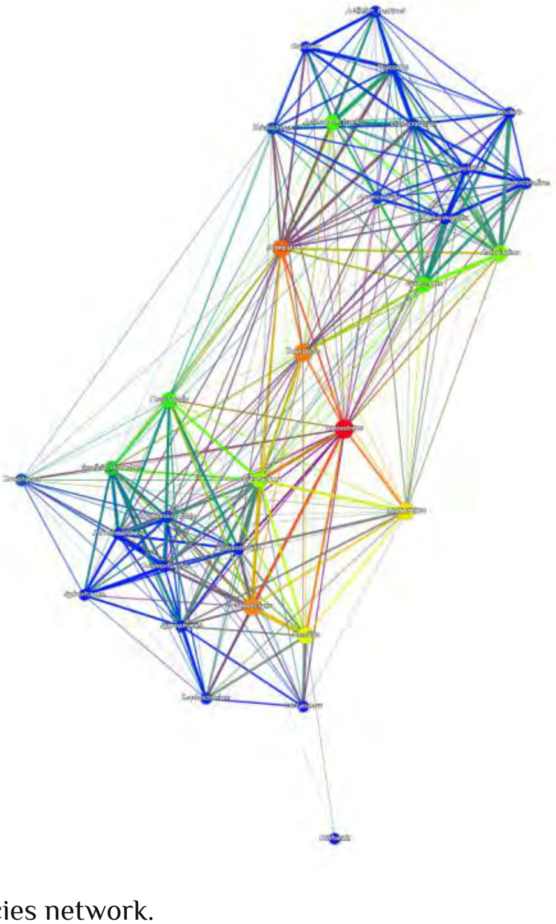

Fig. 1. Ichnofacies network.

The precision of outline drawings: a comparison based on dinosaur tracks

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Keywords: dinosaur tracks, outline drawings, accuracy, measurments, variance

Despite recent advances in various documentation technologies (Falkingham, 2012; Mallison and Wings, 2014), outline drawings are still the most common way of collecting and publishing dinosaur track data. They present undeniable advatages, but they are also highly affected by the subjectivity of the researcher, who cannot avoid introducing some personally- or evironmentally-driven interpretation while drawing.
But how precise is an outline drawing? How reliable are the information published? Are the data and measures affected by the style of the sketches? The only way to answer these question is having several researcher interpreting and drawing with the same tools the same footprint.
To allow this comparison a tridactyl footprint (DEIO CXXVIII/16, Belvedere, 2008) was digitized, scaled and 3D printed by Lasersintering with Polyamide 12 and a z-axis resolution of 0.1 mm. The footprint was then drawn, at the moment of submission, by 15 people with different backgrounds and experiences with ichnolgy on transparent Geha F01 polyester sheets with a black Stabilo OHPen, size S. The sheets were scanned and analyzed with image processing software to reliably measure the key features for each sample. Preliminary results indicate that variance between samples is not significantly greater than the variance in direct measurements of the footprint in the field. Increasing the number of samples and conducting the test on a number of different footprints will provide more significant results and that could be used to quantify the measurement precision when extracting information from old and newer publications based only on outline drawings.

References

Belvedere Matteo. “Ichnological researches on the Upper Jurassic dinosaur tracks in the Iouaridène area (Demnat, central High-Atlas, Morocco)”. PhD thesis, Università degli Studi di Padova, 2008. Print.

Falkingham, Peter L. "Acquisition of High Resolution Three-dimensional Models Using Free, Open-source, Photogrammetric Software." *Palaeontologia Electronica*. 15.1T (2012): 15p. Web. 9 Febraury 2016

Mallsion, Heinrich, and Oliver Wings. "Photogrammetry in Paleontology - a Practical Guide." *Journal of Palaeontological Techniques.* 12 (2014): 1-31. Web. 9 Febraury 2016

The Use of Burrow Orientation in Understanding Architecture, Ecology, and Evolutionary History

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Keywords: Thalassinoides, orientation, behaviour, GIS, Cretaceous

Burrow orientation research is a relatively young field with the initial investigation by Adolf Seilacher in 1961. Since then, improving techniques have increased the speed and accuracy of preferential burrow orientation determination. Thalassinoides isp. burrow orientation has been studied for the first time in the Mesozoic at the Joe Hanna Ranch (Lat: 31.328610°, Lon: -97.903645°) in the Glen Rose Formation (Lower Cretaceous; Glen Rose, Texas, United States of America), providing a model for future studies across ichnogenera. Orientation was found to have a mean directional axis of 337.87543° and 157.87543° with a circular standard deviation of 52.72148°. When combined with previous studies by Hohenegger & Pervesler (1985), Pervesler & Dworschak (1985), Dworschak & Pervesler (1988), and Pervesler & Hohenegger (2006) on extant tracemakers, this study demonstrates that preferential orientation existed since at least the Cretaceous. It is proposed that burrow orientation in marine organisms contribute to already utilized architectural classification tools by providing a complimentary dataset to bioturbation intensity figures, dimensional measurements, and geographic location. Additionally, burrow orientation may provide a useful means for gaging organism response to surface currents, changing trophic modes, and evolutionary adaptions for respiration efficiency. For this data to become more useful to an assortment of paleontological investigations, orientation data will need to be collected across time, ichnogenera, and depositional environments. The use of 3D imaging, GIS software (e.g. ArcGIS or QGIS), GIS add-ons such as Polar plots for ArcGIS and other statistical software such as PAST, makes this a practical tool for use in a variety of environments.

References

Dworschak, P.C., Pervesler, P. "Burrows of Callianassa bouvieri NOBILI 1904 from Safaga (Egypt, Red Sea) with some Remarks on the Biology of the Species." Senckenbergiana maritima 20 (1988): 1-17.

Hohenegger, J., Pervesler, P. "Orientation of Crustacean Burrows." Lethaia 18 (1985): 323-339

Pervesler, P., Dworschak, P.C. "Burrows of Jaxea nocturna NARDO in the Gulf of Trieste" Senckenbergiana maritima 17 (1985): 33-53.

Pervesler, P., Hohenegger, J. 2006 "Orientation of Crustacean Burrows in the Bay of Panzano (Gulf of Trieste, North Adriatic Sea)." Lethaia 39 (2006): 173-186.

Seilacher, Adolf. "Krebse Im Brandungssand." Natur Und Volk 91 (1961): 257-64.

Zoophycos as a productivity proxy in palaeoceanography – the 1.5 Myr long record at The West Iberian Margin as example

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Keywords: Zoophycos, deep-sea sediments, productivity, palaeoceanography, core research

Ichnology provides useful information about palaeoenvironmental conditions in the deep-sea. This has been increasingly demonstrated during the last decades when trace fossils have been used as ecological indicators of oxygenation or benthic food content among other factors (Wetzel and Uchman, 2012 for a recent review). In particular, when studying cores, *Zoophycos* is especially interesting because of its easy identification, even by non-ichnologists, as a helicoidal spreiten structure that appears as multiple chevron-patterned bands. The longest continuous record of *Zoophycos* spanning the last 1.5 Ma and covering 45 glacial-interglacial cycles has been analysed in a composite section drilled at the West Iberian Margin (site U1385) during the IODP Expedition 339. Detailed high-resolution image treatment (Rodríguez-Tovar and Dorador, 2015 and references therein) reveals that *Zoophycos* is not randomly distributed rather than its presence is associated to glacial-interglacial intervals ($\delta^{18}O$) and sedimentation rate (Fig. 1). In particular, its occurrence is mostly restricted to those terminal glacial events when primary production is high due to an increase in upwelling intensity in the study area and sedimentation rate exceeds 5cm/kyr. Other areas around the world show a similar relationship between seasonal organic-matter deposition and *Zoophycos* presence (e.g. Löwemark, 2015). Therefore, *Zoophycos* could be considered as a proxy of seasonally high primary productivity in Neogene hemipelagic deposits.

References

Löwemark, Ludvig. "Testing Ethological Hypotheses of the Trace Fossil Zoophycos Based on Quaternary Material from the Greenland and Norwegian Seas." *Palaeogeography, Palaeoclimatology, Palaeoecology* 425 (2015): 1-13. Print.

Rodríguez-Tovar, Francisco J., and Javier Dorador. “Ichnofabric characterization in cores: a method of digital image treatment.” *Annales Societatis Geologorum Poloniae* 85 (2015): 465-471. Print.

Wetzel, Andreas, and Alfred Uchman. "Hemipelagic and Pelagic Basin Plains." *Trace Fossils as Indicators of Sedimentary Environments*. Eds. Knaust, Dirk and Richard G. Bromley. Amsterdam: Elsevier, Developments in Sedimentology 64, 2012. 673-701. Print.

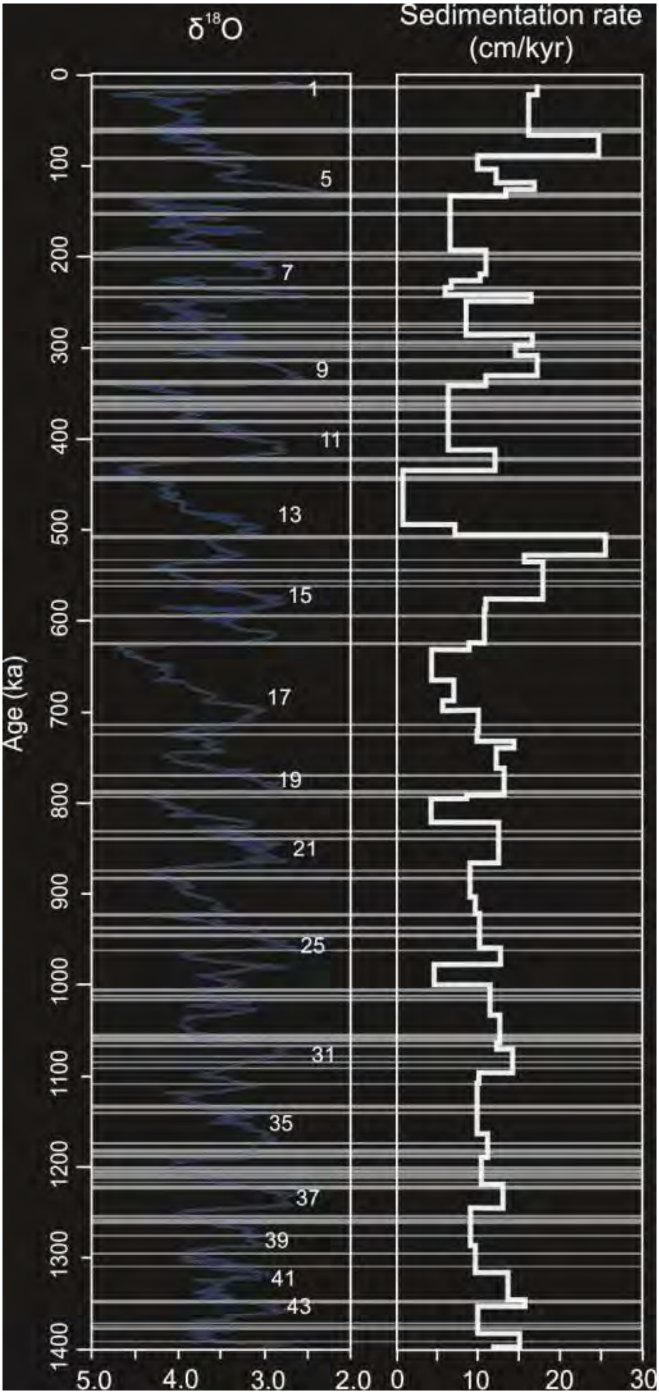

Fig. 1. *Zoophycos* distribution along the site U1385 record over glacial-interglacial cycles (δ18O) and sediment rate values. Horizontal grey lines represent intervals where *Zoophycos* are identified and numbers in δ18O curve correspond to the Marine Isotope Stages.

Bioturbation in supratidal carbonates: cutting-edge field technologies enhance neoichnological and zoogeomorphological research, San Salvador, Bahamas

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Keywords: georadar, drone, decapod, burrow, paleo-surface

Non-invasive techniques are increasingly complementing traditional field surveys (Buynevich, 2011; Kinlaw and Grasmueck, 2012; Buynevich et al., 2014), aimed at refining existing ichnofacies models, establishing diagnostic features for tracemaker identification, and quantifying mesoscale bioturbation. A case study in unconsolidated carbonates on San Salvador Island utilized high-frequency (800 MHz) georadar imaging to augment existing methodologies (casting, burrow counts, length, depth, diameter, inclination) in brachyuran bioturbation research (*Ocypode quadrata* and *Gecarcinus lateralis)*, and as part of a new dataset characterizing the large decapod (average length: 12 cm) *Cardisoma guanhumi* (Figure 1). Drone-mounted aerial coverage provided the first high-definition images of the mounded topography and large burrow openings of *Cardisoma* in organic supratidal muddy sands. Measurements of 20 burrows (minimum length, entrance diameter, and spoil mound size) were complemented by endoscopic camera observations (burrow fill, large bioglyphs, and occupants). Extensive 2D transects and quasi-3D georadar grids not only reveal characteristic subsurface interfaces (open vs. filled burrow, water table, saltwater) but also serve as an archive of bulk *in situ* sedimentary characteristics of the bioturbated substrate. Signal resolution in dry carbonate sand (~4 cm) was sufficient to differentiate tunnel/chamber floor from ceiling, allowing calculation of burrow diameters on post-processed (fill-corrected) radargrams. This approach can be extended into lithified substrates with the promise of recognizing similar biogenically altered paleo-landscapes. Co-located and geo-referenced aerial, ground-based, and geophysical databases allow rapid and effective assessment of the spatial distribution and elevation range of various biogenic and geomorphic features, with implications ranging from event ichnostratigraphy to prospective conservation studies.

References

Buynevich, I.V. "Buried tracks: ichnological applications of high- frequency georadar." Ichnos 18 (2011): 189-191.

Buynevich, I.V., Curran, H.A., Wiest, L.A., Bentley, A.P.K., Kadurin, S.V., Seminack, C.T., Savarese, M., Bustos, D., Glumac, B., Losev, I.A. "Near-surface imaging (GPR) of biogenic structures in siliciclastic, carbonate, and gypsum dunes." Experimental Approaches to Understanding Fossil Organisms: Lessons from the Living. Eds. Hembree, D.I., Platt, B.F., and Smith, J.J. The Netherlands: Springer, Dordrecht, 2014. 405-418.

Kinlaw, A.E. and Grasmueck, M. "Evidence for and geomorphological consequences of a reptilian ecosystem engineer: the burrowing cascade initiated by the gopher tortoise." Geomorphology 157 (2012): 108-121.

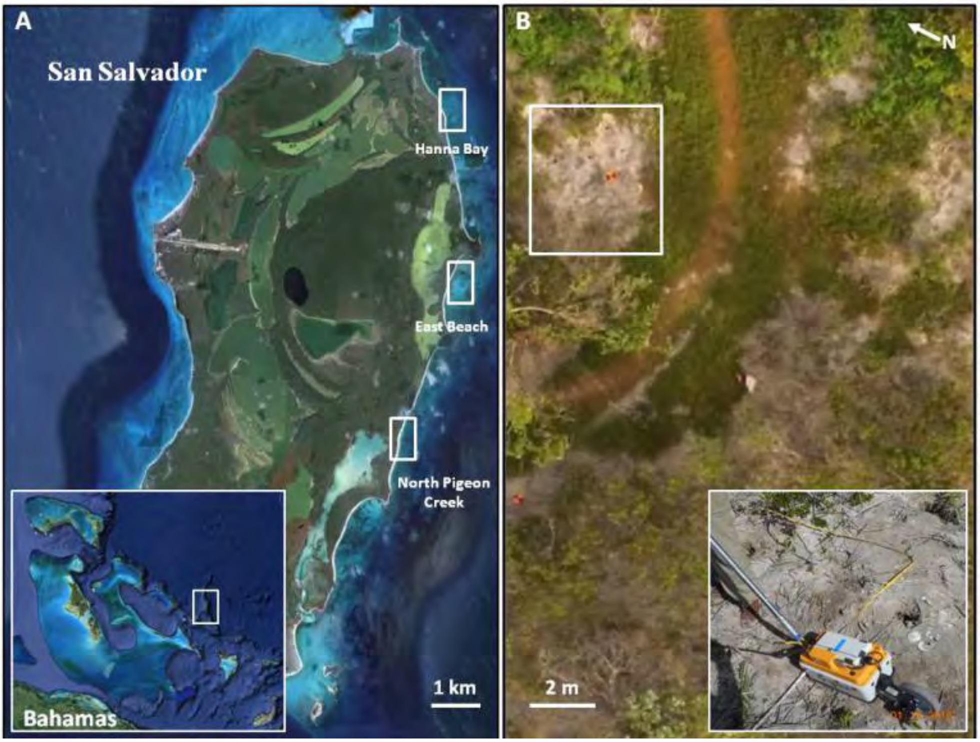

Figure 1. Drone images of three field sites (A) on San Salvador, Bahamas yielded high-resolution aerial images with visible burrows and topography (B), particularly of the densely spaced, large (>10 cm) entrances and spoil piles of Cardisoma guanhumi (B, upper left). A georadar survey (B, inset) of the outlined grid provided subsurface characterization of these burrow complexes.

Digital library of ichnofossils in the Karoo Supergroup, South Africa

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Keywords: Karoo, southern Africa, digital 3D models, statistical descriptions, deep learning algorithms, graphical user interfaces

The Karoo Supergroup in southern Africa boasts a stratigraphic record that: a) contains evidence for the end-Permian and end-Triassic mass extinction events, ~252 and ~200 Ma ago, respectively; and b) is rich in trace and osteological fossil assemblages. Ichnofossils are important in capturing the biotic changes associated with these events and can provide unique insights into the interactions among organisms and their sustaining ecosystems. To date, no consolidated South African ichnotaxa database exists, and thus the spatiotemporal distribution and abundance of the Karoo ichnites are unknown.

We are creating a Karoo ichno-database using primarily the digital re-appraisal of various museum collections in the country. Photogrammetry has been a sustainable technique, because it requires simple tools (camera) and skills (photography, basic computer literacy) that form part of the general ichnological and geological practice. Photogrammetry has been relatively efficient in the digital 3D modelling of larger trace fossils (e.g., vertebrate burrows; Fig. 1). However, smaller ichnofossils require more specialised photographic equipment such as macro lenses and photostacking rigs, making the technique less practical for producing digital 3D models. Laser scanning is effective for converting small ichnites into digital 3D models, however it requires specialised, less affordable equipment. We propose that, for small trackways and traces, the data collection should focus on capturing the variations in these highly repetitive structures with the aid of techniques that involve semi-automated, statistical descriptions. Our ultimate aim is to utilize the data in the ichnological applications of deep learning algorithms, especially those that are equipped with graphical user interfaces.

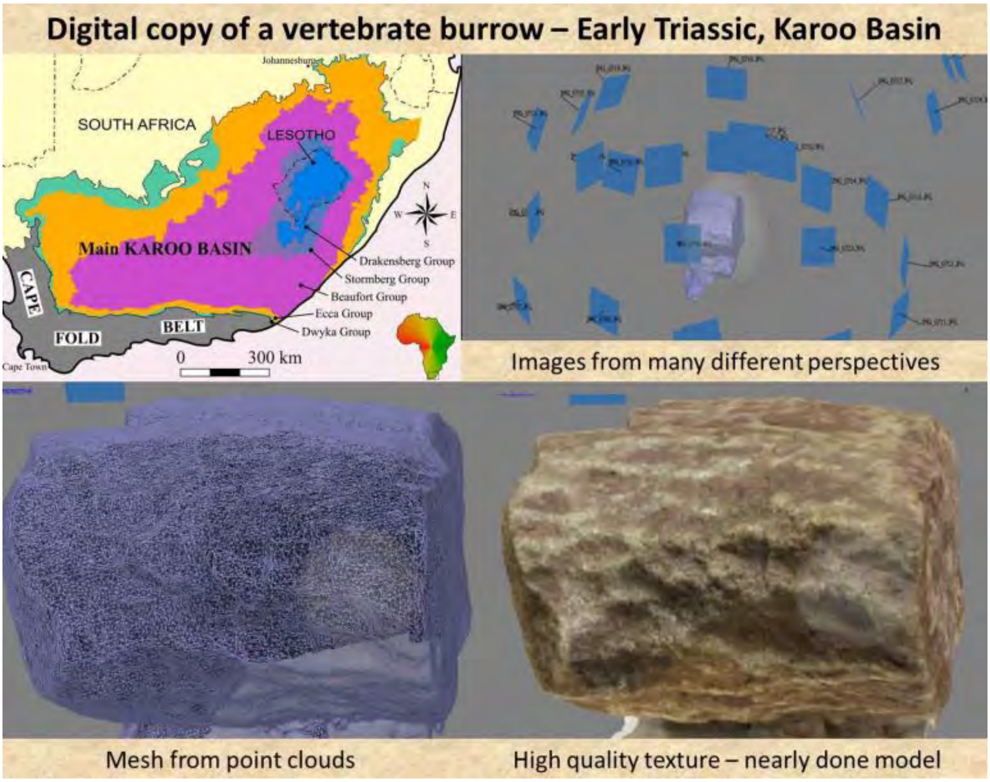

Fig. 1. Digital copy of a vertebrate burrow.

The Cambrian revolutions: timing, links and the ichnologic record

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Keywords: Cambrian, Agronomic Revolution, Cambrian Substrate Revolution, Cambrian Information Revolution, trace fossils

Several concepts pertaining to the dramatic changes that occurred during the Cambrian have been proposed, namely the Agronomic Revolution, the Cambrian Substrate Revolution and the Cambrian Information Revolution. The Agronomic Revolution refers to the replacement of matgrounds by mixgrounds based on an analogy with the development of agriculture and efficient plowing and its resulting effects upon soils. The Cambrian substrate revolution highlights the evolutionary and ecological effects of Cambrian substrate changes on benthic metazoans. Finally, the concept of the Cambrian Information Revolution refers to the distribution of environmental signals in an environment that an organism can potentially respond to, underscoring an increased complexity and heterogeneity of marine environments, which may have played a major role as a driving force of further evolutionary change during the Cambrian. A systematic review of the Ediacaran-Cambrian trace-fossil record allows to delineate a chronology of these evolutionary breakthroughs and to explore their potential links. The Agronomic revolution is not coincident with the Ediacaran-Cambrian boundary, but rather it clearly manifested in Cambrian Age 2. Because the Cambrian substrate revolution is an expression of the Agronomic revolution, both were essentially synchronic. In contrast, the Cambrian information revolution involved the appearance of sophisticated, innovative feeding strategies that allowed benthic organisms to exploit resources in an increasingly more heterogeneous sea bottom. The occurrence in the Fortunian of highly patterned grazing trails reflects the establishment of strophotactic, phobotactic and thigmotactic behavior indicative of efficient navigational devices.

Ichnogeny: an expansion to the conceptual framework of ichnology

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Keywords: Ichnology, Bioturbation, Bioerosion, new concept, Lepe

Ontogeny studies the origin and development of organisms by defining consecutive ontogenetic stages. Ontogenetic stages can be expressed in biogenic structures in three main ways: 1) unchanged general morphology (i.e. animal-sediment interactions are maintained during animal development, resulting in the production of the same trace fossil that only varies in size) (e.g. *Sinusichnus sinuosus*); 2) multiple, intergrading morphologies (compound trace fossils) recording different behaviors, commonly with different sizes (e.g. traces of a modern fly larvae; see Muñiz et al., 2014); or 3) involving specialized brooding structures (e.g. ichnogenus *Maiakarichnus*) that record the activities of the offsprings of the adult tracemaker responsible of the overall trace wherein such brood structure is included.

In the literature, a plethora of different terms, such as 'growth phases ', 'formative process', 'gradational stages of behavioral evolution', 'ontogenetic stages' and 'track ontogeny', have been proposed (e.g. Myint, 2001; Falkingham and Gatesy, 2014). However, confusion remains because morphological variability may not be exclusively related with ontogeny and careful analysis is advised. In order to unify terminology, the new concept 'Ichnogeny' is proposed herein based on exceptional material from the Miocene of Lepe, SW Spain. Ichnogeny refers to the origin and development of a modern or fossil trace (bioturbation and bioerosion), using closely related 'ichnogenetic stages' that record a continuum of morphologies through development of a boring or a burrowing structure.

References

Falkingham, Peter L., and Stephen M. Gatesy. "The birth of a dinosaur footprint: Subsurface 3D motion reconstruction and discrete element simulation reveal track ontogeny." Proceedings of the National Academy of Sciences, 111 (2014): 18279-18284.

Muñiz, Fernando, M. Gabriela Mángano, Luis A. Buatois, Virginija Podeniene, José A. Gámez-Vintaned, and Eduardo Mayoral. "Compound biogenic structures resulting from ontogenetic variation: An example from a modern dipteran." Spanish Journal of Palaeontology 29 (2014): 83-94.

Myint, Myo. "*Psilonichnus quietis* isp. nov. from the Eocene Iwaki formation, Shiramizu group, Joban coal field, Japan." Ichnos: An International Journal for Plant and Animal Traces 8 (2001): 1-14.

Radius of curvature analysis: A method for inferring forelimb proportions from fossil burrows

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Keywords: vertebrate burrows, tracemaker inference, radius of curvature, claw marks

Most commonly used features in fossil vertebrate burrow descriptions are not directly related to tracemaker morphology. The general form of vertebrate burrows reflects behaviour and ecology (colonial or solitary; subterranean or surface-dwelling; hibernating or not) that can be found in unrelated and morphologically distinct groups. Burrow diameter is not directly related to morphology but only gives an approximate size range. In contrast, bioglyphs (surface marking) are directly linked to the morphology of appendages and other body parts. In particular, claw marks represent trajectories of digging movements. Although trajectories themselves are often taxon-specific, they can be used to make only limited inferences about tracemaker morphology, because similarly oriented digging strokes can be produced by forelimbs with different proportions.

This study suggests a method for inferring the length of forelimb elements from one feature of claw marks, the radius of curvature and its variation. The forelimb can be represented as a kinematic chain with three or four links (Fig. 1). The trajectories produced by movements at each joint are arcs with the radius of curvature corresponding to the distance between the joint and the tip of the claw. The trajectory described by the claws during digging depends on the resistance of the substrate which, in turn, varies with the angle of attack (Fig. 2, 3). The variation of the radius of curvature within a single claw-mark reflects changing proportions between movements at several joints. A single burrow can contain hundreds of claw marks that represent a sufficient sample to make conclusions about forelimb proportions.

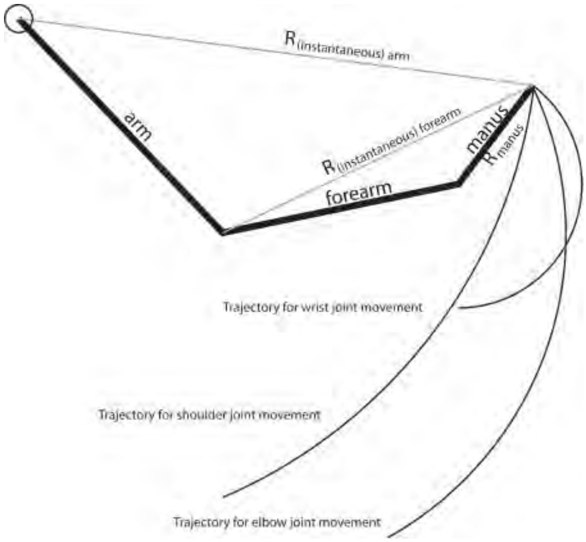

Figure 1. Kinematic chain.

Figure 2. Trajectory of the claws.

Figure 3.The trajectories produced by digging.

The ichnologic heritage of Robert W. Frey (1938-1992)

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Keywords: museum collections, ichnotaxonomy, history of science

Robert W. Frey's first ichnologic inspiration came while an undergraduate at the University of Montana, where reading Ager's books led him to notice trace fossils in local glaciolacustrine strata. His first ichnologic papers resulted from doctoral research at Indiana University on the Cretaceous Niobrara Chalk of Kansas. As his interest deepened, Frey worked with James D. Howard at the University of Georgia to study modern traces, establishing himself as a teacher, researcher, and editor of exceptional clarity. As the utility of ichnology in petroleum exploration became appreciated, Frey's reputation increased. His willingness to listen and teach made many international friends, particularly through the *Ichnology Newsletter,* SEPM Friends of Trace Fossils, *The Study of Trace Fossils,* and extensive correspondence. After Howard withdrew from teaching, Frey began a long and fruitful collaboration with George Pemberton.

Frey taught many students at Georgia, including the authors of this abstract. His teaching methods included the instilling of search images through an extensive slide collection. Students were shown animals and structures they might see during a weekend field trip, and in the evening were shown slides corresponding to what they had seen. Frey's writing similarly used reinforcement to convey ideas.

Though Frey preferred to photograph field specimens, he accumulated a large collection of trace fossils at the University of Georgia. With Sally Walker's help, the authors recently examined this collection and rediscovered unlabeled type specimens of *Cylindrichnus pustulosus* Frey & Bromley, 1985, *Ophiomorpha irregulaire* Frey, Howard & Pryor, 1978, and *Schaubcylindrichnus coronus* Frey & Howard, 1981.

References

Frey, Robert W., ed. The study of trace fossils: A synthesis of principles, problems, and procedures in ichnology. Springer Verlag, 1975.

Frey, R. W., and Bromley, R. G. "Ichnology of American chalks: The Selma Group (Upper Cretaceous), western Alabama." Canadian Journal of Earth Sciences 22(1985): 801-828.

Frey, R. W., and Howard, J. D. *Conichnus* and *Schaubcylindrichnus*: Redefined trace fossils from the Upper Cretaceous of the Western Interior. Journal of Paleontology, 55(1981): 800-804.

Frey, R. W., Howard, J. D., and Pryor, W. A. "*Ophiomorpha*: Its morphologic, taxonomic, and environmental significance." Palaeogeography, Palaeoclimatology, Palaeoecology 23 (1978): 199-229.

In a galaxy far, far away... traces? Astrobiological potential of ichnology

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Keywords: astrobiology, biosignatures, exobiology

Organism-substrate interactions and their products – individual traces and ichnofabrics – are important biosignatures on Earth as they represent direct evidence of biological behaviour.

Nevertheless, ichnology received relatively little attention as a tool for searching life beyond Earth, and iconic traces such as burrows, footprints and coprolites have widely been ignored in the field of astrobiology, with few exceptions (microbially induced sedimentary structures, microborings).

In the context of astrobiology, traces are characterized by the following characteristics:

1) Trace fossils preserve the activity of soft-bodied organisms;
2) Biogenic structures are resilient to processes that obliterate other biosignatures (e.g. mechanical and chemical degradation, diagenesis, tectonism, metamorphism);
3) Traces are very visible biosignatures;
4) Traces indicate environment and behaviour;
5) Traces are evidences of behaviour, therefore they can indicate life independently from morphology, size and biochemistry of tracemakers.

These properties make ichnology a promising tool for the search for present and past life beyond Earth.

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Ichnofacies Analysis with Digital-Image Treatment of a Miocene Carbonate Distally-Steepened Outer Ramp, Southeastern Florida Platform, USA

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Keywords: Trace fossils, ichnofacies, digital-image treatment, carbonate ramp, Florida Platform

Seismic-reflection and data from wells penetrating the southeastern Florida Platform indicate that the early-to-middle Miocene upper Arcadia Formation is comprised of three prograding, distally-steepened, heterozoan grain-dominated carbonate ramps (Cunningham, 2015), wherein the youngest ramp shows backstepping followed by progradation (Figs. 1 and 2). Each ramp is an individual depositional sequence (DS) that comprises of high-frequency cycles (HFCs). To understand the succession of depositional environments composing the individual HFCs it is important to identify the vertical ichnofacies succession of each. Identification of the ichnofacies is challenging because many of the trace fossils in slabbed core samples are poorly visible. Digital-image treatment of core jpeg images from a single HFC (Fig. 1) was used to improve trace-fossil visualization and ichnofacies characterization (Fig. 3). The treatment was conducted using image-editing computer software and the recent method successfully applied by Rodríguez-Tovar and Dorador (2015) to support the ichnofabric characterization of modern deep-sea cores. Particular modifications of several image adjustments, including brightness and vibrance levels, were incorporated into this first application on carbonate rock cores, and they improved trace-fossil visualization (Fig. 3). A fining-upward HFC, bound by marine erosional surfaces, and underlain by a *Glossifungites* Ichnofacies was delineated, spanning the upper part of a transgressive systems tract of DS Ar7 (Fig. 2). Within the HFC there is a shift upward from a distal expression of the *Cruziana* Ichnofacies to an archetypal *Cruziana* Ichnofacies (Seilacher, 1967), indicating an upward shift from relatively deep to shallower outer-ramp environments approximating the maximum flooding surface of DS Ar7 (Fig. 2).

References

Cunningham, K.J., 2015. Seismic-sequence stratigraphy and geologic structure of the Floridan aquifer system near "Boulder Zone" deep wells in Miami-Dade County, Florida. U.S. Geological Survey Scientific Investigations Report 2015-5013, 28 p. http://dx.doi.org/10.3133/sir20155013.

Rodríguez-Tovar, F.J., Dorador, J., 2015. Ichnofabric characterization in cores: a method of digital image treatment. Annales Societatis Geologorum Poloniae 85(4), 465-471.

Seilacher, A., 1967. Bathymetry of trace fossils. Marine Geology 5, 413-428.

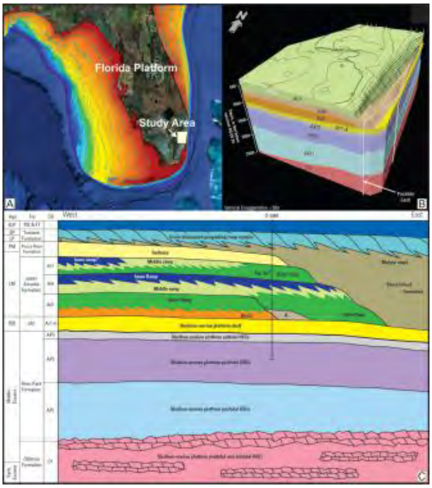

Figure 1. Eocene to Pleistocene lithostratigraphy and sequence stratigraphy of the study area and stratigraphic position of samples in Figs. 2 and 3. (A) Location of the study area on the Florida Platform. (B) Subsurface geomodel of the study area with focus on the three distally-steepened heterozoan grain-dominated carbonate ramps of the early-to-middle Miocene upper Arcadia Formation. (C) Conceptual west-to-east cross section across the study area with small black arrow pointing to location in depositional sequence Ar7, wherein core specimens were acquired for ichnofacies analysis and 'digital-image treatment' experimentation. Abbreviations: Depositional sequence (DS), lithostratigraphic formation (Fm), high-frequency cycles (HFCs), early Miocene to latest-early Oligocene (MO), late-early to middle Miocene (LM), late Pliocene to late Miocene (PM), late Pliocene (LP), early Pliocene (EP), early Pleistocene (EP), early to late Pleistocene (ELP), lower Arcadia Formation (lAF), Fort Thompson Formation (FT), Miami Limestone (ML), and grain-dominated ramp-margin slope apron (A).

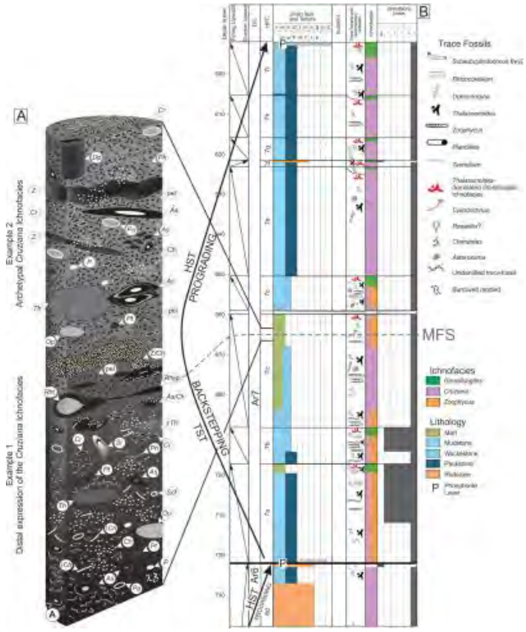

Figure 2. (A) Schematic split core model of trace suites typical of distal ramp marls. Example 1 is a distal expression of the *Cruziana* Ichnofacies. Example 2 is an archetypal *Cruziana* Ichnofacies. Trace fossil abbreviations: *Asterosoma* (As), *Chondrites* (Ch), longitudinal *Chondrites* (lCh), *Cosmorphaphe* (Cr), *Diplocraterion parallelum* (Dp), *Ophiomorpha* (Op), *Palaeophycus heberti* (Pa), *Palaeophycus tubularis* (Pt), peloids (pel), *Phycosiphon* (Ph), *Planolites* (P), *Rhizocorallium tube* (Rht), *Rhizocorallium spreiten* (Rhsp), *Schaubcylindrichnus freyii* (Scf), *Siphonichnus* (Si), *Thalassinoides* (Th), reworked *Thalassinoides* (rTh), *Zoophycos* (Z). (B) Sequence stratigraphy of the upper part of the upper Arcadia Formation. Abbreviations: transgressive systems tract (TST), highstand systems tract (HST), maximum flooding surface (MFS), depositional sequence (DS), depositional sequence Ar6 (Ar6), and depositional sequence Ar7 (Ar7).

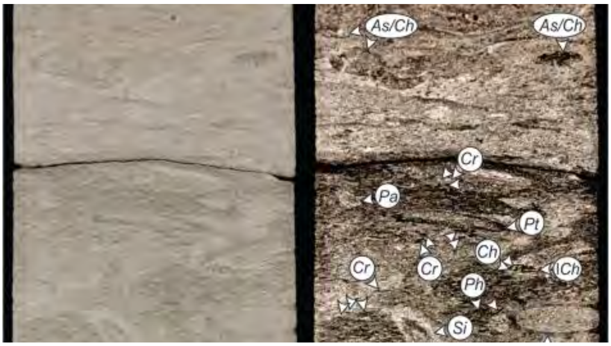

Figure 3. Digital images of slabbed core composed of marl from Example 1 in Fig. 2A, which show trace fossils of the archetypal *Cruziana* Ichnofacies. (A) Untreated jpeg image of slabbed core specimen and (B) same jpeg image as in A with digital-image treatment. Trace fossil abbreviations: *Asterosoma* (As), *Chondrites* (Ch), longitudinal *Chondrites* (lCh), *Cosmorphaphe* (Cr), *Ophiomorpha* (Op), *Palaeophycus heberti* (Pa), *Palaeophycus tubularis* (Pt), *Phycosiphon* (Ph), and *Siphonichnus* (Si).

A new record of an ornithopod footprint in Lower Cretaceous of Cabo Espichel (Sesimbra, Portugal)

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Keywords: Ichnofossils, Ornithopods, photogrammetric 3D model, Espichel, Lower Cretaceous

In the area of Cabo Espichel, dinosaur tracks are identified in three outcrops: Praia do Cavalo has theropods footprints, Pedra da Mua has trackways of sauropods and theropods (both from the late Jurassic) and Lagosteiros (Lower Cretaceous) with trackways of theropods and ornithopods.

In Praia do Guincho a new dinosaur footprint was discovered. It is a small beach about 2 km to the north of Cabo Espichel, with a cliff composed by limestone, marls, sandstones and conglomerates, that haven been deposited in shallow marine, lagoon and estuary environments. The succession belong to the Papo-Seco Formation, of Lower Cretaceous (Barremian). In this formation remains of dinosaurs (ornithopods, theropods and sauropods), reptiles (crocodiles, pterosaurs and turtles) and fishes, have been reported (Antunes & Mateus, 2003; Lapparent & Zbyszewski, 1957; Figueiredo et al., 2015). During fieldwork for palaeontological prospecting, in 2011, promoted by CPGP, a mold of a dinosaur tridactyl footprint was discovered lose. The sediment of the footprint is stratified quartz-rich limestone boulder. It is the first discovery of a dinosaur footprint from the Barremian of Cabo Espichel.

From the first analysis of the shape of this footprint, it looked like a theropod footprint: it has digit III longer than II and IV. A later study in laboratory, that consisted of a visual analysis, according to different angles of light and a photogrammetric 3D model, using a *Nikon Coolpix P520* camera we realize that digit III wasn't as long as it first appeared to be, but a lot shorter and rounded, a substantial part of the shape of this digit III being sediment that does not belong to the footprint. From this analysis we concluded that the footprint is one of an ornithopod.

References

Antunes, M.T., Mateus, O. (2003): Dinosaurs of Portugal. Comptes Rendus, Palevol 2, 77–95.

Figueiredo, S., Rosina, P., Figuti, L., (2015): Dinosaurs and other vertebrates from the Papo-Seco Formation (Lower Cretaceous) of southern Portugal, Journal of Iberian Geology 41 (3) 2015: 301-314 http://dx.doi.org/10.5209/rev_JIGE.2015.v41.n3.47828

Lapparent, A.F. de, Zbyszewski, G. (1957): Les dinosauriens du Portugal. Memórias dos Serviços Geológicos de Portugal, Lisboa (N.S.) 2, 1-63.

Fig. 1. Photo of the footprint (CPGP. 3.11.1) with shallow angle. In this angle it is possible to distinguish a slight difference in the sediment in the zone of the III digit.

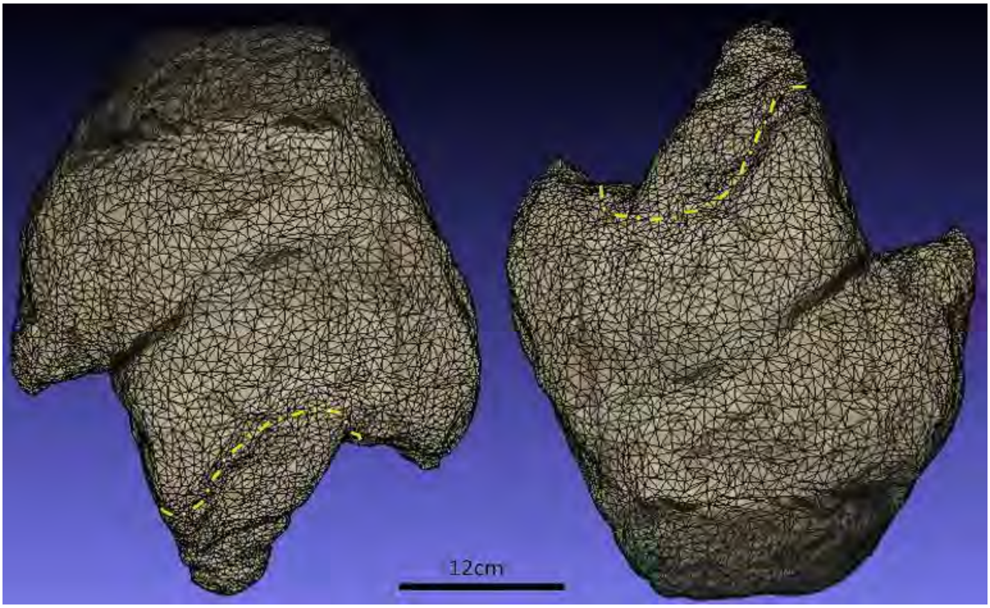

Fig. 2. Photogrammetric 3D model of the footprint. By this angle is clear that the III digit is shorter and rounded than those observed in the footprints of theropods and it looked like those observed in the footprint of the ornithopods dinosaurs.

The discrete topography analysis concept for 3D vertebrate ichnology

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Keywords: 3D fossil track, model iso-orientation, inverse analysis, discrete topography, statistics

Vertebrate ichnologists apply 3D tracking acquisition, although they still often use 2D measurements to linearize the data set (Bates et al. 2008, Lockley 2009). The great variety of shapes of a monotaxoomic fossil track is the result of dynamical systems depending on environment, morphometric and time-averaging variables (Manning, 2004, Marty 2008). A 3D software purchasing non-linear inverse theorems capable of analyzing this shape variability applies a mathematical model called "discrete topography analysis". The software compares small surface-portions between two iso-oriented 3D surfaces placed in a similar relative space with respect to the centroid of the considered shapes (Fig. 1). The method is applied in all geospatial sciences, and used in modern morphometric (Polly 2008, Martin Serra 2014), allowing quantitative and graphical comparisons.
Many software centroid-align the models applying a statistical distributed net of referring space coordinates. Next would be verifying uniform overlapping and dimensional parameters, obtaining the shape deviation between the analyzed models. Results would be showed by a Gaussian graph, by a colored filter or by dataset. Gaussian graph purchase allows verifying 3D model best-fitting and algorithm-fixing parameters before saving data.
Comparisons between two monotaxonomic trackways from Molfetta (SE Italy); -an eroded track and holotype attributed to *Apulosaurypus federicianus* from Altamura (SE Italy); -a right and left pes on an antalgic ornithopod trackway from La Rioja (Spain); -a true track and an undertrack of bovids from the quaternary sediments of Spinazzola (SE Italy), are here reported as four differently acquired field examples analyzed through Cloud Compare freeware.

References
Bates, K.T. et al. "-Three-dimensional modelling and analysis of dinosaur trackways". *Palaeontology*, 51.4 (2008), 999-1010.

Lockley, M.G. "-New perspectives on morphological variation in tridactyl foot prints: clues to wide spread con vergence in develop mental dynamics." *Geol. Quart.,* 53.4 (2009): 415–432. Warszawa.

Manning, P.L. "- A new approach to the analysis and interpretation of tracks: examples from the dinosauria. *Geological Society." London, Special Publications*, 228.1 (2004): 93-123.

Martin Serra, A; Figueirido, B.; Palmqvist, P. "- A three-dimensional analysis of the morphological evolution and locomotor behaviour of the carnivoran hind limb." *BMC evolutionary biology*, 14.1 (2014): 129.

Marty, D. "- Sedimentology, taphonomy, and ichnology of Late Jurassic dinosaur tracks from the Jura carbonate platform (Chevenez-Combe Ronde tracksite, NW Switzerland): insights into the tidal-flat palaeoenvironment and dinosaur diversity, locomotion, and palaeoecology." Doctoral Thesis N° 1608, Faculté des Sciences de l'Université de Fribourg (Suisse), *Geo Focus, 21* (2008): 278.

Polly, P.D. "Adaptative zones and the pinniped ankle." In Sargis E.J. and Dagosto M. (eds.), *Mammalian Evolutionary Morphology: A Tribute to Frederick S. Szalay, (2008)* 167–196.

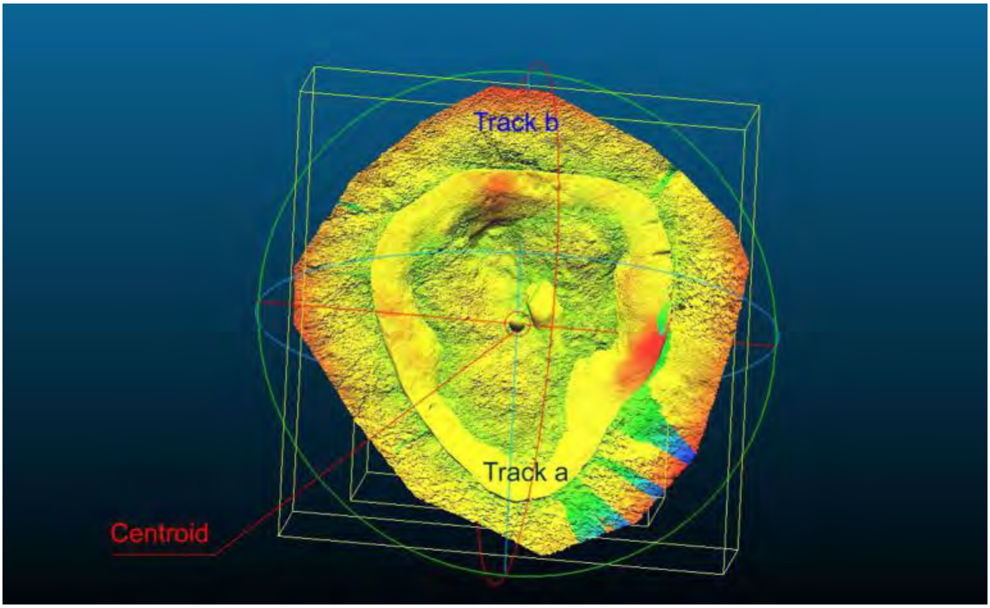
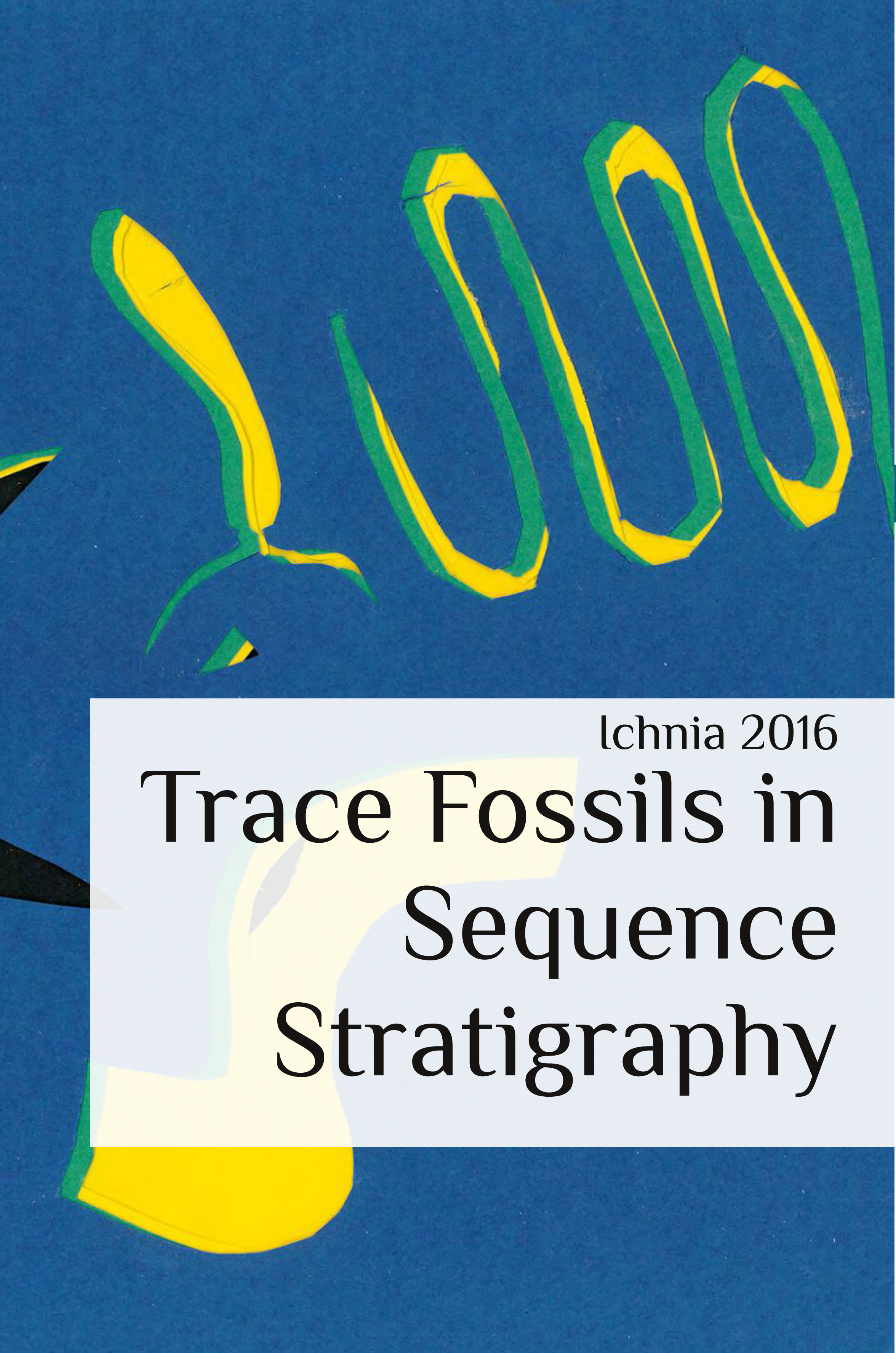


Fig. 1. 3D model fitting respect the centroid of a two different shaped tracks (ankylosaur and a theropod) from different sites. The different shape of the samples is evident by the chaotic color path of the graphical



Ichnia 2016

Trace Fossils in Sequence Stratigraphy

Ichnostratigraphy of the Triassic-Jurassic in Lesotho and South Africa

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Keywords: Late Triassic, Early Jurassic, Karoo, Elliot Formation, dinosaur tracks

The fluvio-lacustrine and aeolian rocks of the Upper Triassic to Lower Jurassic Elliot and Clarens formations (Stormberg Group, Karoo Supergroup; Lesotho and South Africa) preserve not only a range of vertebrate fossils, but also a plethora of ichnofossils that collectively recorded messages about the palaeoecological dynamics of southern Africa some ~200 Ma ago. Furthermore, these fossiliferous rocks may help the southern African placement of the Triassic-Jurassic boundary which marks the third largest of five major biological crises in the Phanerozoic geological record (Figure 1). Establishing the ecological changes that occurred prior and during Early Jurassic has a potential to generate new knowledge on the causes of this event, as well as the tempo and adaptation strategies of the biota both regionally and globally.

The Triassic-Jurassic vertebrate footprints in Lesotho and South Africa have been assigned to a great diversity of tetrapod genera, but accounts of the sedimentological or taphonomic contexts of the footprint sites are largely lacking. Our high-resolution study of individual ichnologically important sites aims to address this shortcoming as well as to: (a) determine the locomotion, behaviour and ecology of specific reoccurring ichnotaxa; (b) compare the taxa with those that occur in other sedimentary basins of similar age, e.g. Fundy Basin, Canada; (c) further refine the age of the informal biozones and (d) improve the precision of the existing model on the dynamics of the local ancient ecosystems. The ultimate aim of the project is to define the spatiotemporal distribution of trace fossils in the southern African Triassic-Jurassic boundary successions.

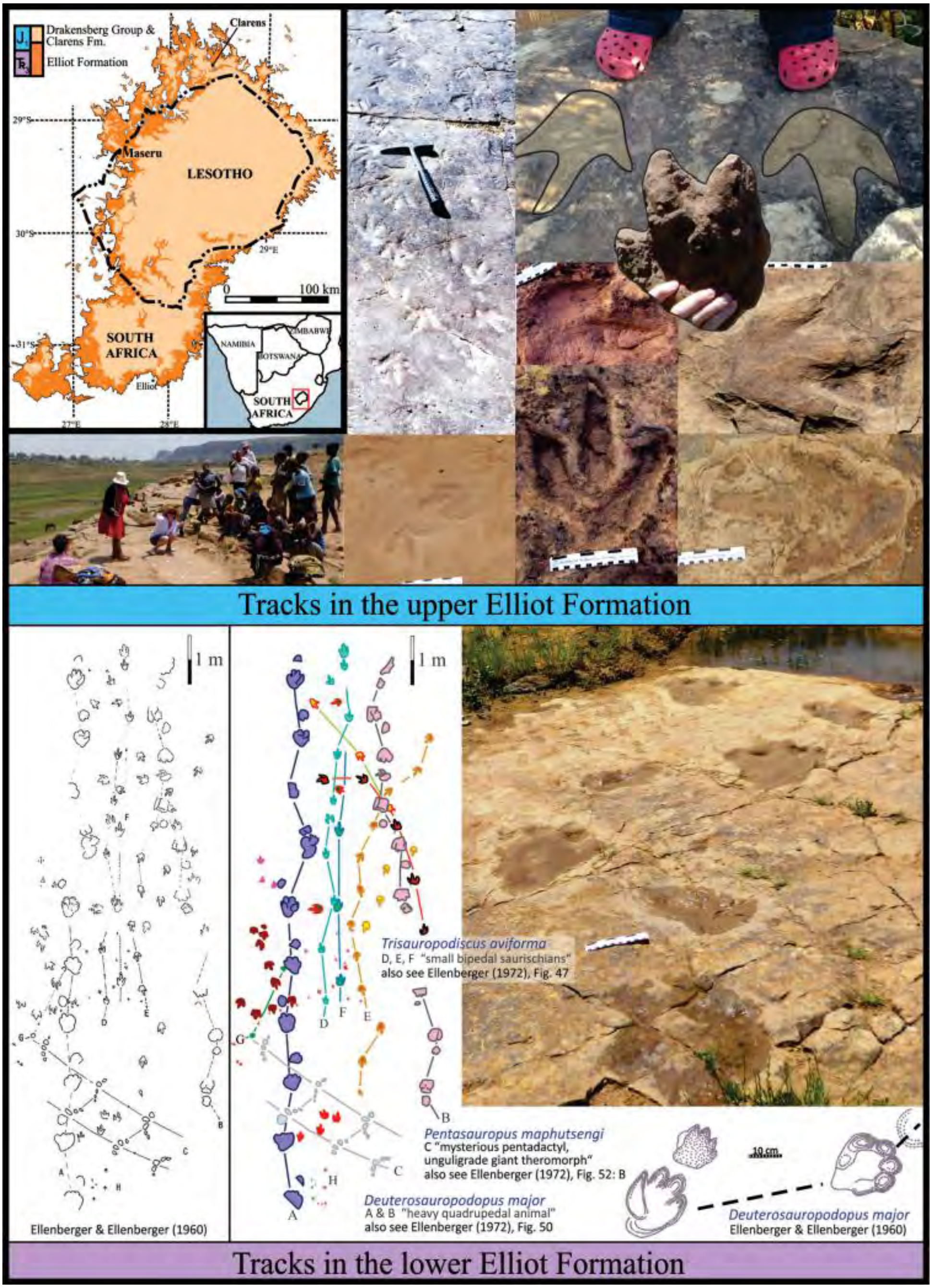

Figure 1. Dinosaur footprints in the Upper Triassic to Lower Jurassic Elliot Formation. Inset shows the simplified geological map of the formation, which is part of the Stormberg Group (Karoo Supergroup) in Lesotho and South Africa.

The role of colonization windows in a restricted marine setting under transgressive conditions: The Upper Devonian-Lower Mississippian Bakken Formation of Saskatchewan, Canada

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Keywords: applied ichnology, marginal-marine, colonization window, Devonian, Mississippian

The Upper Devonian-Lower Mississippian Bakken Formation of west-central Saskatchewan, Canada, is a tripartite clastic/carbonate unit, where a heterolithic middle member is bound by upper and lower black shale members. Eight facies clustered into two facies associations, FA1 (open-marine) and FA2 (marginal-marine), have been defined. The occurrence of a distal *Cruziana* ichnofacies within the heavily bioturbated siltstone of FA1 (Bioturbation Index; BI 3-5), characterized by horizontal trace fossils of deposit feeders, such as *Nereites missouriensis*, *Phycosiphon incertum*, and *Asterosoma* isp., indicates that FA1 represents open-marine deposits, which occurred during initial highstand conditions. FA2 ranges from unbioturbated to sparsely bioturbated. The lowermost interval consists of mudstone, siltstone, and very fine- to fine-grained sandstone displaying inclined heterolithic stratification (BI 0-2) interbedded with very fine- to fine-grained sandstone (BI 0-1). These deposits record sedimentation in channel-related tidal flats within an embayment during subsequent falling-stage conditions. The paucity of biogenic activity indicates that brackish-water conditions were the main limiting factor with regards to the colonization window. FA2 is capped by bioturbated sandy siltstone, which is characterized by a remarkable increase in bioturbation intensity (BI 4-5). The assemblage, characterized by *Planolites montanus* and *Teichichnus rectus* with subordinate *Rosselia socialis* and *Asterosoma* isp., is interpreted as an impoverished *Cruziana* ichnofacies, representing deposition during early transgression. The intense bioturbation indicates a relatively continuous colonization window. However, the relatively low ichnodiversity suggests that salinity conditions were not fully marine. These deposits are replaced upward by F2, signaling the return to fully marine conditions through continued transgression.

Distinguishing between allogenic and autogenic surfaces: An example from the late Pliocene palaeo-Orinoco delta in Trinidad

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Keywords: autogenic, marine erosion, paleo-Orinoco, stress factor(s), irregular sea-urchin

In the lowest interval of the Morne L'Enfer Formation along the SW Trinidad shoreline of Cedros Bay (Gulf of Paria), an erosional discontinuity can be traced throughout the exposures, which separates the underlying open shelf deposits and the overlying prograding clastic wedge of the palaeo-Orinoco delta. The surface displays no preservation of any firmground suite, and the softground trace fossil suite of the underlying deposits persists in the overlying units, although their expressions appear to be highly stressed and variable according to the subenvironments of the clastic wedge. Irregular echinoid trace fossils are abundant in the underlying deposits, persisting in smaller number immediately above the erosive surface. The stratigraphic nature of the surface is evaluated with respect to the existing models, namely (1) a Regressive Surface of Marine Erosion in wave-influenced shelf setting, and (2) an incised valley surface as sequence boundary. Both models, implying allogenic surfaces resulting from sea-level fall, seem to be inconsistent with this case. Integrated ichnological and sedimentological observations reveal the autogenic subaqueous origin of the surface. The clastic wedge deposition was dominated by river-influenced underflows, longshore currents, wave activity, and hypopycnal discharges. Furthermore, a complicated relationship can be interpreted among the different stress factors in different subenvironments affecting the infaunal colonizers, the irregular sea-urchins in particular. In a subaqueously prograding clastic wedge, the influences of river-influx affect the highly stressed niches not only for the adult endobenthos, but possibly also for their planktonic larvae, especially near the subaqueous distributary channels.

Ichnological features of the Eocene-Oligocene transition sediments of Manipur-Nagaland, Northeast India

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Keywords: Eocene, Oligocene, fan delta, trace fossils, Manipur-Nagaland

The Eocene-Oligocene transition (EOT) sediments of Manipur and Nagaland, Northeast India (Fig. 1), contain a relatively diverse trace fossils comprising of 38 ichnospecies belonging to 34 ichnogenera which can be grouped into mud dwelling pre-depositional structures, typical of fairly stable environmental conditions and sand dwelling post-depositional structures associated with turbidites and higher hydrodynamic environment where opportunistic dwellers exist. The ichnospecies belong to the *Skolithos*, *Skolithos-Cruziana*, *Cruziana*, *Glossifungites*, *Zoophycos* and *Nereites* ichnofacies, which are linked to three important lithofacies, i.e. dark grey shale facies, silty shale facies and sandstone facies (Fig. 2). They implied depositional environment that range from sublittoral to offshore settings, from proximal to distal delta fan regime, with relatively nutrient-rich, medium- to fine-grained sediments. The *Glossifungites* ichnofacies marks intertidal and shallow marine settings that immediately followed sea level lowstands. The alternate occurrence of mud dominated and sand dominated sediments also suggest a basin that experienced highly pulsating crustal stretching during the EOT times (Soibam et al., 2013), which is also evident from the sequence stratigraphic successions in the Thongjaorok section of Manipur and the Kiruphema section of Nagaland. The sections show general upward coarsening, typical of a prograding delta or shoreline. The report of *Chiloguembelina cubensis* from the Disang-Barail transition, Leimaram section, suggests the Priabonian-Rupelian transition for the EOT (approximately 34Ma; Brown et al., 2016). Petrographic analyses of the host and infill sediments of traces indicate rapidly eroding granitic and metamorphic terrains in a cold climate.

References

Brown, R. E., Koeberl, C., Montanari, A., Bice, D. M. "Evidence for a change in Milankovitch forcing caused by extraterrestrial events at Massignano, Italy, Eocene–Oligocene boundary GSSP". The Late Eocene Earth – Hothouse, Icehouse and Impacts. Ed. C. Koeberl, A. Montanari. Geological Society of America Special Papers 452 (2009): 119–137. Web. 10 Feb. 2016.

Soibam, I., Sanasam, S. Singh, Chabungbam, M. Khuman, Rajkumar, H. Singh. "Indo-Myanmar Ranges: Sedimentary basin of continental margin". Souvenir, National Conference on Sedimentation and Tectonics with Special Reference to Energy Resources of Northeast India and XXX Convention of Indian Association of Sedimentologists, 28–30 Nov. 2013. 61–81.

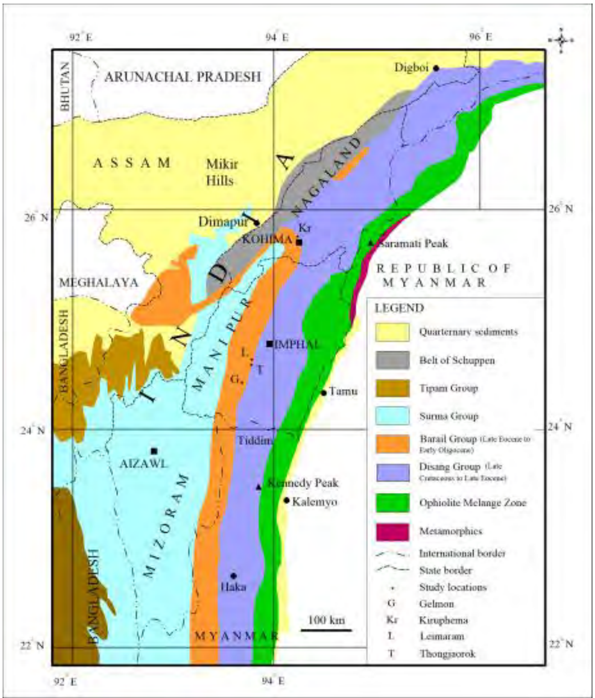

Fig. 1. Geological map of Northeast India showing the Disang-Barail transition.

Fig. 2. Intercalations of dark grey shale facies, silty shale facies and sandstone facies in Gelmon section, Manipur.

Transition from tide- to wave-dominated regimes in a middle Cambrian to Lower Ordovician seaway in southern Saskatchewan: Integrating ichnologic and sedimentologic datasets

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Keywords: Earlie Formation, Deadwood Formation, core analysis, ichnology, Saskatchewan

The middle Cambrian to Lower Ordovician succession in Saskatchewan is found only in subsurface at the southern half of the province, representing the initial sedimentary filling of the Western Canada Sedimentary Basin in the area. This succession is composed by three main lithostratigraphic units which in chronological order are: the Basal Sandstone Unit (BSU), consisting mainly of coarse-grained sandstone; the Earlie Formation, made up of fine- and very fine-grained sandstone with shale and the Deadwood Formation, consisting in interbedded shale, siltstone, very fine- to coarse-grained sandstone and flat-pebble conglomerate. Detailed core analysis was carried out and eleven lithofacies and six ichnoassemblages were proposed based on sedimentological and ichnological analysis. Bioturbation intensity and ichnodiversity is highly variable in the succession; bioturbated intervals mainly contain *Planolites, Palaeophycus, Skolithos, Asterosoma, Teichichnus* and *Phycodes,* among other ichnogenera. Although this succession has been traditionally interpreted as deposited in a shallow-marine shelf environment, under a classical wave-dominated model, the collected data reveal a more complex mosaic of sedimentary environments: fluvial to protected-shallow marine deposition in the BSU, tidally influenced shallow-marine deposition in the Earlie Formation and a wave-dominated to deltaic influenced shallow-marine setting for the Deadwood Formation. Overall, the BSU and the Earlie Formation record deposition in a protected shallow-marine setting prone to tidal amplification, showing higher bioturbation index and ichnodiversity, whereas the Deadwood Formation displays evidence of deposition in a strandplain/delta complex more vulnerable to wave action with sparse bioturbation and low ichnodiversity, reflecting stressful conditions linked to high-energy and freshwater input from distributary channels.

Redefining the *Treptichnus pedum* Ichnofossil Assemblage Zone: A critical reassessment of the Ediacaran-Cambrian boundary.

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Keywords: Treptichnus pedum, Ediacaran-Cambrian, Ichnofossil Assemblage Zone

The Ediacaran-Cambrian transition is the only boundary defined by the first appearance datum (FAD) of a trace fossil (*Treptichnus pedum*). Consequently, the placement of the Global Boundary Stratotype Section and Point (GSSP) at Fortune Head, Burin Peninsula, Newfoundland, has recently resurfaced as a topic of interest. Reluctance to the use of ichnofossils as biostratigraphic markers is based upon the idea that ichnofossils are facies controlled. While the broad environmental tolerance of *T. pedum* has been demonstrated, its suitability as an index fossil remains questioned by some. Redefining the boundary by using an ichnoassemblage spanning a broader range of depositional environments may address these queries. Ongoing research in Fortune Head and a global compilation of the ichnology of the Ediacaran-Cambrian boundary emphasizes the importance of re-evaluating previous ichnotaxonomic determinations worldwide. In addition to *T. pedum*, other elements of this Ichnofossil Assemblage Zone (IAZ) are *Gyrolithes, Allocotichnus, Diplichnites* and *Streptichnus*. Re-examination of the interval containing the Ediacaran-Cambrian boundary and lowermost Fortunian strata may benefit from incorporating conceptual and methodological tools from the emerging field of stratigraphic paleobiology. One approach would be to re-examine and categorize the ichnofossils in these strata based on their complexity. In turn, a hierarchical classification of the ichnofossils based upon evolutionary innovations would be created, assisting in the definition of an IAZ. This more robust boundary would be less dependent on discrete depositional environments. Rather, it would be strongly based upon evolutionary innovations, following in the spirit of the original decision by the International Commission on Stratigraphy (ICS).

Ichnology of the Upper Jurassic-Lower Cretaceous Vaca Muerta Formation, Neuquén Basin, Argentina: Delineating environmental changes in fine-grained depositional systems

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Keywords: oxygen-depleted sediments, fine-grained sediments, Vaca Muerta Formation.

The Vaca Muerta Formation represents the bottomsets and foresets facies of a clinoform system and minor proximal deposits. This formation consists of a mixed siliciclastic-carbonate system mainly composed by mudstone, marlstone and limestone with high organic matter content (2-10% TOC). An integrated sedimentologic and ichnologic analysis in two outcrops and 190 meters of cores, located at the southern and central zone of the basin, respectively, allowed an initial assessment on the main controls on bioturbation. The Vaca Muerta Formation consists of a transgressive-regressive succession. In outcrop, the transgressive interval is represented by coarse- to fine-grained sandstone sharply overlying eolian dune deposits of the Tordillo Formation. These transgressive deposits are sparsely bioturbated containing *Palaeophycus* and ?*Thalassinoides*. The regressive interval consists of coarsening-upwards cycles, at several scales, of parallel-laminated mudstone, limestone and marl, with minor intercalations of fine- to medium-grained sandstone and tuff levels. These cycles comprise unbioturbated and sparsely bioturbated zones (BI=1-2), containing *Planolites*, *Thalassinoides*, *Teichichnus*, *Phycosiphon* and *Zoophycos*. The upper part of these cycles shows a higher degree of bioturbation (BI=3-5). This ichnofauna records (1) the presence of an infaunal community of suspension feeders and passive predators in the transgressive succession of the southern part of the basin, (2) regressive cycles showing oxygen-depleted conditions in the fine-grained sediments, with an abundance of unburrowed anoxic levels, and (3) the onset of more oxygenated waters in the upper section, due to sedimentation in relative higher-energy environments affected by oscillatory flows and bottom currents.

Recognizing cyclicity using terrestrial ichnology in marginal environments of lacustrine and marine basins

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Keywords: lake, cycle, stratigraphy, climate, terrestrial

Flooding and exposure cycles of lake margins and deltaic/coastal plain environments can be controlled by climate as well as by tectonics and sediment supply. Terrestrial trace fossils, such as those produced by termites and beetles, signify periods of water table drop in marginal environments of lake and marine basins, and can be used to recognize climate cycles and stratigraphic packaging. Stratigraphic analyses of different marginal environments from the Cretaceous Belly River Group of Alberta Canada, the Eocene Green River Formation of the western United States, and Pleistocene lakes of the Kenya Rift Valley demonstrate that similar trace fossil assemblages signify hiatuses coinciding with peaks in progradation or climate-controlled drying. In East Africa, termite nests and tunnels signify low water tables in relatively dry climates. In the North American examples, periods of water-table drop in marginal environments are mainly marked by meniscate backfilled burrows (e.g., *Taenidium barretti*). Deep-tier traces cross-cut lake, fluvial, and splay deposits, and represent the overprinting of environments that occurred during depositional hiatuses. These surfaces are often sharply overlain by mudstones deposited in lacustrine or brackish-water marginal marine environments. In examples corresponding to increased clastic sediment supply, the progradational cycles can be interpreted as either highstand or lowstand, with uppermost surfaces as sequence boundaries or maximum regressive surfaces. In cycles more clearly related to periods of climate-induced wetting and drying, sediments signify shallowing upwards but not necessarily progradation prior to water table drop and subaerial bioturbation by terrestrial animals.

Arthropod trace fossils refute the alleged Ediacaran age of the earliest bilaterian trace fossils in the "Tacuarí Formation" from Uruguay

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Keywords: Arthropod trace fossils, "Tacuarí Formation", Pennsylvanian–earliest Asselian, Uruguay.

Veroslavsky *et al.* (2006) described the Tacuarí Formation outcropping in the Cerro Largo County (northeastern Uruguay), and dated it as Ediacaran based on palynological data and relationships with other rocks. Based on the supposed Ediacaran age of the unit, Pecoits *et al.* (2012) reported the alleged oldest bilaterian grazing trace fossils from the Tacuarí Formation and confirmed the Ediacaran age using the age of a granite supposed to intrude the sedimentary unit. Here we report the revision of these strata at the same localities, and show that the true trace fossil assemblage itself is not coherent with an Ediacaran age. Besides the "grazing trails", we found the resting trace *Gluckstadtella* (Fig. 1), and the walking traces *Maculichna* (Fig. 2) and *Umfolozia*. These ichnotaxa were also found in the surrounding area where the San Gregorio Fm. crops out, together with a new ichnospecies of *Rusophycus* (Fig. 3), in rythmite facies. Additionally, similar ichnoassemblages also appear in Brazilian (Itararé Group, Pennsylvanian) and South African deposits (Dwyka Series, Pennsylvanian–earliest Asselian), where the mentioned lithofacies occurs repeatedly. The new findings strongly argue against an Ediacaran age for the Tacuarí Fm. The first occurrence of true arthropod trace fossils in the Cambrian System is in the *Rusophycus avalonensis* Zone, well above the Precambrian-Cambrian boundary, and none of the already mentioned ichnotaxa are characteristic of Ediacaran-Cambrian successions. Ichnological data suggest that the ichnofossiliferous strata of the Tacuarí Fm. should be placed, in fact, within the San Gregorio Fm. (Pennsylvanian–earliest Asselian), and not in a separate unit of Ediacaran age.

References

Pecoits E., Konhauser K.O., Aubet N.R., Heaman L.M., Veroslavsky G., Stern R.A., and Gingras M.K. "Bilaterian Burrows and Grazing Behavior at 585 Million Years Ago." *Science* 336 (2012): 1693-696.

Veroslavsky G., De Santa Ana H., and Daners G. "Formación Tacuarí (nov. Nom.): Litoestratigrafía, Facies, Ambiente, Edad Y Significado Geológico." *Revista De La Sociedad Uruguaya De Geología* 13 (2006): 21-33.

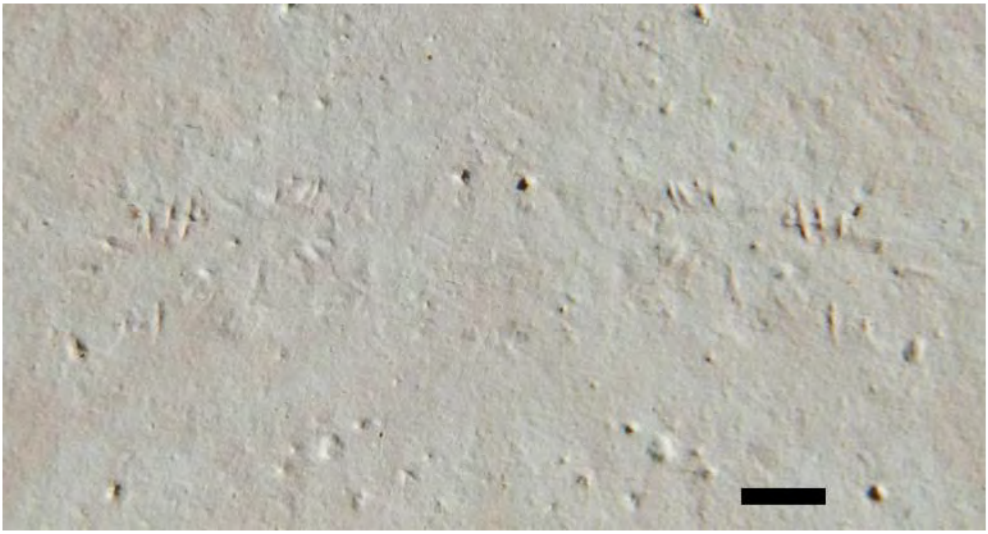

Fig. 1. Arthropod resting trace *Gluckastadtella cooperi* (part and counterpart). Scale bar: 0,5 cm.

Fig. 2. Arthropod repichnia, *Maculichna varia*. Scale bar: 1 cm.

Fig. 3. Arthropod resting trace, *Rusophycus* isp. Scale bar: 0,5 cm.

Trace fossils of the Pliensbachian–Toarcian hemipelagic deposits of the Lusitanian Basin, Portugal. Stratigraphic distribution and palaeoenvironmental significance

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Keywords: Trace fossils, hemipelagic deposits, palaeoenvironmental conditions, Lower Jurassic, Portugal

The Pliensbachian–Toarcian sediments of the Lusitanian Basin (Portugal) mainly consists of marl-limestone alternations deposited on a homoclinal carbonate ramp, which are dated in detail by means of ammonites.

The trace fossil content of these sediments is constant throughout the whole series. It has been scarcely studied however it can be an important tool to further investigations of sedimentary environment. A preliminary ichnological analysis is presented. It is based on the study of the Vale das Fontes, Lemede, S. Gião and the basal part of the Póvoa da Lomba formations (Duarte, 2007). These formations contain *Arenicolites*, *Chondrites*, ?*Diplocraterion*, *Phymatoderma*, *Planolites*, *Sphaerichnus*, *Thalassinoides* and *Zoophycos*. *Planolites* and *Chondrites* are dispersed through the sections. Other trace fossils show isolated occurrences, for instance, *Arenicolites* and ?*Diplocraterium* from the top of the Margaritatus to the base of the Emaciatum zones. Five main stratigraphic intervals can be tentatively differentiated based on the trace fossils content (Fig. 1): 1) *Chondrites* and *Phymatoderma* in the Davoei–Margaritatus zones (lower – upper Pliensbachian); 2) *Zoophycos* in the Polymorphum Zone (lowermost Toarcian); 3) *Thalassinoides* in the lowest part of the Levisoni Zone (lower Toarcian); 4) *Sphaerichnus* in the middle–upper part of the Levisoni Zone (lower Toarcian); and 5) *Zoophycos*, *Thalassinoides* and *Chondrites* in the Meneghinni–Aalensis zone interval (upper Toarcian).

The stratigraphic distribution of the trace fossils was clearly conditioned by changes in sea level, sedimentation rates, and redox conditions, supporting the sequence stratigraphic interpretation of the sediments presented in previous works (e.g., Duarte et al., 2004; Silva et al., 2015).

References

Duarte, Luís V. "Lithostratigraphy, sequence stratigraphy and depositional setting of the Pliensbachian and Toarcian series in the Lusitanian Basin (Portugal)." The Peniche section (Portugal). Contributions to the definition of the Toarcian GSSP. Ed. Rocha, R.B. Lisbon: International Subcommission on Jurassic Stratigraphy, (2007): 17–23, Print.

Duarte, Luís V., Nicola Perilli, Rodolfo Dino, René Rodrigues and Ricardo Paredes “Lower to Middle Toarcian from the Coimbra region (Lusitanian Basin, Portugal): sequence stratigraphy, calcareous nannofossils and stable-isotope evolution”. *Rivista Italiana Paleont. Strat.* 110 (2004): 115–127, Print.

Silva, Ricardo L., Luís Vítor Duarte and Maria José Comas-Rengifo ”Carbon isotope chemostratigraphy of Lower Jurassic carbonate deposits, Lusitanian Basin (Portugal): Implications and limitations to the application in sequence stratigraphic studies”. Ed. Ramkumar, M.: Chemostratigraphy: concepts, techniques, and applications, Elsevier (2015): 341–371, Print

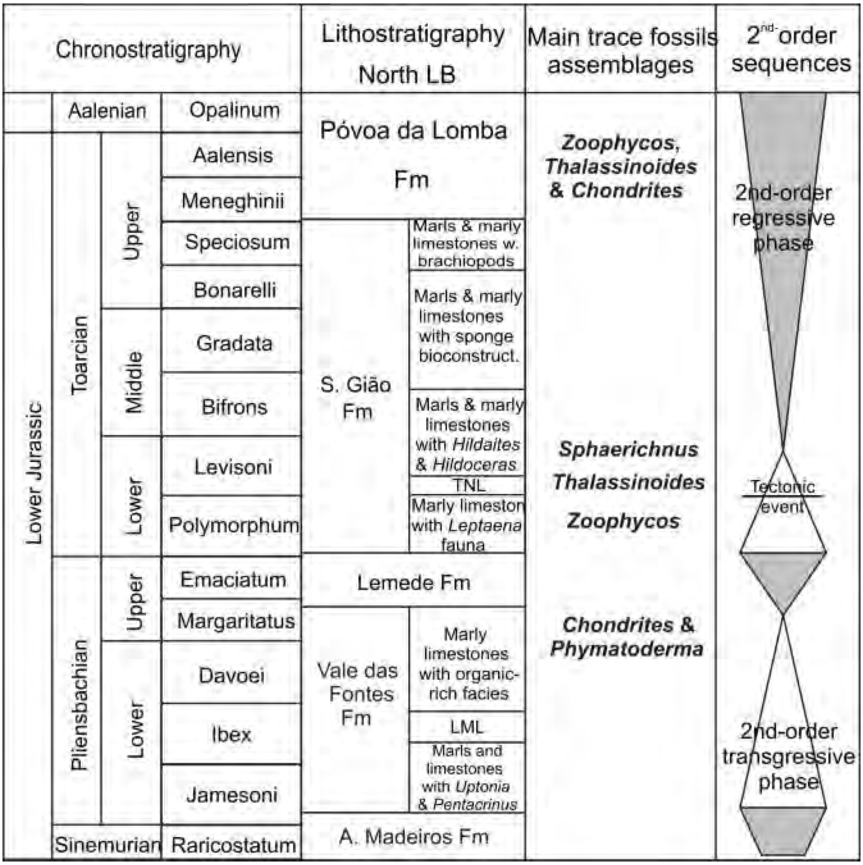

Fig. 1. Stratigraphic chart and relevant ichnofossils occurrences for the uppermost Sinemurian–lowermost Aalenian hemipelagic deposits cropping out in distal part of the Lusitanian Basin (biostratigraphy, lithostratigraphy and sequence stratigraphy based in Duarte, 2007). Fm – Formation; LML – Lumpy marls and limestones; TNL – Thin nodular limestones.

Glossifungites Ichnofacies demarking sequence boundaries: an example from Middle Devonian

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Keywords: Substrate-controlled ichnofacies, sequence boundary, palimpsest preservation

The *Glossifungites* Ichnofacies have been largely used in sequence stratigraphy but few examples come from early Paleozoic. The Devonian beds of Paraná Supersequence (Paraná Basin, S Brazil) are rich in trace fossils but stratigraphic analyses based on ichnology are still poor in most of the sedimentary units. Six third-order depositional sequences (A to F; Bergamaschi, 1999 and Grahn *et al.,* 2013) were recognized in this supersequence, all them representing transgressive and highstand systems tracts. Stiffgrounds and firmgrounds occur locally, being inferred by the presence of vertical to inclined-oriented unlined burrows with irregular borders and passively filled by clay. In Tibagi region (Paraná State), the most outstanding record occurs at the top of sequence C, in fine to medium-grained sandstone with low-angle trough cross-lamination previously bioturbated by *Macaronichnus* (Fig. 1). These deposits are overlaid by fine-grained sandstones with hummocky cross stratification and wave ripples containing *in situ* lingulids and *Lingulichnus* (*L. hamatus, L. verticalis*; Horodyski *et al.*, 2015), demarking the establishment of the sequence D transgressive systems tract (Fig. 1). The stiffground preserved at the top of sequence C potentially indicates a period of still stand in which the shallow marine soft sandy substrate containing *Macaronichnus* became stiff after a period of shoaling upward and substrate quiescence. During this period, the stiffground was reworked by the producer of *Glossifungites*-type burrows. The transgressive surface of the sequence D put an end in the quiescence period and demarcated a sequence boundary, being the *Glossifungites* Ichnofabric assemblage the ichnological signature of this stratigraphic break.

References

Bergamaschi, S. 1999. Análise estratigráfica do Siluro-Devoniano (Formações Furnas e Ponta Grossa) da sub-bacia de Apucarana, Bacia do Paraná, Brasil. Doctoral Thesis, Institute of Geosciences, São Paulo University.

Grahn, C.Y., Mendlowicz-Mauller, P., Bergamaschi, S., Bosetti, E.P., 2013. Palynology and sequence stratigraphy of three Devonian rock units in the Apucarana Sub-basin (Paraná Basin, south Brazil): additional data and correlation. Review of Palaeobotany and Palynology 198, 27 – 44.

Horodyski, R.S., Netto, R.G., Bosetti, E.P. 2015. *Lingulichnus* and *in situ* lingulid assemblage from a Middle Devonian transgressive systems tract in Paraná Basin, Brazil. *In.* Tercer Simposio Latinoamericano de Icnología, Colonia del Sacramento, Uruguay. v 1. p 51.

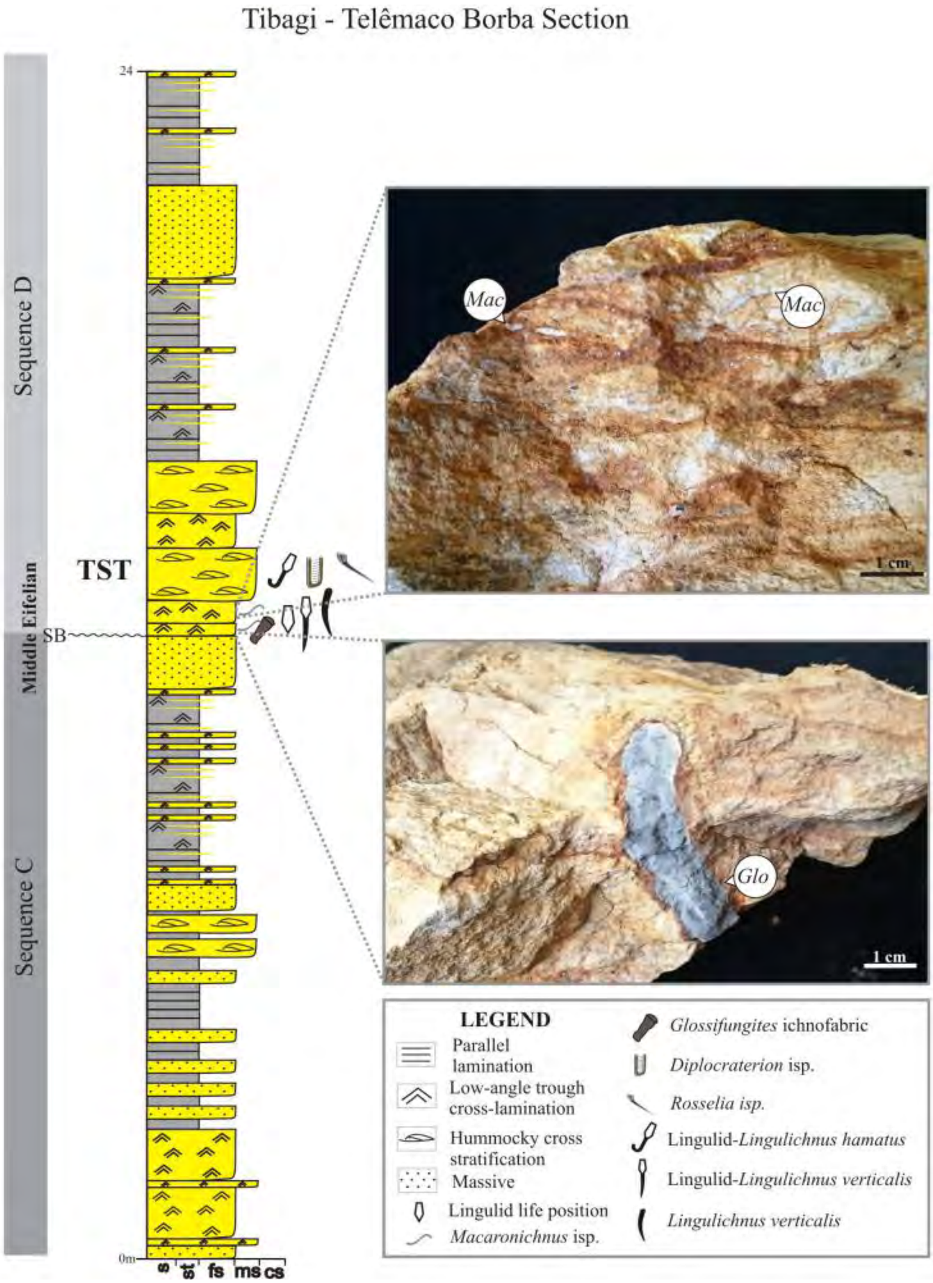
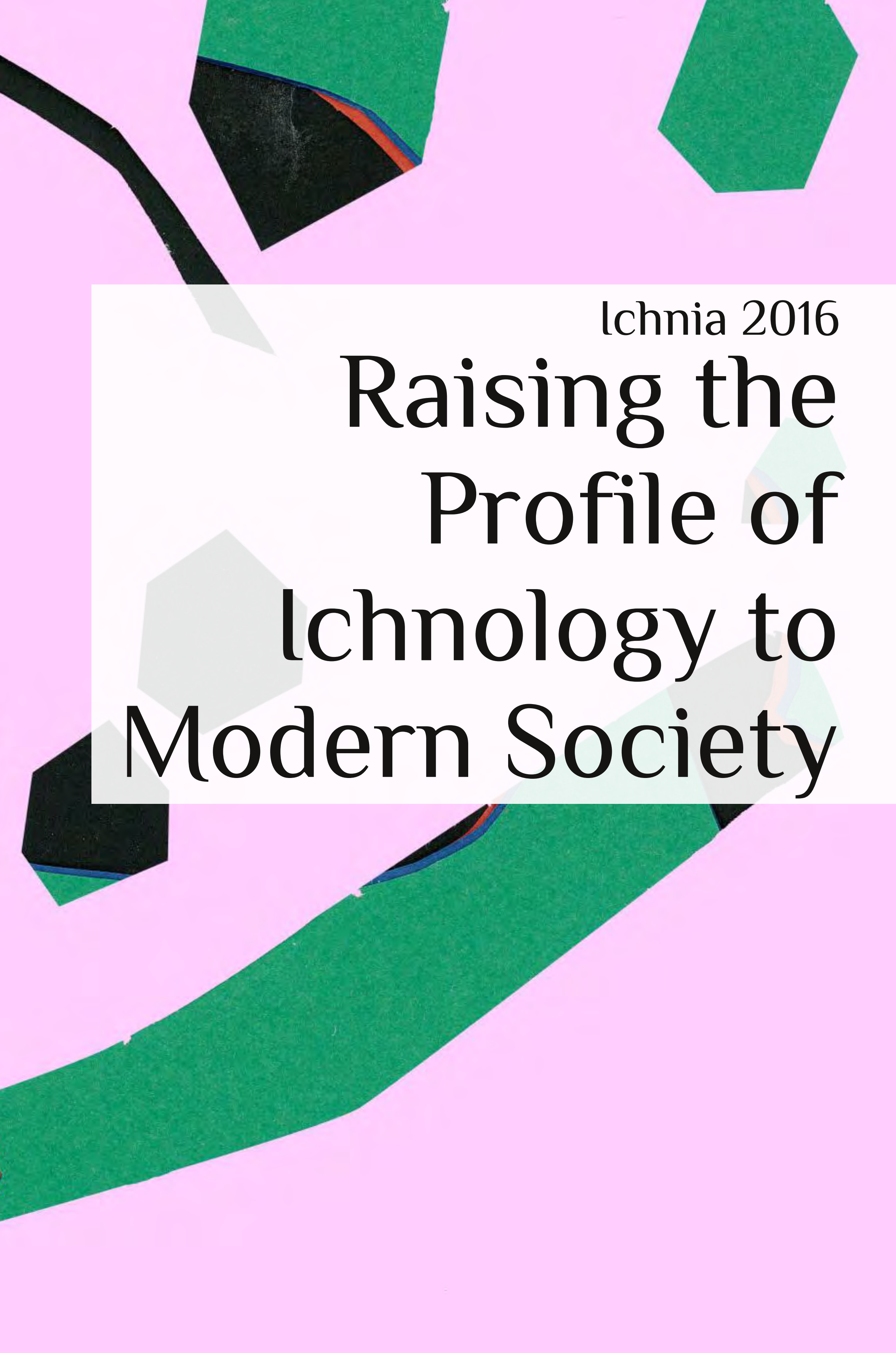


Fig. 1. Stratigraphical profile and main ichnological occurrences of the boundary between sequences C and D (modified from Horodyski *et al.* 2015).



Ichnia 2016

Raising the Profile of Ichnology to Modern Society

Remarkable ichnological sites in the Armorican Quartzite (Lower Ordovician) from the Almadén-Porzuna areas (Central Iberian Zone, Spain)

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Keywords: Ordovician, Central Iberian Zone, trace fossils, Geological heritage, Spain

Uppermost Armorican Quartzite strata in the synclines of Almadén and Porzuna comprise thick-bedded sandstones with an outstanding ichnofossil record. A locality near Ermita de San Blas (Agudo, Ciudad Real) exposed a large top surface of a quartzite bed yielding numerous *Cruziana furcifera* and weathered “*Catenichnus*” isp. in a concave epirelief preservation. The second locality lies 1km southwest of Ermita La Cruz de Mayo, near Porzuna, also in the province of Ciudad Real. The *Skolithos* and *Cruziana* ichnofacies alternate in successive thick sandstone beds. The first one stands out by the “pipe-rock” concentrations of *Skolithos* that vertically grades in large concentrations of wide *Daedalus* visible in cross-sections. The *Cruziana* ichnofacies is represented by large exposures showing circling behaviour of cruzianids, preserved as concave epireliefs.

These outcrops were erroneously interpreted by locals and cultural officers as archeological rather than paleontological sites.

The existence of these large ichnological surfaces may contribute in the future to allow a detailed study on the behaviour of trace markers in the shallow epicratonic South Gondwana shelf.

This research is a contribution to the projects CGL2012-39471 of the Spanish MINECO, 727/2012 of the Spanish National Parks Network, and IGCP-591 (IUGS-UNESCO).

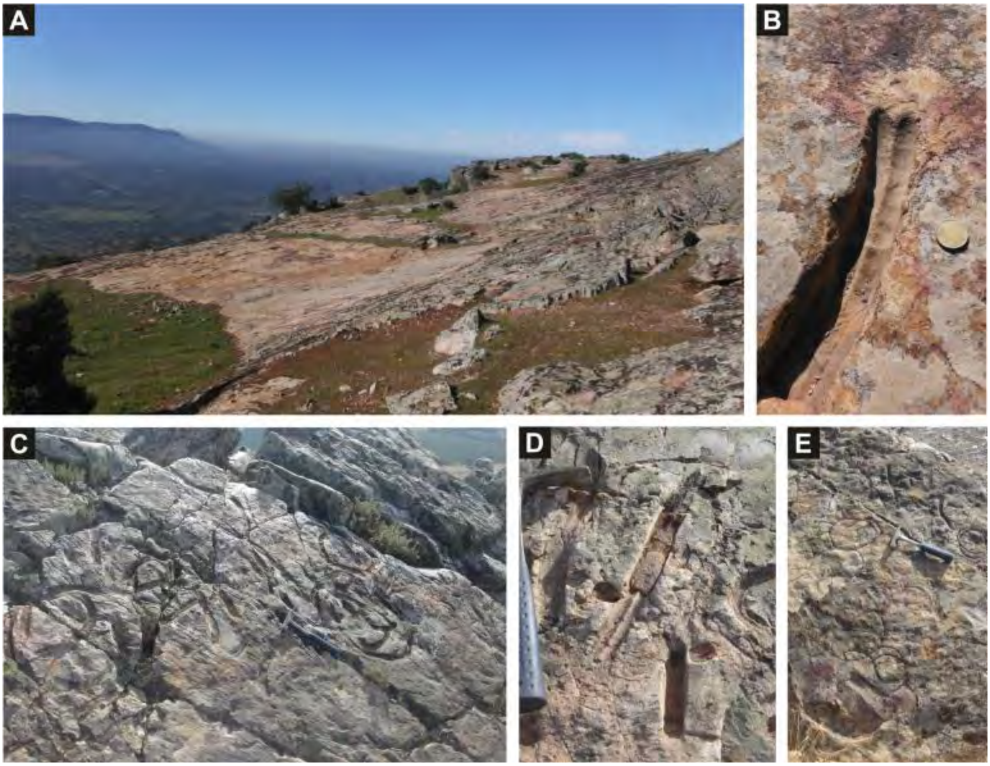

Fig. 1 – Large exposures of top bedding planes of Armorican Quartzite at ichnological localities Ermita de San Blas (A-B) and Ermita de Cruz de Mayo (C-E) (B,D, single epireliefs of *Cruziana furcifera*; C, circling *Cruziana*; E, transverse sections of large *Daedalus*)

Ichno what? Outreach and Informal Education in a Science Centre in Algarve (Portugal)

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Keywords: Science outreach, dinosaur tracks, invertebrate traces, outdoor visits, informal education

Science outreach and engagement are crucial core objectives of the Lagos Ciência Viva Science Centre (CCVL). However, one knows the need of taking audiences back into the real world, ensuring that visitors link their science centre experience with the natural environments in which they live. Therefore it has been an institutional option to have in CCVL's offer geological outdoor activities including an ichnological element.

Dinosaurs are an appealing science subject when dealing with students and general public. The CCVL has a long tradition in organizing and guiding field visits to two dinosaur track sites – Salema and Santa beaches (Vila do Bispo, southwest Algarve). These sites, both Lower Cretaceous in age and with theropod and iguanodontian footprints (*Iguanodontipus* isp. was identified at the Santa tracksite) (Santos et al., 2013), allows students and tourists to be introduced to dinosaur ichnology, as well as to the geology of the area (structural and stratigraphy) and to beds with *Ophiomorpha* pavements. Additionally, a lecture to middle and high schools as well for the general public has an ichnology component and reached more than 2000 students in the last 7 years.

The CCVL has prepared and performed guided visits at Oura's beach, a Miocene a site with a mega bioeroded surface with borings of bivalves interpreted as belonging to the ichnogenus *Gastrochaenolites* (Cachão et al., 2009). The observation and interpretation of this site could be used both as an example of past life changes as well Earth's sea level rises and falls contributing to the concept of a dynamic Planet.

Urban spaces could be used as well in ichnology science outreach. Three Urban Geology and Paleontology books of three Algarve's cities were published and constitute another component of the science outreach activities (Rodrigues and Agostinho, 2016).

References

Santos, V.F., Callapez, P.M., Rodrigues, N.P.C. (2013) - Dinosaur footprints from the Lower Cretaceous of the Algarve Basin (Portugal): New data on the ornithopod palaeoecology and palaeobiogeography of the Iberian Peninsula. *Cretaceous Research*. 40: 158–169.

Cachão, M., da Silva, C.M., Santos, A., Domènech, R., Martinell, J., Mayoral, E., (2009). The bioeroded megasurface of Oura (Algarve, south Portugal): implications for the Neogene stratigraphy and tectonic evolution of southwest Iberia. Facies 55, 213–225.

Rodrigues, L.A., Agostinho, M. (2016) Lagos – Guia de Geologia e Paleontologia Urbana - Urban Geology and Paleontology Guide. Lagos Ciência Viva Science Centre Editions, 124pp. ISBN 978-989-99519-2-1.

Fig. 1. A – Salema beach dinosaur tracksite; B – Santa beach dinosaur tracksite; Oura bioeroded megasurface; D - cover of Lagos Urban Geology and Paleontology Guide; E – Planolites in Faro's Cathedral staircase – from Faro Urban Geology and Paleontology Guide.

Communication of Ichnological Heritage in UNESCO Naturtejo Global Geopark (Portugal)

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Keywords: Ichnological Heritage, Geoconservation, Portugal.

UNESCO Naturtejo Global Geopark (Portugal) promotes the protection of the geological heritage and fosters its accessibility to different audiences through enhancement and interpretation.

Raising awareness for ichnological heritage embraces complex perception of geological time, abstract geological processes, fossilization of behaviour, as well as popularization of these complex concepts. If vertebrate ichnology has already achieved some notoriety through outstanding dinosaur tracksites, invertebrate trace fossil geosites are scarcely promoted and rarely available.

This phenomenon is explained by the lower appeal and the smaller size of invertebrate trace fossils, as well as the less immediate concepts of invertebrate ichnology. In addition, since the paradigms of modern society have changed, the communication strategies need to follow the new strains, with a more demanding audience, which is not only seeking for information, but for engaging interpretation experiences.

The ichnological heritage from Naturtejo Geopark includes 9 geosites inventoried in the Armorican Quartzite Formation (Lower Ordovician), including the internationally recognized Penha Garcia ichnosite. This geomonument features giant *Cruziana* and *Rusophycos*, that are protected and valorized by the institution of the Penha Garcia Ichnological Park. Here, the ichnological heritage is communicated along the Fossils Trail through the following activities: (a) panels, (b) interpretative center (Fossils Home), (c) a mobile app, (d) guided tours and (e) even a trilobite and an orthoceratid cephalopod, that are part of the Penha Garcia fossil record, floating in a natural pool!

Fossil sites from Muradal mountain, such as the ones revealing remarkable specimens of *Daedalus*, were included in the Trail-Muradal Pangea, now part of the legendary International Appalachian Trail, in this section devoted to primitive life and landscapes, 480 million years ago.

Multimedia technologies enable the simulation of processes and behaviors production in attractive and interactive way: (a) the “*Diplocraterion* game”, for mobile phone, encouraging the player to control the production of *spreite* structures in U-burrows produced by worms, (b) the multimedia kiosk “*Cruziana maker*” involving the users arms in the feeding behavior of trilobites and the production of *Cruziana*.

The communication of the ichnofossils boosted the new paradigm of social and economic development of the region and today they are real geotourism references that legitimize sustainable business opportunities and educational practices.

Fig. 1. Interpretation Panel about the feeding behavior of trilobites and the production of Cruziana in the Penha Garcia Ichnological Park

Ichnological Heritage in Portugal

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Trace fossil record decipher their producers' behaviors and ecological conditions, individual and social activities, evolutionary trends and taphonomic windows that contribute to the understanding of the evolution of Life and the memory of Earth. In Portugal, there are several geosites with ichnological interest that are known to publics, integrated in Natural Monuments, Natural Parks, Geoparks, museum collections and nature footpaths, and integrating the Geological Heritage National Inventory.

The Portuguese record includes important sites for invertebrates, preserving excepcional trackways and burrows such as in Penha Garcia, Apúlia, Muradal or Mareta. There are also important Fossil-ichnolagerstätte, such as Boca de Chapim dated from the Lower Cretaceous, with the almost unique record of populations of *Mayeria* within their original burrows. The recently discovered Cabeço da Ladeira fossil site preserves impressive echinoderm-dominated communities as well as the earliest record of sideways walking attributed to crabs and the first record of a fossil crinoid trail. The vertebrate trace fossil record is wide, in particular for dinosaurs. Cabo Espichel dinosaur tracksite yield one of the first evidences of sauropod gregarious behaviour due to parallel trackways, and the Vale de Meios Quarry holds large tridactyl footprints with remarkable preservation. The presence of *Elephas antiquus* tracks and trackways in the Pleistocene eolianite of Malhão reveals some of the latest occurrences of *E. antiquus* in Europe, and expected gregarious behaviour expected for these animals.

The Geological Museum hosts the most complete collection of trace fossils in Portugal, mainly collected during the time of Nery Delgado work in the second half of 1800's, recently in revision under new ichnological advances.

The geoconservation movement in Portugal was born in the 1990's, with mediatic safeguard campaigns of dinosaur tracksites, threatened by the activity of quarries (Fig. 1) and by the construction of a highway. The highway was reorganised to save one of the longest trackway known in that time, with the construction of a 300 m tunel under the geosite and the quarry was bought by the State and decreed Natural Monument. In consequence other tracksites were transformed in protected areas. The Ordovician trace fossils from Penha Garcia that became famous under the international exhibition Fossil Art of Adolf Seilacher were the bottom line for the creation of the first Portuguese geopark, the UNESCO Naturtejo Global Geopark, including a long-term sustainable strategy for a 5000 km2 area, and are interpreted under the guided visits to the Fossils Trail and its Fossils House (Fig. 2). Geosites with ichnological interest like the Sesimbra dinosaur tracksites from the Late Jurassic and Lower Cretaceous, the Praia Grande dinosaur tracksitefrom the

Lower Cretaceous, or the Serra do Muradal *Daedalus* megaichnosite from the Lower Ordovician have outdoor visitation and interpretation structures, contributing for the dissemination of Earth History, enhance scientific literacy among schools and geotourists, and raise awareness for geoconservation. Furthermore, for several ichnological sites were developed didactical and leisure equipments, educational programs and some of them were integrated in popular tourist routes.

Fig. 1. Galinha tracksite (Bairro, Serra de Aire, West–Central Portugal) is a natural monument and reveal long sauropod trackways produced by a basal eusauropod and possibly a member of Turiasauria.

Fig. 2. Penha Garcia Ichnological Park, Lower Ordovician Armorican Quartzite with *Cruziana* from unusual size recording the feeding patterns of giant trilobites.

Gomes (1915-1916) to Ichnia 2016 – one hundred years of vertebrate Ichnology in Portugal

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Keywords: Dinosaurs, footprints, History, Cabo Mondego, Portugal

One of the oldest records of trace fossils can be found in Portugal, and was related with the cult of Virgin Mary and the reason for building a sanctuary. Dinosaur footprints in Portugal were for the first time scientifically identified, studied and excavated under the supervision of Jacinto Pedro Gomes (1844-1916), a naturalist at the Mineralogical and Geological Museum (in the former Polytechnic School of Lisbon) after being informed, in 1884, about the discovery of "big and very curious fossils" by miners from the Cabo Mondego coalmine (Figueira da Foz). He recognized that they were natural casts of tridactyl footprints preserved near the entrance of the coalmine and remarkably compared their morphology to those produced by extant huge birds. Afterwards, he revealed illustrations of this new and still uncommon occurrence to some European naturalists and they came to the conclusion that Cabo Mondego footprints were made by ornithopods (Gomes, 1915-1916). This posthumous publication is the first scientific document on dinosaur footprints in Portugal and one of the earliest scientific works on dinosaur Ichnology in the world with a remarkable accurate understanding of the tracks.

From Jacinto Pedro Gomes pioneering work in the study and protection of dinosaur tracks to the present day several tracksites were protected and valued as scientific assets, educational tools and tourist attractions, in what can be considered as a long walk that culminated with the systematic research on dinosaur ichnology developed in the Mesozoic Basins for the last 30 years (e.g. Santos, 2008), and the early public actions to protect the geological heritage, in Portugal.

References

Gomes, J.P. Descoberta de rastos de saurios gigantescos no Jurássico do Cabo Mondego. *Comunicações dos Serviços Geológicos de Portugal* 11 (1915-1916): 132-134. Print.

Santos, Vanda Faria dos. *Pegadas de dinossáurios de Portugal.* Lisboa: Museu Nacional de História Natural, Universidade de Lisboa, 2008. Print.

The role of the *Museu Nacional de História Natural e da Ciência* in the study of dinosaur tracksites and its contribution to the conservation and enhancement of Portuguese geological heritage

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Keywords: Dinosaur tracksites, Geoheritage, Geoconservation, Portugal

The role of the *Museu Nacional de História Natural e da Ciência* (Lisbon University) in the study of dinosaur tracksites and its conservation begun in the end of the XIX century, when it was the Mineralogical and Geological Museum in the former Polytechnic School of Lisbon, with the pioneering work of Jacinto Pedro Gomes (1844-1916). Beside the study on dinosaur footprints from Cabo Mondego (Figueira da Foz), this naturalist supported the idea of rescuing the footprints from marine erosion (Gomes, 1915-1916). He took the generous offer from the Cabo Mondego coalmine administration of sponsoring the campaign to remove the tracks and transfer them to Lisbon, to what is nowadays the National Museum of Natural History and Science.

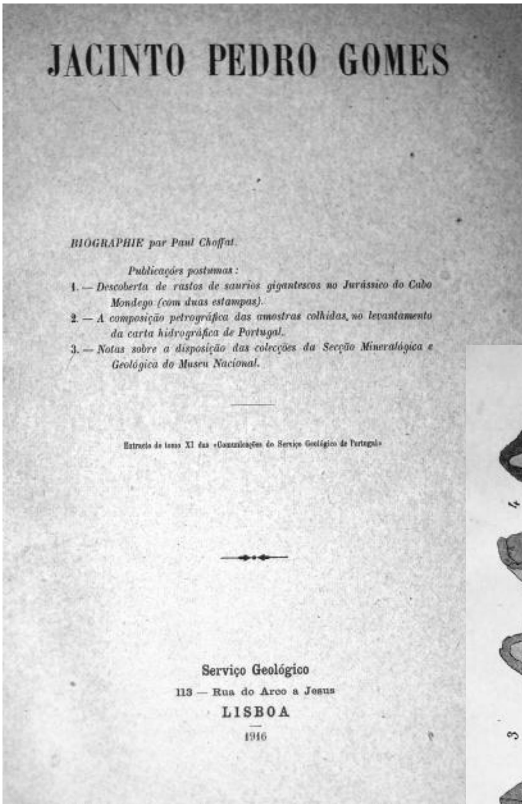
Later, a few scientific works on new dinosaur tracksites were published. Santos *et al.* (1991) is a first milestone of a new stage in the study of dinosaur tracksites in Portugal promoted by a campaign headed by Professor Galopim de Carvalho (at the time Director of the National Museum of Natural History) which allowed to obtain financial support from institutions like *Fundação Calouste Gulbenkian* and *Fundação para a Ciência e Tecnologia* to study dinosaur tracks and to do scientific spreading actions. His strategy had the goal to enhance public awareness of geological heritage and obtain recognition in order to get the support and commitment of city mayors and governmental departments and also the crucial contribution of journalists, to preserve and protect relevant tracksites. Definitely and due to joint efforts five Portuguese dinosaur tracksites became classified as Natural Monument in 1996 and in 1997. Despite the much that has been done recently (e.g. Pólvora *et al.*, 2014) difficulties to promote and enhance some of them like Galinha tracksite still persist.

References

Gomes, J.P. Descoberta de rastos de saurios gigantescos no Jurássico do Cabo Mondego. *Comunicações dos Serviços Geológicos de Portugal* 11 (1915-1916): 132-134. Print.

Pólvora, A., Caetano, P.S. and Santos, V.F. "Geocircuito de Sesimbra – uma iniciativa municipal para divulgação e valorização do património geológico local". *In*: J.M. Mata-Perelló (Ed.), *Libro de resúmenes del XV Congreso Internacional sobre Patrimonio Geológico y Minero; XIX Sesión Científica de la SEDPGYM, Logrosán (Cáceres)* (2014): 123-124. Print.

Santos, V.F., Moratalla, J.J., Dantas, P.M., Coke, C., Cachão, M.A., Silva, C.M. and Sousa, L.N. "Icnofósseis de Dinossáurios do Cenomaniano médio da região de Lisboa". *Actas III Congresso Nacional de Geologia*, Coimbra (1991): 133. Print.


JACINTO PEDRO GOMES

BIOGRAPHIE par Paul Choffat.

Publicações postumas:

1. — *Descoberta de rastos de saurios gigantescos no Jurássico do Cabo Mondego (com duas estampas).*
2. — *A composição petrográfica das amostras colhidas, no levantamento da carta hidrográfica de Portugal.*
3. — *Notas sobre a disposição das colecções da Secção Mineralógica e Geológica do Museu Nacional.*

Extracto do tomo XI das «Communicações do Serviço Geológico de Portugal»

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113 — Rua do Arco a Jesus
LISBOA
1916

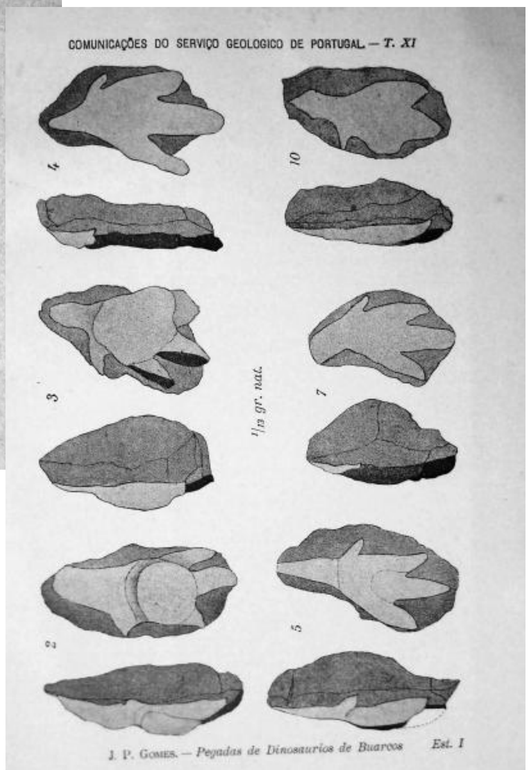

Fig. 1. Frontispiece of the posthumous publication of Gomes (1915-1916) and the illustration of the dinosaur footprints at Cabo Mondego, Portugal.

The potential of Dinosaur tracksites to enhance Earth Sciences Literacy

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Keywords: Earth Sciences Literacy, Dinosaur tracksites, Geoheritage, Portugal

There is a strong connection between Earth Sciences Literacy and Geoheritage awareness (e.g. Reis *et al*., 2014). This connection can also work the other way around as Geoheritage can act as a trigger to reach or enhance Earth Sciences Literacy.

It is likely that since the dawn of Mankind people have been coming across footprints on bedrocks and trying to explain them. Herodutos (*c*. 484 - 425 BC) actually mentions marks that he perceived as footprints, in some of his writings (Mayor & Sarjeant, 2001). These authors also refer to several other myths across continents that are probably related to dinosaur tracksites. Indeed, nowadays dinosaur tracks still have the potential to appeal to the curiosity and imagination of people and are also able to provide them with meaningful experiences that might also be learning opportunities.

Last century, in the nineties there was a burst of publications derived from several projects headed by Galopim de Carvalho (former Director of the National Museum of Natural History, Lisbon University). Being on the spotlight on that occasion provided him an opportunity to address the public on the importance of dinosaur's tracksites and expose them as places to learn geosciences and comprehend the significance of natural heritage.

Nowadays, Portuguese dinosaur tracksites are still being found and studied and there have been an effort not only in their conservation but also to promote through the musealization of some of them (e.g. Santos *et al*., 2015).

References

Mayor, A., and W.A.S. Sarjeant. "The Folklore of Footprints in Stone: From Classical Antiquity to the Present." *Ichnos* 8.2 (2001): 143-63. Web.

Reis, J., L. Póvoas, F. J. A. S. Barriga, C. Lopes, V. F. Santos, B. Ribeiro, J. Cascalho, and A. Pinto. "Science Education in a Museum: Enhancing Earth Sciences Literacy as a Way to Enhance Public Awareness of Geological Heritage." *Geoheritage* 6.3 (2014): 217-23. Web.

Santos, V.F., Caetano, P.S., and Pólvora, A. "Monumento Natural da Pedreira do Avelino: paradigma de conservação e valorização do património natural de Sesimbra." *Sesimbra, cultura e património*, Câmara Municipal de Sesimbra, *akra Barbarion* 1 (2015): 69-83. Print.

Dinosaur tracksites in Teruel (Spain) and Yanqing (China)

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Keywords: dinosaur tracks, Jurassic-Cretaceous transition

Despite being separated by a long distance (some 9,000 km), dinosaur tracksites in Teruel (Spain) and Yanqing (Beijing, China) share several characteristics. Firstly, we can find tracks outcrops near the Jurassic-Cretaceous boundary. Also, both present tracksites included in UNESCO Global Geoparks. And visitor centres attract the interest of general public by means of geotourism, as well.

Limestones, sandstones and clays of the Villar del Arzobispo Formation (Kimmeridgian–Berriasian) have yielded in Teruel area (southeastern Iberian Range) dozens of sites with dinosaur bones: being sauropod and stegosaur dinosaurs the most abundant, while ornithopods are scarce, and theropods very rare. Concerning tracksites, two new ichnospecies have been described: *Deltapodus ibericus*, produced by a stegosaurian related to *Dacentrurus armatus* and *Iberosauripus grandis*, whose trackmaker would be a megatheropod Tetanuran (Cobos *et al*., 2010, 2014). Both large (e.g., *Polyonyx*-like morphotype) and small sauropod tracks, and also small quadrupedal ornithopod tracks have been identified.

The Tuchengzi Formation comprises terrestrial strata formed in an arid and hot environment. In Yanqing area, the Formation can be divided into four members, and tracksites are found in the Third Member (Upper Jurassic-Lower Cretaceous), composed of polymictic conglomerate and tuffaceous sandstone, overlaid by sandstones, siltstones and mudstones. Most abundant are theropod tracks similar to those of the *Grallator–Eubrontes* (theropod trackmakers were small to medium-sized individuals that probably belonged to coelurosaurs, including functionally didactyl dromaeosaurs); the sauropod trackways belong to medium and large-sized animals that represent both narrow-gauge and wide forms, while the presence of ornithopods remains a rather scarce element (Xing et al., 2015).

Both in Teruel and Yanqing the presence of theropods of this age has been better established by tracks than by bone records.

References

Cobos, Alberto, Rafael Royo-Torres, Luis Luque, Luis Alcalá, and Luis Mampel. "An Iberian stegosaurs paradise: The Villar del Arzobispo Formation (Tithonian–Berriasian) in Teruel (Spain)." *Palaeogeography, Palaeoclimatology, Palaeoecology* 293.1-2 (2010): 223-36. Print.

Cobos, Alberto, Martin G. Lockley, Francisco Gascó, Rafael Royo-Torres, and Luis Alcalá. "Megatheropods as apex predators in the typically Jurassic ecosystems of the Villar del Arzobispo Formation (Iberian Range, Spain)." *Palaeogeography, Palaeoclimatology, Palaeoecology* 399 (2014): 31-41. Print.

Xing, Lida, Jianping Zhang, Martin G. Lockley, Richard T. McCrea, Hendrik Klein,
Luis Alcalá, Lisa G. Buckley, Michael E. Burns, Susanna B. Kümmell, and Qing He. "Hints of the Early Jehol Biota: Important Dinosaur Footprint Assemblages from the Jurassic-Cretaceous Boundary Tuchengzi Formation in Beijing, China." *Plos One* 10(4) (2015): e0122715. doi:10.1371/journal.pone.0122715. Web.

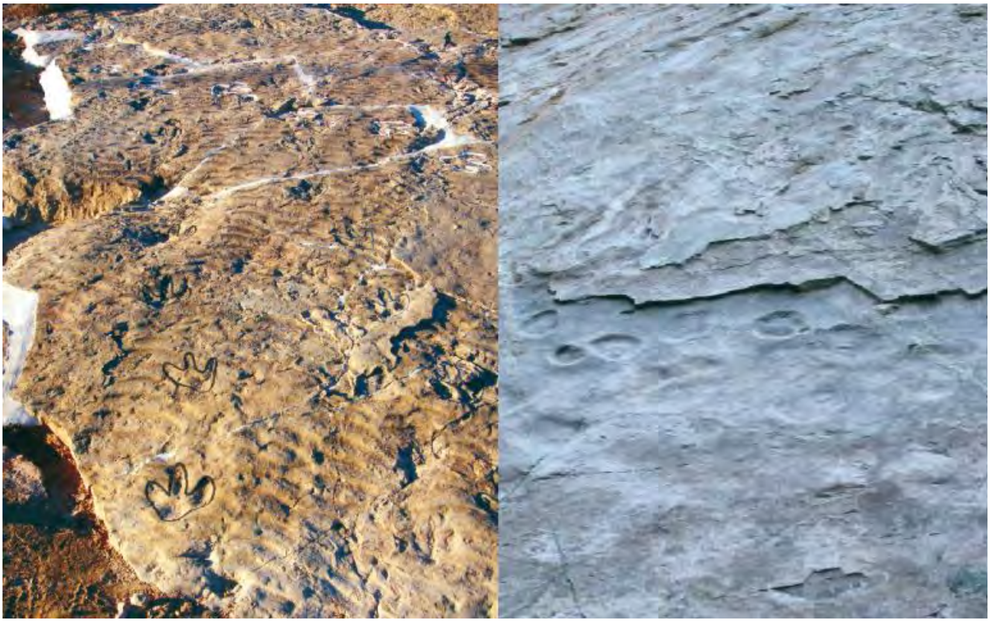

Fig. 1. Upper Jurassic-Lower Cretaceous dinosaur tracksites in Maestrazgo (left) and Yanqing (right) UNESCO Global Geoparks.

The ichnological geosite of Salvador (UNESCO Global Geopark, central Portugal) and the connection of the International Appalachian Trail between Portugal and Spain

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Keywords: Ichnology, Ordovician, Armorican Quartzite Fm., International Appalachian Trail, UNESCO Naturtejo Global Geopark

*The Lo*wer-Middle Ordovician Armorican Quartzite Formation crops out as an antiform at Salvador, in the NW tip of the Penha Garcia-Cañaveral syncline megastructure. The folded succession of quartzites and shales show beds with high bioturbation indices close to others with no or almost no bioturbation. Different ichnospecies of the *Cruziana rugosa* group can be found here in the vertical bedding planes, together with *Skolithos linearis*, *Daedalus halli* and protrusive *Diplocraterion* isp. sectioned by the erosional level at different depths. Interference ripples are shown in one beautiful fold limb, with a large area preserved. The geosite "Quartzite Ridge of Salvador" is one of the 15 included in the municipal inventory of geosites of Penamacor. The identification and study of the geosites takes part of a geoconservation plan in the municipal strategy to foster sustainable tourism, under the recent integration in the UNESCO Naturtejo Global Geopark.

This geosite and its interesting ichnological content is being interpreted under the EU project to make the connection of the International Appalachian Trail, between UNESCO Naturtejo (Portugal) and Villuercas-Ibores-Jara (Spain, Extremadura) geoparks. Both territories are rich in Appalachian-type landforms that are developed in both sides of the Atlantic Ocean by differential erosion of quartzite formations. The Appalachian Trail, one of the most famous footpaths in the world, was recently expanded to cross Europe. In Portugal, the first part of the project was developed in the Naturtejo Geopark, at the Muradal Mountain, Oleiros. It is also a Nature education path where dedicated educational activities can be developed with the main focus on the evolution of Life of Earth, landscape analysis, rocky habitats and adaptation to climate change. Therefore, the geosite will soon have an interpretative panel about local sealife and behaviors during the Ordovician, and included in brochures, guides, etc.

References

Vilas Boas, Mariana, Neto de Carvalho, C., Rodrigues, J.C., and Valente, A. “Património Geológico de Penamacor: inventário de Geossítios e propostas para a sua valorização.” Açafa Online 10, 23-72.

Fig. 1. Quartzite Ridge of Salvador with *Diplocraterion* isp. (black arrow) and interference ripples in a bed showing evidences of microbial mats in the place (white arrow).

Fig. 2. *Diplocraterion* isp. truncated by the bedding plane at different depths

Dinosaur tracksites in the *Sesimbra GEOcircuit:* a municipal project for the characterization and promotion of local Geoheritage

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Keywords: dinosaur tracks, geodiversity, geoconservation, Sesimbra, Portugal

The *Sesimbra GEOcircuit* is a municipal project created, developed and managed in order to inventory, catalog, characterize, interpret and promote the geoheritage of this region which, without doubt, is remarkably diverse (Pólvora *et al*., 2014). Three Natural Monuments of Portugal, designated since 1997, and related to Upper Jurassic – Lower Cretaceous dinosaur tracksites are included in this GEOcircuit: the Avelino Quarry, Pedra da Mua and Lagosteiros tracksites. The *Sesimbra GEOcircuit* webpage (www.cm-sesimbra.pt/geocircuito) reveals the inventoried geosites organized into three categories (landscape, site and outcrop) and yields a brief scientific description of each one and an interactive map with the geosites location. The webpage also displays information concerning the level of scientific, educational and cultural interest of each geosite, the protected status, the level of vulnerability to natural phenomena and to anthropogenic action, and the type of accessibility. The Avelino Quarry Natural Monument was, for nearly two decades, completely ignored as a potential site to promote Geoheritage in spite of its unquestionable geological/palaeontological importance being put into evidence through several scientific dissemination initiatives. Having acknowledged the significance of this tracksite, in 2011 the Sesimbra municipality submitted a proposal to ADREPES, an association for regional development, with the project for its musealization. The application was granted and, in 2012, the till then abandoned quarry was rehabilitated and is presently an excellent example of geoheritage conservation, enhancement and management in Sesimbra (Santos *et al*., 2015). To allow self-guided visits several bilingual outdoor interpretation panels have been put in place (Fig. 1).

References

Pólvora, A., Caetano, P.S. and Santos, V.F."Geocircuito de Sesimbra – uma iniciativa municipal para divulgação e valorização do património geológico local". *In*: J.M. Mata-Perelló (Ed.), *Libro de resúmenes del XV Congreso Internacional sobre Patrimonio Geológico y Minero; XIX Sesión Científica de la SEDPGYM, Logrosán (Cáceres)* (2014): 123-124.

Santos, V.F., Caetano, P.S. and Pólvora, A. "Monumento Natural da Pedreira do Avelino: paradigma de conservação e valorização do património natural de Sesimbra". *Akra Barbarion. Sesimbra, cultura e património*, Câmara Municipal de Sesimbra, nº 1 (2015): 69-83. ISSN: 2183-5756

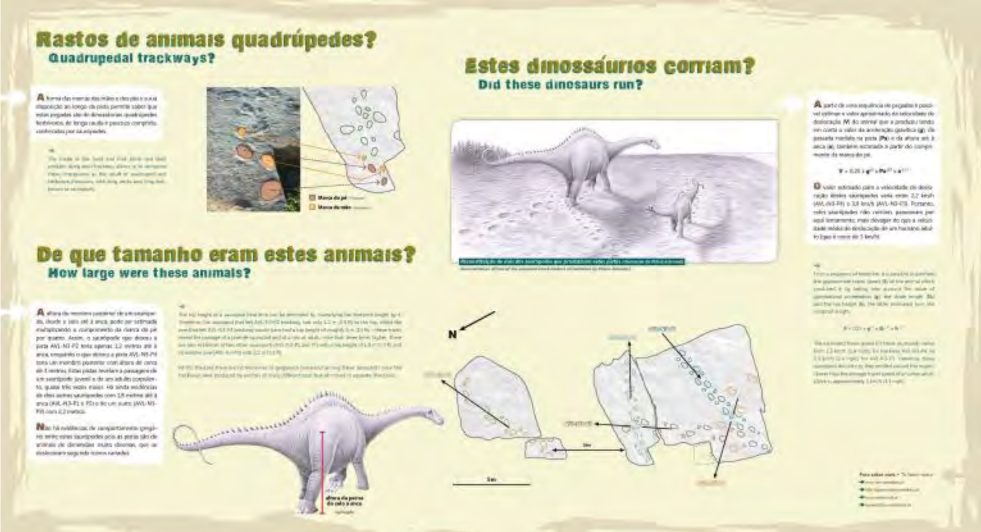

Fig. 1. Outdoor interpretation panel of the Avelino Quarry dinosaur tracksite designated as Natural Monument since 1997, one of the spots of the *Sesimbra GEOcircuit* (Portugal).

Ichnological heritage as a resource to foster geotourism: *The DINOwalk in El Castellar* (Teruel, Spain)

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Keywords: dinosaur tracks, palaeontological heritage, local development, El Castellar, Spain

El Castellar is a small village in the province of Teruel (Aragón, Spain) with only 58 inhabitants at 40 km from the city of Teruel. The Fundación Conjunto Paleontológico de Teruel-Dinópolis has carried out multiple palaeontological activities since 2002, which have brought to light 61 sites with dinosaur fossils (bones and tracks) within five geological formations that delimit a period from the Tithonian to the Aptian. The scientific relevance of some of the sites, specifically four with tracks, led to its statement as Asset of Cultural Interest (*Bien de Interés Cultural*) in the category "*Conjunto de Interés Cultural*", Palaeontological Zone, by the Aragón Government in 2004. Among them, CT-1 (El Castellar) deserves special attention because it is the type locality for *Deltapodus ibericus* and *Iberosauripus grandis* (stegosaurian and large theropod trackmakers respectively).

This enormous diversity of dinosaur fossils has favoured the design of a museographical project called *DINOwalk in El Castellar*. Tourists can admire the diversity of dinosaurs and tracks of the municipality following a route around the streets of the village. Along the route there are several stops with replicas and didactic panels. The DINOwalk also displays, carefully integrated with the local architecture, a reconstruction of a theropod dinosaur, a huge mural of more than 200 square metres recreating a Jurassic landscape (with *Turiasaurus*, *Aragosaurus* and *Dacentrurus*) and a metal sculpture representing *Iberosauripus*. The main aim is to promote the palaeontological heritage of the municipality as a factor for local economic development.

References

Cobos, Alberto, Rafael Royo-Torres, Luis Luque, Luis Alcalá, and Luis Mampel. "An Iberian stegosaurs paradise: The Villar del Arzobispo Formation (Tithonian–Berriasian) in Teruel (Spain)." *Palaeogeography, Palaeoclimatology, Palaeoecology* 293.1-2 (2010): 223-36. Print.

Cobos, Alberto, Martin G. Lockley, Francisco Gascó, Rafael Royo-Torres, and Luis Alcalá. "Megatheropods as apex predators in the typically Jurassic ecosystems of the Villar del Arzobispo Formation (Iberian Range, Spain)." *Palaeogeography, Palaeoclimatology, Palaeoecology* 399 (2014): 31-41. Print.

Fig. 1. Replica of a sauropod ichnite (top) and an *Iberosauripus* metal sculpture (below) in the DINOwalk in El Castellar (Teruel, Spain).

Outstanding Paleozoic ichnofossils from Cabañeros National Park (Central Spain) and large casting processes for the preservation of Geological Heritage

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Keywords: Trace fossils, Cambrian, Ordovician, Geological heritage, large caste

Outstanding trace fossils preserved in Cambrian and Ordovician sandstones constitute part of the geological heritage of Cabañeros National Park (Castilla-La Mancha Region, Central Spain) which has thousands of visitors each year. The lower Cambrian record is represented by the ichnogenus *Astropolichnus*, occurring as convex hyporeliefs, even preserving the central cylinder, or as concave epireliefs on rippled surfaces of the Azorejo Formation (Gutiérrez-Marco *et al*., 2015). Overlaying the Toledanian angular unconformity, the lower Floian "Intermediate Beds" bear unique large burrows, measuring up to 1160 cm long and 20 cm wide, preserved as full-reliefs at the top of several quartzite beds and sometimes forming prominent loops. Further up in the section, the Armorican Quartzite yield abundant traces of the *Cruziana* and *Skolithos* ichnofacies. Among them stands out a large bedding plane covered by "rusophyciform"-like *Cruziana* hyporeliefs, which may reflect a mass-mating event by their producers. Finally, the same beds yielded a very large burrow (45 cm wide) of a still unknown trace (Gutiérrez-Marco *et al*., 2010).
In order to preserve and study these astonishing bedding planes, we made two large casts measuring up to 13.4 m^2. The concentration of a very wide *Cruziana* required the use of thixotropic agents on the moulding silicone and on the polyester shells prepared on-site. The resulting casts were made of epoxy resins, strengthened with woven and non-woven fibreglass fabrics and epoxy rebars, and coloured with mineral pigments (Baeza *et al.*, 2013). The replica of *Cruziana* is the second largest single-piece cast in the world in the field of invertebrate paleoichnology, and is housed in the main Interpretation Centre in Cabañeros National Park as a permanent exhibition.

This research is a contribution to the projects CGL2012-39471 of the Spanish MINECO and 727/2012 of the Spanish National Parks Network.

References

Baeza, E., Gutiérrez-Marco, J.C. & Rábano, I. 2013. Obtención de grandes réplicas de elementos singulares del Patrimonio Geológico del Parque Nacional de Cabañeros (Castilla-La Mancha). Cuadernos del Museo Geominero 15, 573-582.

Gutiérrez-Marco, J.C., Rábano, I., Sá, A.A., Baeza Chico, E., Sarmiento, G.N., Herranz Araújo, P. & de San José Lancha, M.A. de. 2015. Geodiversidad e itinerarios geológicos en el Parque Nacional de Cabañeros. Organismo Autónomo Parques Nacionales, Madrid, Serie investigación en la red, 7, 105-142.

Gutiérrez-Marco, J.C., San José Lancha, M.A. de, Pieren Pidal, A.P., Rábano, I., Baeza Chico, E., Sá, A.A.,

Perejón Rincón, A. & Sarmiento, G.N. 2010. Geología y Paleontología del Parque Nacional de Cabañeros. Organismo Autónomo Parques Nacionales, Madrid, Serie investigación en la red, 3, 29-54.

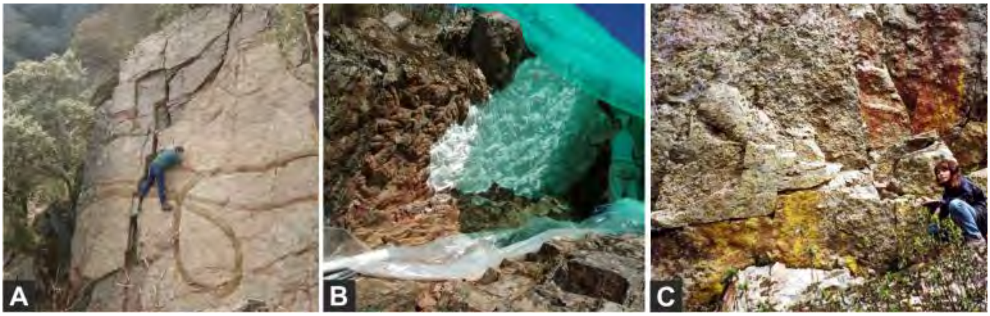

Fig. 1 – Lower Ordovician trace fossils from Cabañeros National Park. A, large looping burrows (under study); B, process of casting a large bedding plane with *Cruziana* on the Estena River section; C, very wide burrow (upper left) in a bed with *Cruziana*.

Ichno diversity disclosure of Salema-Figueira Beach (Algarve)

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Keywords: Ichnofossils, Algarve Basin, Geodiversity disclosure, Geoconservation, Geotourism

Can tourism preserve and promote geoconservation? Will Geotourism be a factor of protection or destruction?

The Algarve Basin coastal area comprehends geological formations spanning from Upper Triassic to Quaternary (Lopes et al., 2000). The coastal area between Salema and Figueira beachs is used by tourists / geotourists, mostly foreigners, that alone or in small groups, usually without a guide, walk across the existing trails.

In this coastal area, the sedimentary rocks of Cretaceous age are rich in ichnofossils, already identified and studied, include tetrapod footprints, such as dinosaurs as well as invertebrate marcks, and arthropod burrow systems (Neto de Carvalho et al., 2010). The latter are less known by tourists, and often cause a lot of curiosity. In order to get more information about these trace fossils, the most curious and interested tourists often go to the Vila do Bispo municipal tourism office. The burrows are three-dimensional intersected galleries horizontally, obliquely and vertically. The exterior of the galleries is characterized by a bulbous texture, due to the reinforced structure by small sediment balls made by arthropods (figure 1).

The disclosure of the rich geological information these places contain must involve local people, providing them with the correct and accurate scientific information of this place. This may rise their awareness for the protection of these and other structures either paleontological or geological.

This disclosure may not increase the tourist pressure on these places, since it already exists, but may help geoheritage and its geoconservation by disclosing / providing information about the geo-history (Hose, 2000) of this place.

References

Lopes, C., Miranda, J.M., Rocha, R.B., Kullberg, J.C. (2000) – *Análise de Subsidência da Bacia do Algarve – Resultados preliminares do estudo da sondagem Ruivo-1.* Assembleia Luso Espanhola de Geodesia e Geofísica. pp. 651-652.

Neto de Carvalho, C., Rodrigues, N.P.C., Viegas, P.A., Baucon, A., Santos, V.F. (2010) – *Patterns of occurrence and distribution of crustacean ichnofossils in the Lower Jurassic–Upper Cretaceous of Atlantic occidental margin basins, Portugal.* Acta Geologica Polonica, 60 (1): 19–28

Hose, T. (2000) - *European "Geotourism": geological interpretation and geoconservation promotion for tourists.* In D. Barettino, W. Wimbledon, E. Gallego (Eds.) Geological Heritage: its conservation and management, IGME, Madrid, 127-146.

Fig. 1. Aspect of the invertebrate arthropod tracks in the Salema Beach - Algarve.

New sauropod ichnites in the Cameros basin, Spain

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Keywords: Sauropods, tracks, Berriasian, Cameros basin, Spain

A new sauropod dinosaurs track site is presented from the Oncala Group, Berriasian of Soria, Spain (Las Aldehuelas district). Twenty-nine ichnites attributable to sauropods, can be identify. The tracks, bad preserved in every case, are found in three levels. In the first one, x tracks seem to belong to the same trackway. Two pes footprints stand out for their height due to be preserved in relief with compacted sediment (Fig.1). Two other ichnites attributable to manus footprints, show similar sedimentary process. The rest of the ichnites of this level (x pes and x manus) are shallow and partially printed. In the third level, with ten tracks, three consecutive footprints, one pes and two manus, allow to estimate a low degree of heteropody (Fig. 2). A third level includes two consecutive subimpresions, attributable to sauropod tracks, in a softer sediment associated with large mud crucks. An ichnotaxonomic assigment of these footprints is difficult due to the bad preservation condition. The track site adds new ichnites to the inventory of sauropods footprint of the Cameros basin. Besides its paleontological interest, this site may have high didactic utility (identification of difficult-to-reed footprints, erosion effects, etc.), altough no touristic value. The area is now used as a livestock pass, and needs conservation measures.
They are preserved in relief with a high mound of compacted sediment layers, consistently with the autopodial size. Very affected by erosion, the ichnites are bad preserved, but their shape, dimensions, and the similarity of the sediment compaction process, make these footprints resemble those of a near track site regarded as Parabrontopodus-like morphotype (Moratalla, 2009 -*Geobios* 42: 797–811-). An ichnotaxonomic assigment of these ichnites is difficult due to the bad preservation condition, and the scarcity of footprints. This site adds new ichnites with this type of relief to the inventory of sauropods footprints of the Cameros basin.

References

Moratalla, José Joaquín. "Sauropod tracks of the Cameros Basin (Spain): Identification, trackway patterns and changes over the Jurassic-Cretaceous". *Geobios* 42 (2009): 797-811.

Galinha tracksite: twenty years as a Natural Monument

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Keywords: sauropod trackways, Middle Jurassic, geoconservation, Natural Monument, Portugal.

The Galinha tracksite begun as a limestone quarry located at Bairro (Ourém – Torres Novas, Portugal), within Serras de Aire and Candeeiros Natural Park, like many others. This situation changes when in 1994 João Carvalho recognized the existence of long sauropod trackways throughout the huge surface that was exposed by the quarry activity. Subsequently to this discovery, Galopim de Carvalho (the former Director of the National Museum of Natural History, Lisbon University) well aware of the importance of that finding initiated a campaign for its protection and in 1996 an agreement was established between the Portuguese Government and Rui Galinha, the former responsible of the quarry. This process culminated with the publication of the Law Decree n.º 12/96 of 22nd October that declare the importance of this dinosaur tracksite (Monumento Natural das Pegadas de Dinossáurios de Ourém - Torres Novas).

Despite of the low, or almost absent, financial support to perform scientific research and scientific spreading actions in this geosite, it has been the subject of several scientific studies due to the collaborative efforts of palaeontologists from different institutions leading to the production of a substantial scientific background that justifies the claims for its scientific and educational relevance (Castanera et al., 2016; Razzolini *et al.*, 2013; Santos *et al.*, 2009). Unfortunately these new data have not yet been included in outreach actions or educational activities in the Natural Monument (Fig. 1) (Santos *et al.*, 2014) and it is worth to have in mind the important fact that this is the most visited site of ichnological interest in Portugal which had a major impact on curricula (revealed in textbooks) and school teachers and also in tourists who recognize the place as a touristic destination of great scientific importance, a place that was the target of a geoconservation strategy and unprecedented musealization in Portugal.

References

Castanera, D., Santos, V.F., Piñuela, L., Pascual, C.; Moratalla, J.J., Vila, B. and Canudo, J.I. "The Iberian sauropod tracks through the time: changes in sauropod manus and pes morphologies". In: P. Falkingham, D. Marty, and A. Richter (Eds.), Dinosaur tracks - The next steps. Indiana University Press, Bloomington (2016): 120-137. Print.

Razzolini, N.L., Santos, V.F., Vila, B., Falkingham, P.L., Castanera, D., Manning, P.L. and Galobart, À. "New ichnological data from Galinha dinosaur tracksite (Bajocian-Bathonian, West-Central Portugal): depth analyses through laser scan". In: S. Brusatte, V. Carrió, N. Fraser, J. Liston and S. Walsh (Eds.), Abstract book of the 61st Symposium of Vertebrate Palaeontology and Comparative Anatomy, Edinburgh, (2013): 62. Web.

Santos, V.F., Moratalla, J.J., Royo-Torres, R. New sauropod trackways from the Middle Jurassic of Portugal. Acta Palaeontologica Polonica 54.3 (2009): 409-22. Web.

Santos, V.F., Alho, J.M., Razzolini, N.L., Castanera, D., Reis, J., Ribeiro, B., Malafaia, E. and Rodrigues, N.P.C. "Twenty years chasing dinosaurs at Galinha tracksite (Portugal). Veinte años persiguiendo a los dinosaurios en el yacimiento de Galinha (Portugal)". In: J.M. Mata-Perelló (Ed.), Libro de resúmenes del XV Congreso Internacional sobre Patrimonio Geológico y Minero; XIX Sesión Científica de la SEDPGYM, Logrosán (Cáceres) (2014): 121-122.

Fig. 1. Outdoor interpretation panel of the Galinha tracksite designated as *Monumento Natural das Pegadas de Dinossáurios de Ourém - Torres Novas*.

"Praia Grande" by Alfredo Keil (1880): a didactic resource for teaching geosciences

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Teaching geosciences in the classroom needs creativeness to explain a wide sort of natural phenomena. Fieldtrips and the analysis of documentaries about situations with geological causes (e.g. earthquakes, volcanic activity, floods, coastal erosion) affecting human population's daily life are essential to materialize theoretical subjects. Some teachers with more affinity with arts may use paintings as a main motif to start a lecture observing them through the eyes of a geologist (Santos & Jácome, 2016) but this is an unusual practice.
It is possible to talk about volcanic phenomena and start a discussion on how weathering affects different kinds of rocks through paintings in museum's art collections, like the painting "Ilha" (1979-80) of the Azorean artist António Dacosta (1914-1990) as exemplified by Santos *et al*. (2014). "Praia Grande" (1880) by Alfredo Keil (1850-1907), representing cliffs near the seashore with boulders and pebbles from the rock scree, can be used to the same purpose. Dinosaur tracks where recognized there by Madeira & Dias (1983) and it became a geosite used as a didactic resource to explain subjects such as coastal erosion and mountains' uplift, dinosaurs diversity, palaeoenvironments and geological time.
This method that links Natural History, museum's art collections and science communication within a non-formal framework can establish a bridge between science and art that may seem not so obvious, to promote public knowledge and awareness about natural history issues and natural heritage, but might also be a way of bringing young students who have chosen a scientific area to art museums.

References

Madeira, J., and Dias, R. Novas pistas de dinossáurios no Cretácico inferior. Comunicações dos Serviços Geológicos de Portugal 69 (1983):147-158.

Santos, V.F., Jácome, G. and Gamboa, D. "Pictures at an exhibition: a look through the eyes of a geologist". Abstract accepted for the European Geosciences Union General Assembly 2016, Vienna, Austria, 17–22 April 2016.

Santos, V.F., Prudêncio, J., Rodrigues, L.A., Costa, A.M., Cavaco, G., Maduro-Dias, F. and Jácome, G. "Communicating natural history through art collections. An example of non formal geoscience education and Geoheritage public awareness through an azorean painting". In: J.C. Nunes, E.A. Lima, M.P. Costa, M. Machado, J. Ponte, F. Gonçalves (Eds.), Abstract Book, Workshop Geoparks in volcanic regions: sustainable development strategies, Terceira and Graciosa Islands, Azores Global Geopark, Portugal (2014): 55-56.

Figura 1. “Praia Grande” (1880), by Alfredo Keil (1850-1907). Museu Nacional de Arte Contemporânea – Museu do Chiado. Direção-Geral do Património Cultural / Arquivo de Documentação Fotográfica (DGPC/ADF). Fotógrafo: Arnaldo Soares.

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