IX Jornadas Internacionales sobre Paleontología de

DINOSAURIOS

y su entorno

9th Symposium about Dinosaurs Palaeontology and their Environment

Abstracts book
Libro de resúmenes

Salas de los Infantes
(Burgos, España)
8 al 10 de septiembre de 2022

Información e inscripciones:
http://dinosaurioscyl.blogspot.com
https://www.facebook.com/dinosaurioscyl
caspaleontologia@gmail.com
teléfono: (0034) 947 397001

Tierra de Dinosaurios

Organiza:

Colectivo Arqueológico y Paleontológico de Salas de los Infantes (Burgos) C.A.S.

Coorganizan:

MUSEO DE DINOSAURIOS Salas de los Infantes

Fundación para el estudio de los Dinosaurios en Castilla y León

Universidad Zaragoza

IUCA Instituto Universitario de Investigación en Ciencias Ambientales de Aragón

Universidad del País Vasco / Euskal Herriko Unibertsitatea

VNiVERSiDAD DSALAMANCA

Colaboradores institucionales:

Excmo. Ayuntamiento de Salas de los Infantes

DIPUTACIÓN DE BURGOS

Entidades colaboradoras:

REALE SEGUROS BENGOECHEA ASESORES

EL POZO

PELAYO EMBUTIDOS ARTESANOS

PASTELERÍA

PANIFICADORA LaSerrana

MIEL MATAVIEJAS

mavic

Editado por: Pedro Huerta, Fidel Torcida Fernández-Baldor, José Ignacio Canudo y Xabier Pereda.

Publica: Colectivo Arqueológico y Paleontológico de Salas, C.A.S.
Plaza Jesús Aparicio, 9, 1º, 09600 Salas de los Infantes (Burgos)
Email: secretaria@colectivosalas.com
Depósito legal: BU 216-2022

ABSTRACTS BOOK / LIBRO DE RESÚMENES

VIII International Symposium about Dinosaurs Palaeontology and their Environment / VIII Jornadas Internacionales sobre Paleontología de Dinosaurios y su Entorno.

Salas de los Infantes, Burgos, Spain

September 8-10th, 2022/ 8 al 10 de Septiembre de 2022

ORGANIZING COMITEE/ COMITÉ ORGANIZADOR

Coordinators / Coordinadores:

- Fidel Torcida Fernández-Baldor, C.A.S. y Museo de Dinosaurios de Salas de los Infantes.
- Pedro Huerta Hurtado, C.A.S. y Universidad de Salamanca.
- José Ignacio Canudo Sanagustín, Universidad de Zaragoza, Grupo Aragosaurus-IUCA.
- Xabier Pereda Suberbiola, Universidad del País Vasco (UPV/EHU).

Members / Miembros:

- Víctor Urién Montero, C.A.S. y Museo Dinosaurios, Salas de los Infantes.
- Gustavo Pérez Martínez, C.A.S. y Museo Dinosaurios, Salas de los Infantes.
- Diego Montero Huerta, C.A.S. y Museo Dinosaurios, Salas de los Infantes.
- Alberto Bengoechea Molinero, C.A.S. y Museo Dinosaurios, Salas de los Infantes.
- Asier Pascual Marquínez, C.A.S. y Museo Dinosaurios, Salas de los Infantes.
- Carlos Llorente Pérez, C.A.S.
- Damián González Ogayar, C.A.S.
- Manuel García Ávila, Asociación Paleontolóxica Galega.
- Jorge Peláez Blanco, Universidad de Wollongong (Australia).
- Diego Escanero Aguilar, Geólogo.
- Sergio Urién Montero, Museo Dinosaurios, Salas de los Infantes.
- Luis Ángel Izquierdo Montero, Museo Dinosaurios, Salas de los Infantes.

SCIENTIFIC COMITEE / COMITÉ CIENTÍFICO

Ainara Badiola	Universidad del País Vasco/EHU, España.
José Luis Barco	Paleoymás. Zaragoza, España.
José Luis Carballido	Museo Egidio Feruglio, Trelew, Argentina.
Penélope Cruzado Caballero	Universidad de La Laguna (España).
Gloria Cuenca Bescós	Universidad de Zaragoza-IUCA, España.
Ángela Delgado Buscalioni	Universidad Autónoma de Madrid, España.
José Manuel Gasca	Universidad de Salamanca, España.
Pascal Godefroit	Royal Belgian Institute of Natural Sciences, Bélgica.
Joaquín Moratalla	Instituto Geológico y Minero de España, Madrid, España.
Adán Pérez-García	Universidad Nacional de Educación a Distancia, España.
Laura Piñuela	Museo del Jurásico de Asturias, España.
Rafael Royo-Torres	Universidad de Zaragoza, grupo Beagle-IUCA, España.
Bernat Vila	Institut Català de Paleontologia Miquel Crusafont, España.
Diego Castanera	Fundación Conjunto Paleontológico de Teruel-Dinópolis, España.
Luis Miguel Sender	Fundación Conjunto Paleontológico de Teruel-Dinópolis, España.
Attila Ősi	Eötvös Loránd University, Hungría.
Elisabete Malafaia	Universidade de Lisboa, Portugal.
Steve Brussate	University of Edinburg, Reino Unido.
Miguel Moreno-Azanza.	Universidade Nova de Lisboa,Portugal.
Adrián Páramo Blázquez	Universidad Autónoma de Madrid, España.
Octávio Mateus	Universidade Nova de Lisboa, Portugal.

INDEX

CONFERENCIAS/KEYNOTE LECTURES

COMMUNICATIONS / COMUNICACIONES

Programa/Schedule

Time	WEDNESDAY 7	THURSDAY 8	FRIDAY 9	SATURDAY 10
8:30		Recogida de documentación		
9:00		Presentation	*Keynote* *P. Martin Sander*	Excursión Yacimientos paleontológicos
9:15		*Keynote* D. Norman		Field Trip
9:30				
9:45				*10:00-14:00*
10:00			Comunicaciones *Oral Communications*	
10:15		Comunicaciones *Oral Communications*		
10:30				
10:45				
11:00		Pausa café/ *Cofee Break*	Pausa café/ *Cofee Break*	
11:30		Comunicaciones *Oral Communications*	*Keynote* A. Paulina-Carabajal	
11:45				
12:00				
12:15				
12:30		Actos Protocolarios	Comunicaciones *Oral Communications*	
12:45				
13:00		*Keynote* I. Díaz Martínez		
13:15				
13:30				
13:45				
14:00		Comida/Lunch	Comida/Lunch	
16:00		*Keynote* V. Díez	*Keynote* E. Cuesta	
17:00		Comunicaciones *Oral Communications*	Pausa café *Cofee Break*	
17:15				
17:30		Pausa café *Cofee Break*	*Keynote* B. Díez	
17:45				
18:00		Comunicaciones *Oral Communications*		
18:15				
18:30		*Keynote* C. T. Gee	Sesión Póster y cerveza Póster Sesión and Beers	
19:00				
19:30		L. Salgado		
20:00	Beer Tasting			
21:00	Concert: The Lucky makers		Gala Dinner	
22:45			Concert: Flamenco Jazz Company	

Horario **Schedule**	**Jueves día 8** **Thursday 8**
8:30	Recepción de asistentes y entrega de documentación / Registration Open.
9:00	Presentación de las Jornadas / Welcome and Opening Remarks.
9:15	Conferencia Plenaria / Conference **D. Norman** New insights concerning the origin of the Ornithischian bauplan (Archosauria: Dinosauria)
10:15	Sesión de comunicaciones / Oral Communications. 10:15-10:30. **Torcida et al.,** A new possible Diplodocoidea from the Berriasian of Spain. 10:30-10:45. **Puértolas et al.,** New fossil assemblage with crocodylomorphs and other vertebrates around the Jurassic-Cretaceous transition of the Cameros basin (Soria, Spain). 10:45-11:00. **Torcida et al.,** New teeth of a basal Macronaria (Sauropoda) from the Jurassic-Cretaceous transition of Spain
11:00	Pausa café / Coffee Break
11:30	Sesión de comunicaciones / Oral Communications. 11:30-11:45. **Castanera et al.,** Los Corrales del Pelejón tracksite (Lower Cretaceous, Galve) revisited: track preservation and ichnotaxonomy. 11:45-12:00. **Filippi et al.,** Infecciones en vértebras caudales de saurópodos titanosaurios del Cretácico Superior de Patagonia, Argentina. 12:00-12:15. **Escanero et al.,** Cranial and mandibular material from a hadrosauriform dinosaur from the Lower Cretaceous of Los Terreros-Altollano I site (Salas de Los Infantes, Burgos, Spain). 12:15-12:30. 12:30-12:45.
12:30	Actos Protocolarios.
13:00	Conferencia Plenaria / Conference. **I. Díaz Martínez** What do their footprints tell us? Many questions and some answers about the life of non-avian dinosaurs.
14:00	Comida / Lunch.
16:00	Conferencia Plenaria / Conference. **V. Díez Díaz** From notebook to computer: new technologies at the service of dinosaur research
17:00	Sesión de comunicaciones / Oral Communications. 17:00-17:15. **Parrilla-Bel, et al.,** Crocodylomorph diversity in Barranco del Hocino-1 site (Barremian, Lower Cretaceous) in Estercuel (Teruel, Spain). 17:15-17:30. **López-Fernández et al.,** Palinoestratigrafía del yacimiento de dinosaurios de Los Ganchos (Fm. Villar del Arzobispo, Alpuente, Valencia).
17:30	Pausa café / Coffee Break.
18:00	Sesión de comunicaciones / Oral Communications. 17:00-17:15. **Rodríguez-Barreiro, et al.,** Middle Jurassic to Late Cretaceous from the Las Loras Geopark (N Iberian Peninsula): An overview of the plant communities based on palynology. 17:15-17:30. **Vila et al.,** The dominion of large-bodied titanosaurs at the run-up to the end-Cretaceous extinction in SW Europe (Eusuchia, Crocodylia) during the Maastrichtian (Late Cretaceous) of the northeastern Iberia.
18:30	Conferencia plenaria / Conference **C. T. Gee** Feeding herbivorous dinosaurs: Young and old.
19:00	Videconferencia plenaria / Video-conference (20 min). **L. Salgado**

Horario Schedule	**Viernes día 9 Friday 9**
9:00	Conferencia Plenaria / Conference **M. Sander** Cut them up to tell them apart: Systematic value of long bone histology of major clades of Dinosauria.
10:00	Sesión de comunicaciones / Oral Communications 10:00-10:15. **Castillo-Visa et al.,** Nodosaurid osteoderms from the Late Maastrichtian (Late Cretaceous) of Southern Pyrenees. 10:15-10:30. **Cabezuelo Hernández et al.,** New data on the appendicular skeleton of the simosaurid *Paludidraco multidentatu*s holotype (Eosauropterygia) from the Upper Triassic of El Atance (Guadalajara, Spain). 10:30-10:45. **Pérez-García, et al.,** Was *Aragochersis* the only helochelydrid turtle that lived in the Spanish Albian area of Ariño? 10:45-11:00. **García-Ávila et al.,** 3D reconstructions of evidence of insect galleries in gymnosperm trunks from the Lower Cretaceous of the Pinilla de los Moros Formation (Salas de los Infantes, Burgos, Spain).
11:00	Pausa café / Coffee Break,
11:30	Conferencia Plenaria / Conference. **A. Paulina-Carabajal** Sensory biology in dinosaurs: what we know and how we know it?
12:30	Sesión de comunicaciones / Oral Communications. 12:30-12:45. **García-Cobeña et al.,** An overview of the dinosaur faunas from the El Castellar Formation (upper Hauterivian-lower Barremian, Lower Cretaceous) of Teruel, Spain). 12:45-13:00. **Santos et al.,** Palinología de la sucesión del Jurásico Superior en “La Costa de los Dinosaurios” (Asturias, España): Nuevos datos palinoestratigráficos y paleoambientales de la Formación Lastres. 13:00-13:15. **Martín-Jiménez and Pérez-García,** Neuroanatomy of the bothremydid turtle *Zolhafah bella* (Pleurodira) from the Maastrichtian of Egypt. 13:15-13:30. **Martínez de Espronceda et al.,** One of the last dinosaur-bearing sites before the K/Pg boundary (Veracruz 1, NE Spain): A palynostratigraphical and paleoecological approach. 13:30-13:45. **Sanguino et al.,** Ecological constraints of the titanosaur nesting areas from the Upper Cretaceous of the Villalba de la Sierra Fm (Cuenca and Guadalajara, Central Spain). 13:45-14:00. **Páramo et al.,** A sampling method to study the Titanosaurian pelvis with 3D Geometric Morphometrics.
14:00	Comida / Lunch.
16:00	Conferencia plenaria / Conference. **E. Cuesta** From *Concavenator* to *Pelecanimimus*: Everything you wanted to know about the theropods from Las Hoyas, Cuenca.
17:00	Pausa café / Coffee Break,
17:30	Conferencia plenaria / Conference. **B. Díez** Flowering among dinosaurs
18:30	Sesión Póster y Cervezas / Poster Session and Beers.

21:00	Cena de clausura (gratuita para todos los participantes) / Closing Dinner (free)
22:45	Concierto / Concert: *Flamenco Jazz Company*
Horario **Schedule**	**Sábado día 10** **Saturday 10**
10:00	Excursión yacimientos paleontológicos / Field Trip to palaeontological sites.
14:00	

Pósters

Basso, A. Carbonatic rocks in the quarry of La Corte-Campanedda, Nurra, Sardinia N-W: sedimentological, stratigraphic analysis and paleo-environmental reconstruction.

Blanco, A., Pol, D., Rauhut, O.W.M. Reigniting Stromer's crocodyliforms from the Bahariya Formation (Cenomanian, Late Cretaceous, North Africa).

Cabezuelo Hernández, A. y Pérez-García, A., First record of a probable squamate reptile from the Cenomanian of Algora (Guadalajara, Central Spain).

Castillo Visa, Ó.; Serrano, J.; Baiano, M. A.; Vila, B., Review of the theropod teeth from the Upper Maastrichtian Molí del Baró-1 locality (Southwestern Pyrenees).

Franco, R., Análisis tafonómico de los límites de secuencia de la formación Picofrentes (Cretácico Superior) en Segovia.

Guerrero y Pérez García, Shell anomalies of the Spanish Cenomanian bothremydid turtle *Algorachelus peregrine.*

Medrano Aguado, E.; Parrilla-Bel, J.; Canudo, J.I., New data about the Sauropoda record of the Blesa Formation (Lower Cretaceous) in northeast Spain.

Pérez García, A.; Camilo, B.; Ortega, F., New shell information for the oldest European pleurosternid turtle: the Portuguese Kimmeridgian *Selenemys lusitánica.*

Pérez García, A. New information provided by the recent finds of helochelydrid turtle remains in the Spanish Cenomanian site of Algora.

Rial, S. Santos, A. A., Rodríguez-Barreiro, I., Piñuela, L.; García-Ramos, J.C., Diez, J.B., Palinología del Pliensbachiense superior-Toarciense inferior de la Formación Rodiles en los acantilados de Lastres (Asturias, España).

Salas Herrera, J. Escaso, F., Gasulla, J.M.; Ortega, F., A tibia of *Iguanodon bernissartensis* with patological morphology from the Lower Cretaceous of Arcillas de Morella Formation (Castellón, Spain).

Simarro. A.; Arias-Riesgo C.; Torcida Fernández-Baldor, F. New insights on the theropod paleodiversity of the Upper Jurassic of the Cameros Basin (N. Spain).

Suñer Fuster, M., Royo-Torres, R., Marin-Monfort, M.D., Sánchez-Fenollosa, S., Gamonal, A., Galobart, A., Santisteban de, C. El braquiosáurido de Los Ganchos (Jurásico Superior) de Alpuente (Valencia, España). Recuperación, estudio y divulgación.

Vázquez López, B.; Vila, B.; Castanera, D., Titanosaurian (Dinosauria: Sauropoda) dental material from the Els Nerets locality (Upper Cretaceous, Southern Pyrenees).

CONFERENCIAS/ KEYNOTE LECTURES

From *Concavenator* to *Pelecanimimus*: Everything you wanted to know about the theropods from Las Hoyas, Cuenca

Cuesta, E.[1]

[1] *Bayerische Staatssammlung für Paläontologie und Geologie, Richard-Wagner-Straße 10, 80333 München, Germany.elena.cuestaf@gmail.com*

Keywords: Dinosaur, Cretaceous, Carcharodontosauridae, Ornithomimosauria, Spain

Las Hoyas fossil site is a *Konservat-lagersttäte*from the Lower Cretaceous of Cuenca (east of Iberian Peninsula) that it is worldwide known due to the excellent state of preservation of its fossil record. Despite of large non-avian dinosaurs are rare in this record, Las Hoyas is also well-known for the amazing discoveries of several representatives of this group, which have the distinctive features of preservation found in all the fossil of the site. The non-avian dinosaur record in Las Hoyas is represented by three taxa so far. An ornithopod conferred to *Mantellisaurus* (Llandrés-Serrano et al., 2013), whose fossil material is a completely articulated foot that preserves skin impressions around its toes. The other two taxa from the site are theropods and they are the core of this research. *Concavenator corcovatus* Ortega et al (2010) is the biggest dinosaur found in Las Hoyas and it is one of the most complete and articulated theropod found in Europe, just few caudal vertebrate are missing. *Concavenator* is an early-branched carcharodontosaurid based on recent phylogenies (e.g. Rauhut and Pol, 2019). Carcharodontosauridae is a clade with a wide distribution around Laurasia and Gondwana during the Cretaceous. Historically, the group was considered exclusive of Gondwana (e.g.; Novas et al., 2005). However, posterior discoveries of carcharodontosaurids in Europe and Asia (e.g. Ortega et al., 2010; Gasca et al., 2014) involve that the group have a wider palaeogeographical distribution.

Within Carcharodontosauridae, *Concavenator* shows several autapomorphies in the skull such as the grooves connecting the recesses in the nasal surface or a rounded ventral morphology of the postorbital boss (Cuesta et al., 2018a). The axial skeleton of *Concavenator* is characterized by an unusual hump in its back due to the unique presence of hypertrophied dorsal and caudal neural spines. Other axial autapomorphies are the imbricated dorsal neural spines, accessory processes in the anterior caudal neural spines and the excavated lateral groove in posterior caudal vertebrae. Finally, the appendicular skeleton also presents some autapomorphies as an anteriorly low deltopectoral crest or a low proportion of the olecranon process relative to ulna length. The skeleton of *Concavenator* reveals several evidences of gigantism from the earlier-branched node of

Carcharodontosauridae, such as the reduction of the forelimb as result of a pedomorphic process (Cuesta et al., 2018b; 2019); and an early specialization of the skull in Carcharodontosauridae, which tends to peramorphic conditions (Cuesta et al., 2018a). These hypotheses from the osteological analysis of *Concavenator* are recently supported by new discoveries in the group (Canale et al., 2022).

The excellent preservation of *Concavenator* allowed to analyse the tegumentary impression around the hindlimb (Cuesta et al., 2015; Hendrickx et al., 2022). This analysis enables evidences, for the first time, of the presence of an avian podotheca structure in a non-avian theropod, which sparked a revolution in the research field of the ichnology. The podotheca of *Concavenator* has been featured by three different types of scales distributed in the same pattern that those observed in extant birds. Moreover, the pes of *Concavenator* preserved the pedal pads silhouette and the ungual corneal sheat.

The first non-avian dinosaur found in Las Hoyas was the theropod *Pelecanimimus polyodon* Pérez-Moreno et al. (1994), which was also the first ornithomimosaur described in Europe. The holotype of *Pelecanimimus* is also almost complete but only the anterior half of the skeleton, including the skull, is preserved. It is also extremely well-preserved in relation of the soft-tissues structures. Ornithomimosauria is a Coelurosaurian clade, more derived than Tyrannosauroidea and the sister group of Maniraptora, being one of the earlier-branched clades within maniraptoriforms (Choiniere et al., 2012). Moreover, this is a clade of highly specialized theropod dinosaurs, whose functional behaviour has hitherto been subject of debate. Ornithomimosaurs are widely distributed throughout the world, especially in Cretaceous beds of Asia and North America. The most striking feature of *Pelecanimimus polyodon* is the presence of over 200 teeth in the upper and lower jaws, contrary to the edentulous condition on most of the taxa of this group. Pérez-Moreno et al. (1994) proposed that the teeth acted as a functional counterpart of the cutting edge of a beak. This function becomes an exaptation with a slicing effect, eventually leading to the cutting edge observed in most derived ornithomimosaurs. This hypothesis has been supported most recently by Zanno and Makovicky (2011), who observed that the conical teeth in primitive taxa of a clade are present in the same areas of subsequent tooth loss, and thus, might have the same functionality. Ornithomimosaurian feeding behaviour has been debated over the years (e.g. Norell et al., 2001). Recent studies consider that the principal morphological features of ornithomimosaurs are indicative of herbivorous feeding (e.g. Cuff and Rayfield, 2015). If *Pelecanimimus* is assumed to be also herbivorous, this implies that the evolution of herbivory preceded that of tooth loss in ornithomimosaurs, and was probably present in the entire group Macrocheiriformes (*Pelecanimimus* + derived ornithomimosaurs, Cuesta et al., 2021). To perform a biomechanical analysis to understand its feeding behaviour, the skull of *Pelecanimimus* was CT-scanned and segmented bone by bone. A posterior reconstruction of the skull, requiring an assembly of bones with fragments preserved in the slab and counterslab, was carried out and, then, it was completed with an articulation of complete bones and teeth and finally the reintegration of missing parts, most done by mirroring more complete counterlateral bones. Retrodeformation was made both manually and automated based on landmark symmetry.

There are not just unusual features in the skull of *Pelecanimimus*. *Pelecanimimus* is also the only ornithomimosaur that preserves an ossified sternum. The sternum of *Pelecanimimus* has morphology similar to other dinosaurs closely related to birds, such as *Velociraptor, Oviraptor* and early-branched birds and even early-branched theropods as *Tawa* (Cuesta et al., 2021). However, this bone is rare to found in the record, so understand its evolution is still awkward. It is also the only known ornithomimosaur with uncinate processes. These bony processes are associated to the ribs and they are present in other non-avian dinosaurs closely related to birds, as *Velociraptor*, and extant and extinct birds (e.g. Codd, 2010). The uncinate processes have been related to the breathing apparatus because they are insertion areas for intercostal muscles, whose function is moving the ribs and sternum. The presence of long uncinate processes may have helped keep cost of ventilation down in early birds (Brocklehurst et al., 2020). Since *Pelecanimimus* has these long processes, this could indicate that it also had a breathing mechanism similar to that of birds. Finally, the hand of *Pelecanimimus* is strongly characteristic in this taxon. Observing the most plesiomorphic hand of *Nqwebasaurus* (Choiniere et al., 2012), with short phalanges and a short metacarpal I, there is a tendency to elongate the digits in the other ornithomimosaurs, including *Pelecanimimus* (Cuesta et al., 2021). This elongation is related to the elongation of the metacarpals and the distal phalanges in most of ornithomimosaurs. For that, a new group within Ornithomimosauria was named, Macrocheiriformes (Cuesta et al., 2021), which includes the most recent common ancestor of *Ornithomimus* and *Pelecanimimus* and all its descendants.

The completeness and well preservation of both theropod dinosaurs from Las Hoyas fossil site have allowed to decipher the evolutionary history of both groups that they belong to, Carcharodontosauridae and Ornithomimosauria. All this compilation of the highlighted outcomes from the recent researches related to these taxa is a summary of the potential of this fossil material that will continue to be studied for future research to further improve our understanding of this lineage.

References

Brocklehurst, R. J., Schachner, E. R., Codd, J. R., Sellers, W. I. (2020): Respiratory evolution in archosaurs. *Philosophical Transactions of the Royal Society B*, 375 (1793), 20190140.

Canale, J. I., Apesteguía, S., Gallina, P. A., Mitchell, J., Smith, N. D., Cullen, T.M., Shinya, A., Haluza, A., Gianechini, F.A.,Makovicky, P.J. (2022): New giant carnivorous dinosaur reveals convergent evolutionary trends in theropod arm reduction. *Current Biology,* In press.

Choiniere, J. N., Forster, C. A., de Klerk, W. J. (2012): New information on *Nqwebasaurusthwazi*, a coelurosaurian theropod from the Early Cretaceous Kirkwood Formation in South Africa. *Journal of African Earth Sciences*, 71, 1-17.

Codd, J.R. (2010): Uncinate processes in birds: morphology, physiology and function. *Comparative Biochemistry and Physiology – A Molecular and Integrative Physiology*, 156, 303–308.

Cuesta, E., Diaz-Martinez, I., Ortega, F., Sanz, J. L. (2015): Did all theropods have chicken-like feet? First evidence of a non-avian dinosaur podotheca. *Cretaceous Research*, 56, 53-59.

Cuesta, E., Ortega, F., Sanz, J. L. (2018b): Appendicular osteology of *Concavenator corcovatus* (Theropoda: Carcharodontosauridae) from the Lower Cretaceous of Spain. *Journal of Vertebrate Paleontology*, 38(4), 1-24.

Cuesta, E., Ortega, F., Sanz, J. L. (2019): Axial osteology of *Concavenator corcovatus* (Theropoda; Carcharodontosauria) from the Lower Cretaceous of Spain. *Cretaceous Research*, 95, 106-120.

Cuesta, E., Vidal, D., Ortega, F., Sanz, J. L. (2018a): The cranial osteology of *Concavenator corcovatus* (Theropoda; Carcharodontosauria) from the Lower Cretaceous of Spain. *Cretaceous Research*, 91, 176-194.

Cuesta, E., Vidal, D., Ortega, F., Shibata, M., Sanz, J. L. (2021): *Pelecanimimus* (Theropoda: Ornithomimosauria) postcranial anatomy and the evolution of the specialized manus in Ornithomimosaurs and sternum in maniraptoriforms. *Zoological Journal of the Linnean Society*, 194 (2), 553-591.

Cuff, A. R., Rayfield, E. J. (2015):Retrodeformation and muscular reconstruction of ornithomimosaurian dinosaur crania. *PeerJ*, 3, e1093

Gasca, J.M.; Canudo, J.I.; Moreno-Azanza, M. (2014): A large-bodied theropod (Tetanurae: Carcharodontosauria) from the Mirambel Formation (Barremian) of Spain. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen,* 273, 13–23.

Hendrickx, C., Bell, P. R., Pittman, M., Milner, A. R., Cuesta, E., O´Connor, J., Loewen, M., Currie, P.J., Mateus, O., Kave, T.G., Delcourt, R. (2022): Morphology and distribution of scales, dermal ossifications, and other non-feather integumentary structures in non-avialan theropod dinosaurs. *Biological Reviews,* 97 (3), 960-1004.

Llandrés-Serrano, M., Vullo, R., Marugan-Lobon, J., Ortega, F., Buscalioni, A.D. (2013): An articulated hindlimb of a basal iguanodont (Dinosauria, Ornithopoda) from the Early Cretaceous Las Hoyas Lagerstätte (Spain). *Geological Magazine,* 150 (3), 572-576.

Norell, M. A., Makovicky, P., Currie, P.J. (2001): The beaks of ostrich dinosaurs. .*Nature*, 412:873–874.

Novas, F.E.; De Valais, S.; Vickers-Rich.P.; Rich, T. (2005): A large Cretaceous theropod from Patagonia, Argentina, and the evolution of carcharodontosaurids. *Naturwissenschaften*, 92: 226–230.

Ortega, F., Escaso, F., Sanz, J. L. (2010): A bizarre, humped Carcharodontosauria (Theropoda) from the Lower Cretaceous of Spain. *Nature*, 467 (7312), 203-206.

Pérez-Moreno, B. P., Luis Sanz, J., Buscalioni, A. D., Moratalla, J.J., Ortega, F., Rasskin-Gutman, D. (1994): .A unique multitoothed ornithomimosaur dinosaur from the Lower Cretaceous of Spain. *Nature*, 370 (6488), 363-367.

Rauhut, O. W., Pol, D. (2019): Probable basal allosauroid from the early Middle Jurassic Cañadón Asfalto Formation of Argentina highlights phylogenetic uncertainty in tetanuran theropod dinosaurs. *Scientific reports,* 9 (1), 1-9.

Zanno, L.E., Makovicky, P. J. (2011): Herbivorous ecomorphology and specialization patterns in theropod dinosaur evolution. .*Proceedings of the National Academy of Sciences*, 108 (1), 232-237.

What do their footprints tell us? Many questions and some answers about the life of non-avian dinosaurs

Díaz-Martínez, I.[1,2,3]

1 Instituto de Investigación en Paleobiología y Geología (IIPG). CONICET. Av. Roca 1242, General Roca, 8332, Río Negro, Argentina. idiaz@unrn.edu.ar
2 Universidad Nacional de Río Negro-IIPG. General Roca. Río Negro, Argentina.
3 Geology Department, Science and Technology Faculty, University of the Basque Country.

Keywords: dinosaur tracks, paleoecology, locomotion, paleoenvironment.

Footprints are ethologic structures made by the autopods of vertebrates modifying a substrate. Its study provides valuable information about the biology of the trackmaker, such as its locomotion mode, anatomy, and intra/inter-specific behavior (e.g., García-Ortiz and Pérez-Lorente, 2014; Citton et al., 2018; Farlow, 2018). The *in situ* nature of footprints, in contrast to the *post-mortem* transportability of body fossils, makes ichnological sites reliable indicators of biodiversity and paleoenvironment, since each footprint represents an animal who lived, at least temporarily, in that area. For all these reasons, ichnological studies contribute to the reconstruction of paleocommunities, paleoecological aspects and paleoenvironments (e.g., Falkingham, 2014; Melchor, 2015; Díaz-Martínez et al., 2022).

Non-avian dinosaurs are a group of very diverse vertebrates that were raised about 230 My ago and became extinct at the end of the Cretaceous. They lived on all continents from low latitudes to the polar circle and their footprints have been found in diverse terrestrial and transitional environments, such as fluvial, lacustrine, alluvial, volcanic, aeolian, or coastal (e.g., Cónsole Gonella et al., 2021; Díaz-Martínez et al., 2015, 2017, 2018, 2022).

From an anatomical perspective, footprints provide valuable information about the locomotion gait and autopod morphology. The arrangement of the footprints in trackways confirms some inferences made from osteology, such as sauropods and much of the large ornithischians are quadrupedal, or that theropods and small ornithischians moved with a bipedal gait (Thulborn, 1990). The footprints also tell us about an intermediate stage between bipedalism and quadrupedalism, the facultative quadrupedality, in some groups of dinosaurs (e.g., sauropodomorphs, iguanodonts, basal thyreophorans) (Le Loeuff et al., 1999; Avanzini et al., 2003; Castanera et al., 2012; Díaz-Martínez et al., 2016). Almost all the bipedal dinosaurs impressed tridactyl footprints, although there are also didactyl or tetradactyl ones (Nouri et al., 2011; Kim et al., 2012). Indeed, the conservative theropod pes morphology (i.e., functionally tridactyl, several pads in each digit, acute claws) appears in the ichnological record, in the Middle Triassic (Brusatte et al., 2011), before the earliest theropods. Quadrupedal dinosaurs usually left tetradactyl to pentadactyl pes tracks and very variable manus tracks from imprints without digit to five-digit impressions (see Torcida Fernández-Baldor et al., 2021). Moreover, footprints can preserve information about the soft tissues of the dinosaur podotheca. Pad impressions show the placement and size of digital cushions (Thulborn, 1990; Cuesta et al., 2015), and scale impressions reveal the shape, size, and arrangement of skin papillae (Kim et al., 2010).

The arrangement and orientation of trackways are usually used to discuss dinosaur ethology. Within the intraspecific behaviour it is possible to infer: running, trackways with long stride length (Navarro-Lorbés et al., 2021); swimming, trackways with only claw impressions made in semi-buoyancy (Ezquerra et al., 2007); limping, trackways with different pace length (Razzolini et al., 2016); courtship, footprints are arranged as in avian-like scrape ceremony (Lockley et al., 2016); tortuosity; trackways with abrupt changes in the direction of displacement (Lockley et al., 2021); and gregariousness, parallel trackways or accumulations with footprints of similar morphology (Castanera et al., 2011; García-Ortiz et al., 2014). Interspecific inferences are not common in the fossil record. The most abundant ones refer to the predator-prey or scavenging relationship. In the Lower Cretaceous of the USA, a theropod trackway was found close to and in the same direction as a sauropod trackway and was interpreted as a possible hunting scene (Thomas and Farlow, 1997).

With this text, I would like to show that footprints provide valuable information about the life of dinosaursthat are often unknown from the study of bones. Nevertheless, there are numerous challenges to be solved in the future. For instance, to use the dinosaur footprints within the ichnofacies studies, it would be necessary to deepen the ecological relationship of each clade of dinosaurs with their environment. In addition, there are still many questions that could be answered with the ichnological evidence on reproduction, initiation of flight, diving, maximum speeds, intraspecific social behavior, etc.

References

Avanzini, M., Leonardi, G., Mietto, P. (2003): *Lavinipes cheminii* ichnogen., ichnosp. nov., a possible sauropodomorph track from the Lower Jurassic of the Italian Alps. *Ichnos*, (10), 179-193.

Brusatte, S.L., Niedźwiedzki, G., Butler, R.J. (2011): Footprints pull origin and diversification of dinosaur stem lineage deep into Early Triassic. *Proceedings of the Royal Society B: Biological Sciences*, (278), 1107-1113.

Castanera, D., Barco, J.L., Díaz-Martínez, I., Herrero-Gascón, J., Pérez-Lorente, F., Canudo, J.I. (2011): New evidence of a herd of titanosauriform sauropods from the lower Berriasian of the Iberian range (Spain). *Palaeogeography, Palaeoclimatology, Palaeoecology*, (310), 227-237.

Castanera, D., Pascual, C., Razzolini, N.L., Vila, B., Barco, J.L., Canudo, J. I. (2013): Discriminating between medium-sized tridactyl trackmakers: tracking ornithopod tracks in the base of the Cretaceous (Berriasian, Spain). *PloS one*, (8, 11), e81830.

Citton, P., Díaz-Martínez, I., de Valais, S., Cónsole-Gonella, C. (2018): Triassic pentadactyl tracks from the Los Menucos Group (Río Negro province, Patagonia Argentina): possible constraints on the autopodial posture of Gondwanan trackmakers. *PeerJ*, (6), e5358.

Cónsole-Gonella, C., Díaz-Martínez, I., Citton, P., de Valais, S. (2021): New record of Late Cretaceous vertebrate tracks from the Yacoraite Formation (Juella, Quebrada de Humahuaca, northwestern Argentina): aerial drone survey, preservation and sedimentary context. *Journal of South American Earth Sciences*, (107), 103116.

Cuesta, E., Díaz-Martínez, I., Ortega, F., Sanz, J. L. (2015): Did all theropods have chicken-like feet? First evidence of a non-avian dinosaur podotheca. *Cretaceous Research*, (56), 53-59.

Díaz-Martínez, I., Cónsole-Gonella, C., de Valais, S., Salgado, L. (2018): Vertebrate tracks from the Paso Córdoba fossiliferous site (Anacleto and Allen formations, Upper Cretaceous), Northern Patagonia, Argentina: Preservational, environmental and palaeobiological implications. *Cretaceous Research*, (83), 207-220.

Díaz-Martínez, I., de Valais, S., Cónsole-Gonella, C. (2016): First evidence of Hadrosauropodus in Gondwana (Yacoraite Formation, Maastrichtian-Danian), northwestern Argentina. *Journal of African Earth Sciences*, (122), 79-87.

Díaz-Martínez, I., García-Ortiz, E., Pérez-Lorente, F. (2015): A new dinosaur tracksite with small footprints in the Urbión Group (Cameros Basin), Lower Cretaceous, La Rioja, Spain). *Journal of Iberian Geology*, (41), 167-175.

Díaz-Martínez, I., González, S.N., de Valais, S. (2017): Dinosaur footprints in the Early Jurassic of Patagonia (Marifil Volcanic Complex, Argentina): biochronological and palaeobiogeographical inferences. *Geological Magazine*, (154), 914-922.

Díaz-Martínez, I., López-Horgue, M. A., Agirrezabala, L. M., Cónsole-Gonella, C., Pereda-Suberbiola, X. (2022): Dinosaur tracks in a Cretaceous (lower Albian) braid delta system (Basque-Cantabrian Basin, western Pyrenees): linking trace fossils suites and short-term preservation windows. *Geological Society, London, Special Publications*, (522), SP522-2021.

Ezquerra, R., Doublet, S., Costeur, L., Galton, P.M., Pérez-Lorente, F. (2007): Were non-avian theropod dinosaurs able to swim? Supportive evidence from an Early Cretaceous trackway, Cameros Basin (La Rioja, Spain). *Geology*, (35, 6), 507-510.

Falkingham, P.L. (2014): Interpreting ecology and behaviour from the vertebrate fossil track record. *Journal of Zoology*, (292), 222-228.

Farlow, J.O. (2018): Noah's ravens: Interpreting the makers of tridactyl dinosaur footprints. Indiana University Press, Indiana.

García-Ortiz, E., Pérez-Lorente, F. (2014): Palaeoecological inferences about dinosaur gregarious behaviour based on the study of tracksites from La Rioja area in the Cameros Basin (Lower Cretaceous, Spain). *Journal of Iberian Geology*, (40), 113.

Kim, J.Y., Kim, K S., Lockley, M.G., Seo, S.J. (2010): Dinosaur skin impressions from the Cretaceous of Korea: new insights into modes of preservation. *Palaeogeography, Palaeoclimatology, Palaeoecology*, (293), 167-174.

Kim, J. Y., Lockley, M. G., Woo, J. O., Kim, S. H. (2012): Unusual didactyl traces from the Jinju Formation (Early Cretaceous, South Korea) indicate a new ichnospecies of Dromaeosauripus. *Ichnos*, (19), 75-83.

Le Lœuff, J., Lockley, M., Meyer, C., Petit, J.P. (1999): Discovery of a thyreophoran trackway in the Hettangian of central France. *Comptes Rendus de l'Académie des Sciences-Series IIA-Earth and Planetary Science*, (328), 215-219.

Lockley, M.G., McCrea, R.T., Buckley, L.G., Lim, J.D., Matthews, N.A., Breithaupt, B.H., Houck, K.J., Gierlinski, G.D., Surmik, D., Kim, K.S., Xing, L., Kong, D.Y., Cart, K., Martin, J., Hadden, G. (2016). Theropod courtship: large scale physical evidence of display arenas and avian-like scrape ceremony behaviour by Cretaceous dinosaurs. *Scientific Reports*, (6), 1-10.

Lockley, M.G., Xing, L., Kim, K.S., Meyer, C.A. (2021): Tortuous trackways: evidence and implications of deviations, turns and changes in direction by dinosaurian trackmakers. *Historical Biology*, (33), 3326-3339.

Melchor, R.N. (2015): Application of vertebrate trace fossils to palaeoenvironmental analysis.

Palaeogeography, Palaeoclimatology, Palaeoecology, (439), 79-96.

Navarro-Lorbés, P., Ruiz, J., Díaz-Martínez, I., Isasmendi, E., Sáez-Benito, P., Viera, L., Pereda-Suberbiola, X., Torices, A. (2021): Fast-running theropods tracks from the Early Cretaceous of La Rioja, Spain. *Scientific Reports*, (11), 1-13.

Nouri, J., Díaz-Martínez, I., Pérez-Lorente, F. (2011): Tetradactyl footprints of an unknown affinity theropod dinosaur from the Upper Jurassic of Morocco. *PLoS One*, (6, 12), e26882.

Razzolini, N.L., Vila, B., Díaz-Martínez, I., Manning, P.L., Galobart, À. (2016): Pes shape variation in an ornithopod dinosaur trackway (Lower Cretaceous, NW Spain): new evidence of an antalgic gait in the fossil track record. *Cretaceous Research*, (58), 125-134.

Thomas, D.A., Farlow, J.O. (1997): Tracking a dinosaur attack. *Scientific American*, (277, 6), 74-79.

Thulborn, R.A. (1990): Dinosaur tracks. Chapman and Hall, London.

Torcida Fernández-Baldor, F., Díaz-Martínez, I., Huerta, P., Montero Huerta, D., Castanera, D. (2021): Enigmatic tracks of solitary sauropods roaming an extensive lacustrine megatracksite in Iberia. *Scientific reports*, (11), 1-17.

Flowering among dinosaurs

Díez J. B.[1,2]

1: Departamento de Geociencias Marinas, Universidad de Vigo, Campus As Lagoas-Marcosende, Vigo, España. jbdiez@uvigo.es

2: Centro de Investigación Mariña, Universidade de Vigo (CIM-UVIGO), Vigo, España.

Keywords: Palaeobotany, Mesozoic, Mesophitic floras, Angiosperms.

Dinosaurs appeared, developed and disappeared during the Mesozoic, and the concept contains some interesting ideas (meso-middle, -zoic animals) and, therefore, "middle age of animals". However, this “palaeozoocentric” point of view is striking from the perspective of palaeobotany. If we look at recent calculations of the biomass distribution on Earth (Bar-On et al., 2018) and extrapolate these results to the past, it is inferred that instead of “flowering among dinosaurs”, we might find “Living among plants”. This sentence implies that it is necessary to develop a complete vision of the evolutionary rhythms in the different biological groups during the Mesozoic.

In Palaeobotany, these rhythms are quite different and do not always coincide with the zoological groups. In fact, from this point of view and applying the same algorithms as Raup and Sepkoski (1982), we would find that there was only one great extinction event that affected plant diversity corresponding to the Permian-Triassic boundary (Cascales-Miñana et al., 2016). However, mesophytic floras already began in Upper Devonian times, with the first progymnosperms coexisting with palaeophytic floras. It is observed that, as a consequence of this crisis, these palaeophytic floras decreased, and the dominance of the mesophytic floras characterised the post-crisis times. They were represented by the paraphyletic group of gymnosperms composed of a great “mixed-box” comprising the clades Cycadophyta, Gnetales, Gingkgophyta, Coniferophyta and also everything all types of plants not included in Bryophyta, Pteridophyta or the “Conventional Angiosperms Group”. This context continued until the great dispersion of this group at the end of the Early Cretaceous, which today consists of 92% of all phytodiversity. So, the roots of our current world are conditioned by the Permian-Triassic crisis and the Mesophytic-Cenophytic transition during the Mesozoic.

Classically, the abundant records of angiosperms appear in the Aptian-Albian deposits such as those of the Potomac Group (USA) described by Hickey and Doyle (1977), or the different outcrops of the North of the province of Teruel (Spain) presented in Sender et al. (2012, 2019), to name a few among several others. The oldest records of this group correspond to the genera *Archaefructus* (Sun et al., 1998) and *Montsechia* (Gómez et al., 2015). These records support Darwin's conception of the "Abominable mystery" (Darwin and Seward, 1903; Friedman, 2009; Chaloner and Crane, 2009), or what is the same a rapid dispersal and abrupt dominance of angiosperms during the Early Cretaceous (Friis et al., 2011), establishing in a part of the palaeobotanical community the idea of the possibility of records before that period should be rejected due to that condition. Nevertheless, we should also remember that *Archaefructus* was dated as Jurassic, although it was later corrected as Cretaceous, and was initially accepted as a significant contribution. This episode should reflect on how we are influenced by the "notable" publications and their corresponding authors.

However, during the last two decades, there has been an intense debate about these ideas. On the one hand, several works on molecular biology points that the "angiosperm condition" would date back to the Late Triassic (Clarke et al., 2011; Barba-Montoya et al., 2018; Li et al., 2019). Pollen grains such as the genus *Afropollis* were also described for the Anisian (Middle Triassic), but until now, they had been found in the Cretaceous deposits and accepted as true angiosperms (Hochuli and Feist-Burkhardt, 2013). In addition, there are various records of Jurassic macroflora that present apparent morphological features resembling those in angiosperms, such as *Euanthus* (Liu & Wang, 2016) and *Yuhania* (Liu & Wang, 2017), or the most recent and evident *Nanjinganthus* (Fu et al., 2018). Experience shows us that some elements of micro- and macrofloras in Jurassic rocks do not fit well what we should expect. In these cases, the records are out of publication as they are considered as poorly preserved and incomplete remains. In reaction to these questions, we find different publications that question the validity of molecular biological data (Herendeen et al., 2017;Coiro et al., 2019), or the records of possible "Jurassic angiosperms" (Sauquet et al., 2017, 2022; Sokoloff et al., 2018).

But the general situation is much more complex if we look at the problem as an evolution of biotas. We find that dinosaurs appear during the Middle Triassic (Langer et al., 2010), mammals during the Upper Triassic (Kielan-Jaworowska et al., 2005), and it is necessary to understand how the evolution of pollination occurs and its relationship with the first angiosperms.

All this controversy has led to a scientific blockage in what is the first angiosperm, which we could define as the "*Syndrome of Unicorn*" that can be explained as looking for what everyone knows, but no one has seen at the moment. This situation is enhanced by the pressure to publish in journals with a more significant impact before understanding how this evolutionary process has occurred. We are faced with the case of having colleagues who continually see primitive angiosperms in many records, which is different to others that systematically denied for not being post-Cretaceous.

The conclusion is that it is necessary to seek ways of consensus in which the various points of view can be shared. The group of the crown of angiosperms that reach the present day forms a reasonably solid monophyletic group and that, except for some minimal considerations, should be accepted. However, for the rest of the plants with angiosperm characteristics, it is necessary to open a taxonomic space where we can locate them. It is not acceptable to throw them into the tangled group of gymnosperms. Copying our Palaeozoologist colleagues when they solved the problem of locating the group of "mammalian reptiles"' that would later lead to the Therapsids, it is necessary to create a new name for our pre-Cretaceous angiosperms that I propose to call "non-conventional Angiosperms", which in principle can group a large part of the new remains assigned to primitive angiosperms, proto-angiosperms or others that we cannot include in the group of "conventional Angiosperms".

References

Asar, Y., Ho, S. Y., Sauquet, H. (2022): Early diversifications of angiosperms and their insect pollinators: were they unlinked? *Trends in Plant Science.* https://doi.org/10.1016/j.tplants.2022.04.004

Barba-Montoya, J., Dos Reis, M., Schneider, H., Donoghue, P. C., Yang, Z. (2018): Constraining uncertainty in the timescale of angiosperm evolution and the veracity of a Cretaceous Terrestrial Revolution. *New Phytologist*, (218, 2), 819-834.

Bar-On, Y.M., Phillips, R., Milo, R. (2018): The biomass distribution on Earth. *PNAS*, (115, 25), 6506–6511.

Cascales-Miñana, B., Diez, José B., Gerrienne, P., Cleal, C. (2016): A palaeobotanical perspective on the great end-Permian biotic crisis. *Historical Biology*, (128, 8), 1066-1074.

Clarke, J.T., Warnock, R.C.M., Donoghue, P.C.J. (2011): Establishing a time-scale for plant evolution. *New Phytologist*,(192), 266–301.

Chaloner, B., Crane, P. (2009): Darwin's "Abominable Mystery". *The Linnean*, (25), 21-23.

Coiro, M., Doyle, J.A.,Hilton, J.(2019): How deep is the conflict between molecular and fossil evidence on the age of angiosperms? *New Phytologist*, (223), 83–99.

Darwin, F., Seward, A.C. (eds.) (1903):*More Letters of Charles Darwin. A Record of His Work in a Series of Hitherto Unpublished Letters*, vol. II. J. Murray, London.

Friedman, D.M. (2009): The meaning of Darwin's "abominable mystery". *American Journal of Botany*, (96), 5-21.

Friis, E.M., Crane, P.R., Pedersen, K.R. (2011): Early flowers and angiosperm evolution. Cambridge University Press, Cambridge, 585p.

Fu, Q., Diez, J.B., Pole, M., García-Ávila, M., Liu, Z.-J., Chu, H., Hou, Y., Yin, P., Zhang, G.-Q., Du, K., Wang, X.(2018): An unexpected noncarpellate epigynous flower from the Jurassic of China. *eLife* 7, e38827.

Gómez, B., Daviero-Gómez, V., Coiffard, C., Martín-Closas, C., Dilcher, D.L. (2015):*Montsechia*, an ancient aquatic angiosperm. *PNAS*, (112, 35), 10985-10988.

Herendeen, P.S., Friis, E.M., Pedersen, K.R., Crane, P.R. (2017): Palaeobotanical redux: revisiting the age of the angiosperms. *Nature Plants*, (3, 3), 1-8.

Hickey, L.J., Doyle, J.A. (1977): Early Cretaceous fossil evidence for angiosperm evolution. *The Botanical Review*, (43, 1), 3-104.

Hochuli, P.A., Feist-Burkhardt, S. (2013): Angiosperm-like pollen and *Afropollis* from the Middle Triassic (Anisian) of the germanic basin (Northern Switzerland). *Frontiers in Plant Science*, (4), 344.

Kielan-Jaworowska, Z., Cifelli, R.L., Luo, Z.X. (2005):*Mammals from the age of dinosaurs: origins, evolution, and structure.* Columbia University Press, New York, 700p.

Langer, M.C., Ezcurra, M.D., Bittencourt, J.S., Novas, F.E. (2010): The origin and early evolution of dinosaurs. *Biological Reviews*, (85, 1), 55-110.

Li, H.T., Yi, T.S., Gao, L.M., Ma, P.F., Zhang, T., Yang, J.B., Gitzendanner, M.A., Fritsch, P.W., Cai, J., Luo, Y., Wang, H., Bank, M. van der, Zhang, S-D., Wang, Q-F. Wang, J., Zhang, Z-R., Fu, C-N., Yang, J. Hollingsworth, P.M., Chase, M.W., Soltis, D.E., Soltis, P.S., Li, D.Z. (2019): Origin of angiosperms and the puzzle of the Jurassic gap. *Nature Plants*, (5, 5), 461-470.

Liu, Z.J., Wang, X. (2016): A perfect flower from the Jurassic of China. *Historical Biology*, (28, 5), 707-719.

Liu, Z.J., Wang, X. (2017):*Yuhania*: a unique angiosperm from the Middle Jurassic of Inner Mongolia, China. *Historical Biology*, (29, 4), 431-441.

Raup, D.M., Sepkoski, J.J. Jr. (1984): Periodicity of extinctions in the geologic past. *PNAS*, (81, 3), 801–805.

Sauquet, H., Von Balthazar, M., Magallón, S., Doyle, J. A., Endress, P. K., Bailes, E. J., Barroso de Morais, E., Bull-Hereñu, K., Carrive, L., Chartier, M. Chomicki, G., Coiro, R., Cornette, R., El Ottra, J.H.L., Epicoco, C., Foster, C.S.P., Jabbour, F., Haevermans, A., Haevermans, T., Hernández, R., Little, S.A., Löfstrand, S., Luna, J.A., Massoni, J., Nadot, S., Pamperl, S., Prieu, C., Reyes, E., Santos, P. dos, Schoonderwoerd, K.M., Sontag, S., Soulebeau, A., Staedler, Y.,Tschan, G.F., Leung, A.W-S. Schönenberger, J. (2017): The ancestral flower of angiosperms and its early diversification. *Nature Communications*, (8, 1), 1-10.

Sauquet, H., Ramírez-Barahona, S., Magallón, S. (2022): What is the age of flowering plants? *Journal of Experimental Botany*, (12, 24), 3840–3853,

Sender, L.M., Villanueva-Amadoz, U., Diez, J.B., Sanchez-Pellicer, R., Bercovici, A., Pons, D., Ferrer, J. (2012): A new uppermost Albian flora from Teruel province, northeastern Spain. *Geodiversitas*, (34, 2), 373-397.

Sender, L.M., Doyle, J.A., Upchurch, Jr. G.R., Villanueva-Amadoz, U., Diez, J.B. (2019): Leaf and inflorescence evidence for near-basal Araceae and an unexpected diversity of other monocots from the late Early Cretaceous of Spain. *Journal of Systematic Palaeontology*, (17, 15), 1093-1126.

Sokoloff, D. D., Remizowa, M. V., Bateman, R. M., Rudall, P. J. (2018): Was the ancestral angiosperm flower whorled throughout? *American Journal of Botany*, (105, 1), 5-15.

Sun, G., Ji, Q., Dilcher, D.L., Zheng, S., Nixon, K.C., Wang, X. (1998):Archaefructaceae, a new basal angiosperm family. *Science*, (296, 5569), 899-904.

From notebook to computer: new technologies at the service of dinosaur research

Díez Díaz, V.[1]

[1] *Museum für Naturkunde - Leibniz Institute for Evolution and Biodiversity Science, Berlin, Germany*

Keywords: digitization, vertebrate palaeontology, dinosaurs, 3D reconstruction, biomechanics, behavioural patterns.

An essential component of research is the dissemination of scientific knowledge, regardless of the field in which the research is carried out. In fact, the way we communicate our work and our findings to the general public will have a major impact on the future development of such research projects, not only financially but also on the way society perceives scientists and the things we accomplish. This is what happens in palaeontology: society generally imagines palaeontologists in the field finding perfectly preserved skeletons, or in museum collections describing bones. But what happens in between, so that dinosaurs can be reconstructed in documentaries and films, with such realistic movements and behaviours?

Since the beginning of the 21st century – and more specifically these last few years – we have witnessed how many palaeontological researchers have opened their sights and implemented innovative methodologies and techniques in our field in order to better know and understand extinct species. The key words here would be "digitization" – or the process of converting an analogue object into a digital one – and "digitalization" – in this specific situation, the process of using and transforming these digital outcomes –, as most of these impressive projects are generally carried out with computer software. In the vast majority of cases, the first steps of these projects involve a process of digitization of the fossils (see e.g., Cunningham et al., 2014). Several factors need to be taken into account before starting the digitization process, like e.g., final purpose of the digital outcome, the expertise of the user, external and/or internal features of the specimen, the balance between planned budget and time, etc. Thanks to this, the proper device will be chosen and the digitization protocol established.

Numerous impressive "digitalization projects" can be developed thanks to these digital outcomes, which primarily depend on the vision and ability of researchers to adapt methods and techniques previously developed in or for other fields of research. One nice example was published by van Bijlert et al. (2021), who used eigenfrequencies (natural frequencies) and spring resonances for estimating the preferred walking speed of *Tyrannosaurus rex*. Indeed, thanks to this work and that carried out by Sellers et al. (2017) using biomechanical multibody dynamic analyses, we know now that this theropod was not a high-speed runner, and we are able to better assess the ethological consequences of this result. Interdisciplinarity is nicely reflected if we also include finite element analyses within these projects to better understand the stress patterns in e.g., hindlimbs or jaws (Rowe & Snively, 2022). Through all these methodologies we are able to almost build a dinosaur (Bishop et al., 2020).

Thanks to improvements in the development of computers (both hard- and software) we are also able to develop projects which were not possible to carry out only a few years ago. One example is the reconstruction (and accurate articulation) of mounted skeletons, an important task, especially with large specimens (Vidal et al., 2020a). Apart from planning the setting up of an exhibition (Vidal et al., 2020b), this can also help to better analyze skeletal adaptations and their evolution within groups. Now it is possible to make three-dimensional reconstructions of non-preserved soft tissues too, like muscles (Díez Díaz et al., 2020) or limb articular cartilage (Voegele et al., 2022), but for accurately accomplishing this we need to know the precise features of the articulation, or the origins and insertions of the muscles. Retopology and retro-deformation techniques might help in this task by reconstructing the anatomy of the fossil that has been distorted by taphonomic and diagenetic processes (Lautenschlager, 2016; Demuth et al., 2022; DeVries et al., 2022).

And going back to the topic of popular science, all these projects have the advantage of being very interesting, visual, and interactive (e.g., educational smartphone apps, augmented reality, 3D printing of fossils, ...) for the general public (e.g., Castillo Ruiz et al., 2018; Cunningham, 2021), which makes palaeontology more accessible and attractive to everyone, also improving and updating the image of palaeontologists and their work.

References

Bishop, P. J., Cuff, A. R., Hutchinson, J. R. (2020): How to build a dinosaur: Musculoskeletal modeling and simulation of locomotor biomechanics in extinct animals. *Paleobiology* (47, 19), 1-38.

Castillo Ruiz, C., Alfayate Casañas, M. D. C., Ahijado Quintillán, A., Cruzado Caballero, P., Fortuny, J., Bernardini, F. (2018): Fósiles inteligentes: aplicaciones educativas de los modelos tridimensionales de los lagartos gigantes de Canarias. In: Vega Navarro, A., Stendardi, D. (coords.), *De la innovación* *imaginada a los procesos de cambio*. Universidad de La Laguna, Servicio de Publicaciones, 323-332.

Cunningham, J. A. (2021): The use of photogrammetric fossil models in palaeontology education. *Evolution: Education and Outreach*, (14, 1), 1-7.

Cunningham, J. A., Rahman, I. A., Lautenschlager, S., Rayfield, E. J., Donoghue, P. C. J. (2014): A virtual world of paleontology. *Trends in Ecology and Evolution* (29, 6), 347–357.

Demuth, O. E., Benito, J., Tschopp, E., Lautenschlager, S., Mallison, H., Heeb, N., Field, D. J. (2022): Topology-Based Three-Dimensional Reconstruction of Delicate Skeletal Fossil Remains and the Quantification of Their Taphonomic Deformation. *Frontiers in Ecology and Evolution*, (10), 828006.

DeVries, R. P., Sereno, P. C., Vidal, D., Baumgart, S. L. (2022): Reproducible Digital Restoration of Fossils Using Blender. *Frontiers in Earth Science*, (10), 833379160.

Díez Díaz, V., Demuth, O. E., Schwarz, D., Mallison, H. (2020): The Tail of the Late Jurassic Sauropod *Giraffatitan brancai*: Digital Reconstruction of Its Epaxial and Hypaxial Musculature, and Implications for Tail Biomechanics. *Frontiers in Earth Science*, (8), 00160.

Lautenschlager, S. (2016): Reconstructing the past: Methods and techniques for the digital restoration of fossils. *Royal Society Open Science*, (30), 160342.

Rowe, A. J., Snively, E. (2022): Biomechanics of juvenile tyrannosaurid mandibles and their implications for bite force: Evolutionary biology. *Anatomical Record*, (305, 2), 373–392.

Sellers, W. I., Pond, S. B., Brassey, C. A., Manning, P. L., Bates, K. T. (2017): Investigating the running abilities of Tyrannosaurus rex using stress-constrained multibody dynamic analysis. *PeerJ*, (5), e3420.

van Bijlert, P. A., van Soest, A. J. K., Schulp, A. S. (2021): Natural Frequency Method: Estimating the preferred walking speed of Tyrannosaurus rex based on tail natural frequency. *Royal Society Open Science*, (8), 201441.

Vidal, D., Mocho, P., Aberasturi, A., Sanz, J. L., & Ortega, F. (2020a): High browsing skeletal adaptations in *Spinophorosaurus* reveal an evolutionary innovation in sauropod dinosaurs. *Scientific Reports*, (10), 6638.

Vidal, D., Ortega, F., & Sanz, J. L. (2020b): Sauropodomorph skeletal mounts as scientific devices for testing hypotheses. *Journal of Iberian Geology*, 46(2), 177–193.

Voegele, K. K., Bonnan, M. F., Siegler, S., Langel, C. R., Lacovara, K. J. (2022): Constraining Morphologies of Soft Tissues in Extinct Vertebrates Using Multibody Dynamic Simulations: A Case Study on Articular Cartilage of the Sauropod *Dreadnoughtus*. *Frontiers in Earth Science*, (10), 786247.

Feeding herbivorous dinosaurs: Young and old

Gee C. T. [1] [1]

[1] *nstitute of Geosciences, Division of Paleontology, University of Bonn, Nussallee 8, 53115 Bonn (Bonn, Germany). cgee@uni-bonn.de*

Keywords: Hohenheim Feed Evaluation Test, Jurassic flora, Jurassic food plants, sauropod diets.

Introduction

Although one of the most important interactions between plants and animals is herbivory, the dietary habits of the herbivorous dinosaurs remain a puzzle. In particular, the giant sizes of adult sauropods and their necessity for high-energy intake must have made bulk feeding of nutritious plants absolutely necessary (Sander et al., 2010). Young and juvenile sauropods may well have pursued different feeding strategies than the fully grown animals, given their smaller stature, limited reach, and need for more protein in their plant diets. For deeper insight into the dietary preferences of sauropods, laboratory experiments were conducted to determine the energy yield and the nutritional content of the nearest living relatives of the Jurassic flora using the Hohenheim Feed Evaluation Test (Hummel et al., 2008; Hummel and Clauss, 2011). This analytical test is a well-established, standardized method of determining the dietary content of livestock feed. Shoots or leaves of such plants such as Equisetum, ferns, cycads, Ginkgo, and conifers were tested for their digestibility to herbivores. In comparison to one another, as well as to grasses and dicot leaves, the foods of choice for many herbivores today, it turns out that the plant group offering the most calories to herbivores is Equisetum, the horsetail. Next are grasses, followed by the foliage of Araucaria. The leaves of dicots and the needles of other conifer families release about the same amount of energy. Ferns are variable in their energy output; some ferns with relatives in the deep Mesozoic, such as Osmunda and Angiopteris, offer much energy, while other ferns are quite low. The plant groups yielding the lowest amount of energy are the cycads and podocarps.

These plant groups were then analyzed from an integrated botanical, paleobotanical, and wildlife perspective (Gee, 2011). It was determined, for example, that when brooding takes place around northern lakes, boreal geese commonly feed on Equisetum, while hatchlings can feed exclusively for a month on the young shoots of Equisetum for their high mineral nutrition and protein content. If Jurassic Equisetum offered as much energy to the sauropods as they do to herbivorous birds, then it may have served a favored food source for the herbivorous dinosaurs, too. Ferns that grow in closed forests, such as Osmunda, were likely not targeted by fully grown dinosaurs due to problems maneuvering of the gigantic animals in a dense habitat. Other plants, such as Angiopteris or cycads, are such slow growers or full of toxins today, that they were probably not frequently targeted plants in the paleontological past. A rating system of Jurassic plant groups was set up that features Equisetum shoots and Araucaria leaves as the most preferred plants for the giant sauropods, while cycad fronds and podocarp needles were likely the least favored.

Further research into dinosaur herbivory has provided several lines of evidence for the dietary preferences of baby and juvenile sauropods (Gee, 2019; Gee et al., 2019). These lines of evidence include height stature of young sauropods and Jurassic plant taxa, new data on the digestibility of plant groups based on the Hohenheim Feed Test (Gee et al., 2019), the nutritional needs of baby and young reptiles today, and the feeding strategies of living herbivorous birds and reptiles.

In conclusion, a list of light-hearted guidelines for the feeding of herbivorous dinosaurs, young and old, is proposed.

References

Gee, C.T. (2011): Dietary options for the sauropod dinosaurs from an integrated botanical and paleobotanical perspective. In: Klein, N., Remes, K., Gee, C.T., Sander, P.M. (eds). *Biology of the Sauropod Dinosaurs: Understanding the Life of Giants*. Indiana University Press, Bloomington, 34–56.

Gee, C.T. (2019): Sauropods and their preferred food plants, with feeding recommendations for hatchlings, juveniles, and adults. *Abstract for a keynote lecture, VII International Symosium on Dinosaur Eggs & Babies 2019.* Qinglongshan National Geopark, Shiyan City, Hubei Province, China, August 17–22, 2019.

Gee, C.T., Howell, M.M., Böttger, C., Südekum, K.-H. (2019): A superfood for Mesozoic herbivores? Emerging data on the extreme digestibility of *Equisetum* and implications for young, growing herbivorous sauropods. *Abstract for an oral presentation, 79th Annual Meeting of the Society of Vertebrate Paleontology.* Brisbane, Queensland, Australia, October 9–12, 2019.

Hummel, J., Clauss, M. (2011): Sauropod feeding and digestive physiology. In: In: Klein, N., Remes, K., Gee, C.T., Sander, P.M. (eds). *Biology of the Sauropod Dinosaurs: Understanding the Life of Giants*. Indiana University Press, Bloomington, 11–33.

Hummel, J., Gee, C.T., Südekum, K.-H., Sander, P.M., Nogge, G., and Clauss, M. (2008.): In vitro digestibility of fern and gymnosperm foliage: implications for sauropod feeding ecology and diet selection. *Proceedings of the Royal Society*, *Series B*, 275: 1015–1021.

Sander, P.M., Gee, C.T., Hummel, J., Clauss, M. 2010. Mesozoic plants and dinosaur herbivory. In: Gee, C.T. (ed), *Plants in Mesozoic Time: Morphological Innovations, Phylogeny, Ecosystems*. Indiana University Press, 331–359.

New insights concerning the origin of the Ornithisquian Bauplan (Archosauria, Dinosauria)*

Norman, D. B.[1], Baron, M. G.[1], García, M. S.[2,3], Müller, R. T.[2,3]

1. Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge CB2 3EQ, United Kingdom. dn102@cam.ac.uk

2. Centro de Apoio à Pesquisa Paleontológica da Quarta Colônia, Universidade Federal de Santa Maria, São João do Polêsine, RS, 598, Brazil.

3. Programa de Pós Graduação em Biodiversidade Animal, Universidade Federal de Santa Maria, Santa Maria, RS 97105-900, Brazil.

Introduction

The Ornithischia is a unique sub-clade within Dinosauria. Its anatomical characteristics, including the eponymous 'ornithischian' pelvic configuration and unique anatomical features seen in the skull, set this sub-clade anatomically far apart from the two other dinosaurian sub-clades Sauropodomorpha and Theropoda that are members of the Saurischia. So distinctive are ornithischians that in the past they were regarded as being not at all closely related to the Saurischia. Harry Govier Seeley, was very clear about the distinction between Ornithischia and Saurischia when he first proposed this subdivision of dinosaurians in 1888. Many authors in the past persisted in advocating a polyphyletic origin of Dinosauria. Equally others, notably Jacques Armand Gauthier (1986), offered cladistic evidence supporting the monophyly of the Dinosauria; the latter proposition is the overwhelming consensus at present. However, the origin of ornithischian bauplan has eluded comprehension.

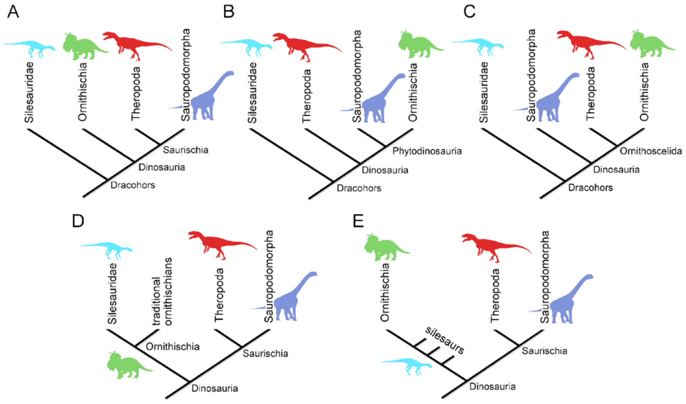

Figure 1. Hypotheses of the phylogenetic relationships of dinosaurs compared (silesaurids added retrospectively to Figs A-C): A. The traditional ('Seeley') hypothesis (Nesbitt 2011) incorporating the clade Silesauridae. B. The 'Phytodinosauria' hypothesis (Bakker; 1986). C. The 'Ornithoscelida' hypothesis (Baron et al., 2017). D. The 'Seeley"hypothesis with Silesauridae placed as the sister-taxon to traditional ornithischians (Langer & Ferigolo, 2013). E. Paraphyletic silesaurs as stem-lineage ornithischians (Müller & Garcia, 2020).

Several competing hypotheses concerning the relationship between Ornithischia and the other principal clades of Dinosauria exist (see Fig. 1), with surprisingly little evidence to choose between them. All of the 'conventional' hypotheses (represented by Fig. 1A-C) have posited a tree topology within Dinosauria that implies a substantial 'ghost-lineage' for Ornithischia (whose representatives make their first unambiguous appearance in the Hettangian Stage, at the base of the Jurassic Period). An 'ornithischian-like' group of Late Triassic dinosauromorphs (silesaurids) has been posited as either a potential sister-group to Dinosauria, or a sister-group to Ornithischia (Fig. 1D). However, a recent large-scale phylogenetic analysis (Müller & Garcia, 2020) recovered an array of silesaurids, positioned as a paraphyletic assemblage of taxa (referred to herein as silesaurs/silesaurians) on the branch leading to the clade Ornithischia (Fig. 1E). Given the so far exclusively Triassic occurrences of silesaurians, the latter hypothesis of relationships could, plausibly, account for the absence of Triassic ornithischians. The taxonomic, palaeobiological and evolutionary implications of this work have been considered, following expansion and re-analysis of the original dataset. What is also apparent from this re-analysis is that phylogenetically successive silesaurian taxa acquire a variety of anatomical characters in an anagenetic sequence, culminating in the assembly of a 'traditional' ornithischian.

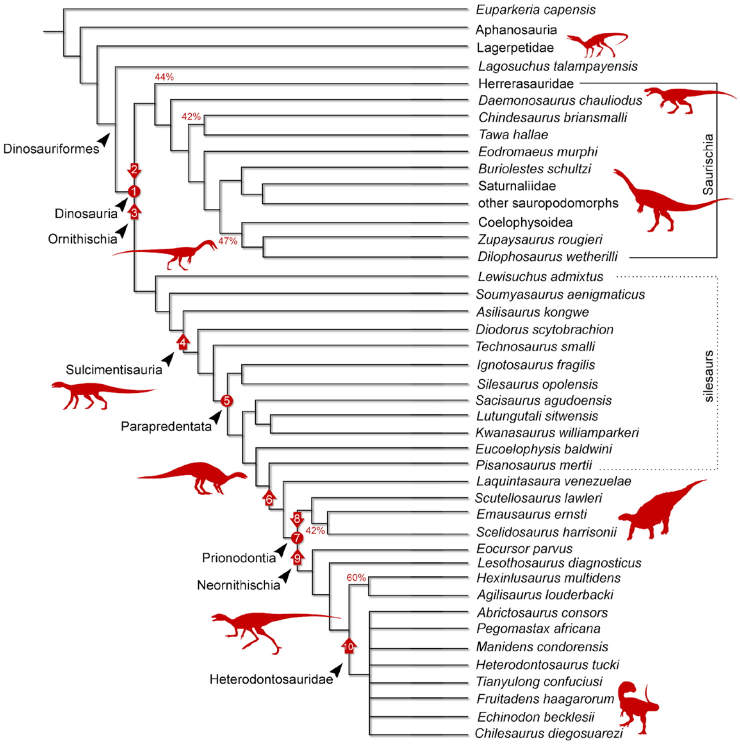

Figure 2. Strict consensus tree from the unconstrained analysis depicting node numbers mentioned in the text and bootstrap values equal to or higher than 40%. Node numbers: 1. Dinosauria, 2. Saurischia, 3.

Ornithischia, 4. Sulcimentisauria, 5. Parapredentata, 6. Unnamed, 7. Prionodontia, 8, Thyreophora, 9. Neornithischia, 10. Heterodontosauridae.

The new topology (Fig. 2) has taxonomic repercussions that need to be considered. To provide stability in this area of the phylogenetic tree, and to preserve the most familiar taxonomic names associated with Dinosauria, we propose a revised taxonomy for ornithischians that is consistent with the new topology. The name Ornithischia is retained for the total-group ('traditional' Ornithischia and its stem-lineage), while we resuscitate a name originally proposed by Richard Owen, **Prionodontia** (in recognition of a grouping of dinosaurs with literally "coarse edged teeth") for the clade containing only the so-called 'traditional' ornithischian (i.e. Seeley's original concept of the "bird-hipped") dinosaurs. This new taxonomic framework provides phylogenetic clarity and a degree of stability within Ornithischia (and Dinosauria more widely) as further analyses and new data continue to refine and re-shape the dinosauromorph tree.

Taxonomic implications.

Several important taxonomic implications flow from the topology generated here (Fig. 2). The arrangement of taxa within what we refer to as the total ornithischian lineage necessitates revision, redefinition, addition or replacement of some clade names. The definition and status of the clade Ornithischia is brought into focus. The inclusion of an array of silesaurs not just within the clade Dinosauria, but more specifically as members of the stem-lineage of Ornithischia raise the questions: what, precisely, the clade Ornithischia is? And, what taxa should be included?

Historically, Ornithischia was defined and diagnosed (apomorphically) by the possession of the "bird-like" opisthopubic pelvis (a consequence of the retroversion of the pubic shaft): this was the inspiration behind the name Ornithischia (hence "bird hipped") coined by Seeley (1888). This group was distinguished from the Saurischia ("lizard/reptile hipped"), which contained all dinosaurian taxa that displayed the (plesiomorphic) forward-pointing pubis, as well as one other apomorphic trait: the osteological markers associated with pneumatism. None of the currently known silesaurs possess either an ornithischian pelvic configuration or evidence of saurischian-like pneumatism.

Using phylogenetically derived definitions (de Queiroz & Cantino, 2020) to establish hierarchical taxonomies for fossil taxa means that clade names will change in their internal composition as new taxa are discovered and tree topologies alter in response. Conserving the taxon Ornithischia in a more inclusive sense does not preclude the possibility that early diverging members of the clade may be discovered that retained the ancestral plesiomorphic "saurischian" hip structure, but these would be positioned proximal to a more exclusive ornithischian node: as is precisely the case for silesaurians. Owen (1874) proposed the name "Prionodontia" as a collective name for just three then-known dinosaur taxa: *Echinodon* Owen, *Iguanodon* Mantell and *Scelidosaurus* Owen, that possess coarsely serrated, leaf-shaped teeth. Present day taxonomies place these taxa within Heterodontosauridae, Neornithischia and Thyreophora respectively. Owen's Prionodontia was encompassed by Seeley's much more utilitarian Ornithischia. As a node-based definition given in the terms set out above, Owen's Prionodontia (given its original membership) precisely encompasses the long-established clade Ornithischia. Owen's taxonomic name remains available and Prionodontia can be re-established as the clade name for 'traditional ornithischians'.

Palaeobiological and evolutionary implications.

This revised topology proposed herein (Fig. 2) generates some thought-provoking evolutionary interpretations. Changes in dental and mandibular anatomy (linked to feeding strategies) that can be traced across the ornithischian clade challenge previous evolutionary models**.** Furthermore, changes in stance and gait that are linked to forelimb, pelvic and hindlimb anatomy, appear to be cumulative (anagenetic) if silesaurs represent a grade of early diverging stem-lineage ornithischians, rather than stem-lineage dinosaurs (non-dinosaurian dinosauriforms) as more commonly envisaged.

Given these apparently coincident changes in morphology (and implied function) the presence of silesaurs on the stem leading to Prionodontia (Fig. 2), offers a new insight into the order, timing and method of acquisition of key components of the derived ornithischian (prionodontian) *bauplan*; these interpretations undermine several character-states that have been regarded as uniquely dinosaurian. We hope that new discoveries will fill some of the gaps in our understanding of the anatomo-functional changes that occurred during the evolutionary history of Ornithischia, as well as the potential for many parallelisms/convergences in anatomy within dinosaurian lineages more broadly.

Hypotheses of relationship: problems.

Steadily increasing numbers of novel taxa alter, or challenge, long-established synapomorphies and, as result, systematic analyses and phylogenetic interpretations have entered a period of intense disturbance. In this study, we have tested alternative topologies using the widest sample of early dinosaurs and their near relatives available and, perhaps not surprisingly, the results challenge orthodoxy. Nevertheless, we recognize that whereas some specimens are exquisitely preserved, early dinosaur relationships are mainly constructed (or affected by) data from a number of poorly preserved or incomplete specimens. Therefore, we recommend caution and circumspection when assessing the veracity of the present or indeed *any* of the currently advocated early-dinosaur phylogenetic trees.

Concluding remarks.

The order, timing and rate of several anatomical changes that occur during the transition from stem-lineage taxa to that seen in more derived (prionodontian) ornithischians had not been explored prior to this analysis. In addition to the anatomo-functional implications that derive from the new topology, the phylogenetics necessitate a reconsideration of the taxonomy as it pertains to the clade Ornithischia within Dinosauria. A case is made for the resurrection of the name Prionodontia (a taxon proposed by Richard Owen) to recognise 'traditional ornithischians'. This usage avoids disturbance of the long-held taxonomy associated with the three principal dinosaurian clades: Theropoda, Sauropodomorpha and Ornithischia.

*This abstract is an abridgement of "Taxonomic, palaeobiological and evolutionary implications of a phylogenetic hypothesis for Ornithischia (Archosauria: Dinosauria" by Norman, Baron, Garcia & Müller, that has been accepted (July 2022) for publication in the *Zoological Journal of the Linnean Society of London* (December 2022 issue).

References.

Bakker, R.T. (1986): *The dinosaur heresies*. New York: William Morrow & Co. Inc.

Baron, M.G., Norman, D.B., Barrett, P.M. (2017): A new hypothesis of dinosaur relationships and early dinosaur evolution. *Nature* 543: 501–506.

Gauthier, J.A. (1986): Saurischian monophyly and the origin of birds. In: Padian K, ed. *The origin of birds and the evolution of flight*. San Francisco: Memoir of the California Academy of Sciences, p. 1–55.

Langer, M.C., Ferigolo, J. (2013): The Late Triassic dinosauromorph *Sacisaurus agudoensis* (Caturrita Formation; Rio Grande do Sul, Brazil): anatomy and affinities. *Geological Society of London. Special Publications* 379: 353–392.

Müller, R.T., Garcia, M.S. (2020): A paraphyletic 'Silesauridae' as an alternative hypothesis for the initial radiation of ornithischian dinosaurs. *Biology Letters* 16 (2020.0417): 1-5.

Nesbitt, S.J. (2011): The early evolution of archosaurs: relationships and origin of major clades. *Bulletin of the American Museum of Natural History* 352: 292pp.

Owen, R. (1874): Monograph of the fossil Reptilia of the Wealden and Purbeck Formations. Supplement V. Dinosauria (*Iguanodon*). *Palaeontographical Society Monographs*

XXVII [27]: 1–18.

Queiroz, K. de, Cantino, P.D. (2020): *International code of phylogenetic nomenclature (PhyloCode)*. Boca Raton: CRC Press.

Seeley, H.G. (1888): On the classification of the fossil animals commonly named Dinosauria. *Proceedings of the Royal Society of London* 43: 165–171.

Sensory biology in dinosaurs: what we know and how we know it?

Paulina Carabajal, A.[1]

[1] *Instituto de Investigaciones en Biodiversidad y Medioambiente (Consejo Nacional de Investigaciones Científicas y Técnicas-Universidad Nacional del Comahue). Quintral 1250 (8400), S.C: de Bariloche, Río Negro, Argentina.* a.paulinacarabajal@conicet.gov.ar

Key words: Paleoneurology. Senses. Mesozoic. Reptiles

Since the discovery of the first dinosaur bones, scientists and people in general (adults and kids alike) have been wondering how these extinct Mesozoic reptiles lived their lives: how they breath, feed, and move, among many other things that a living organism can do. In this regard, hypotheses about sensory biology and behavior have been made based on the anatomy of the central nervous system (particularly the brain), peripheral nerves, and associated sensory organs since these structures were first described more than 150 years ago. Although in the early stages of these kind of paleontological studies these ideas were almost speculations, today paleontologists -together with neontologists- are looking for evidence that can be tested to support such kind of hypotheses (Paulina-Carabajal et al. in press a, and references therein). So, dinosaur paleoneurology is a growing discipline that seeks to understand the evolutionary pattern of the central nervous system in these extinct reptiles, hand-in-hand with the field of comparative neurology of their living relatives. Today, the cranial endocasts of most dinosaur clades are known, and hypotheses about the evolutionary pattern of their brains (particularly in the lineages leading into the flying dinosaurs) and senses (dealing especially with the senses commonly known as sight, smell, hearing and touch) have been proposed (Paulina-Carabajal et al. in press a,b and references therein).

All these available data are the pillars for the recreation of sensory biology, from which in turn ecological and evolutionary aspects of the groups under study are reconstructed. There are, however, limitations: most of the dinosaur paleoneurology research has been focused on the neuroanatomy of a single representative of the taxon under study, being considerably fewer studies that include descriptive analysis in order to understand ontogenetic changes (e.g. Lautenschlager and Hübner 2013), evolutionary patterns (e.g. Witmer and Ridgely 2009; Balanoff et al. 2010; Lauters et. al 2012; Lautenschlager et al. 2012) or documenting neuroanatomical transformations of the modular brain in deep time (e.g. Balanoff and Bever 2017), in specific clades. Although the use of non-invasive technologies (such as X-ray computed tomography or neutron micro-tomography), are increasing the number of studied specimens and taxa -including those groups with the smaller body sizes and heads-, some authors have stated that the major constraints facing research in paleoneurology center on the accuracy and reliability of the correlation between the endocast morphology and the complexity and modularity of the actual brain (Balanoff and Bever 2017). Future studies that may improve our understanding of the neurosensory evolution in dinosaurs include the future addition of unknown taxa (allowing filling gaps in the phylogeny), integrative morphological analyses using quantitative methods (inclusion of larger sets of data), the search of correlation between diversity radiations and evolutionary brain changes through the Mesozoic, and advances in the field of sensory systems and behavior in living reptiles.

This talk will focus then on the current state of knowledge of the discipline, its achievements and problems, as well as future considerations and other aspects that arise from the use of modern methods in paleontology.

References

Balanoff, A.M., Bever, G.S., Ikejiri T. (2010): The braincase of *Apatosaurus* (Dinosauria, Sauropoda) based on Computed Tomography of a new specimen with comments on variations and evolution in sauropod neuroanatomy. *American Museum Novitates* 3677:1-29.

Balanoff, A.M., Bever, G.S. (2017): The role of endocasts in the study of brain evolution. In: Kaas JH (ed.) *Evolution of Nervous Systems Volume 1*. Elsevier, Amsterdan, 223-241.

Lautenschlager, S., Hübner, T. (2013): Ontogenetic trajectories in the ornithischian endocranium. *Journal of Evolutionary Biology* 26(9): 2044-2050.

Lautenschlager, S., Rayfield, E.J., Altangerel, P., Zanno, L.E., Witner, LM. (2012): The endocranial anatomy of Therizinosauria and its implications for sensory and cognitive function. *PLoS One* 7:e52289.

Lauters, P., Coudyzer, W., Vercauteren, M. (2012): The brain of *Iguanodon* and *Mantellisaurus*: perspectives on ornithopod evolution. In: Godefroit P (ed) *Bernissart Dinosaurs and Early Cretaceous Terrestrial Ecosystems*. Indiana University Press, Bloomington, 213-224.

Paulina-Carabajal, A., Bourke, J., Morhardt, A. (in press, a): Dinosaur Senses. In: *The Complete Dinosaur*, Zanno, Holtz, Arbour (eds), 3rd Edition. Indiana University Press.

Paulina-Carabajal, A., Bronzati, M., Cruzado-Caballero, P. (in press, b): Paleoneurology of non-avian dinosaurs: an overview. In: Dozo, Paulina-Carabajal, Macrini and Walsh (Eds.), *Paleoneurology of Amniotes: new directions in the study of fossil endocasts*, Springer.

Witmer, L.M., Ridgely, R.C. (2009): New insights into the brain, braincase, and ear region of tyrannosaurs (Dinosauria, Theropoda), with implications for sensory organization and behavior. *Anatomical Record* 292:1266-1296.

Cut them up to tell them apart: Systematic value of long bone histology of major clades of Dinosauria

Martin Sander, P.[1]

[1] *Section Paleontology, Institute of Geosciences, University of Bonn, Nussallee 8, 53115 Bonn, German.* martin.sander@uni-bonn.de

Key words: Dinosauria, paleohistology, microanatomy

The last three decades have seen a phenomenal growth in the study of dinosaur long bone histology and microanatomy, aimed at answering questions of growth, life history, physiology, and evolution, recently summarized by Buffrenil et al. (2021). It was generally held that dinosaur bone histology is of little systematic value because of the limited number of amniote bone tissues, which also are prone to convergent evolution (Buffrenil et al. 2021). After the initial survey phase with only a few taxa from each major dinosaur clade having been studied histologically, a comprehensive taxon sampling now has accumulated in the published literature (reviewed in Padian & Woodward 2021) and the collection of the author. This reveals remarkable histological uniformity of most major clades of dinosaurs, allowing identification of otherwise undiagnostic bone specimens (often small fragments, as in zooarchaeology) and inviting tests of the systematic value of histological data as characters in phylogenetic analyses.

We have compiled histologic data for each major dinosaur clade (Theropoda, Sauropodomorpha, Sauropoda, Stegosauria, Ankylosauria, Ornithopoda, and Ceratopsia) and mapped them on a consensus phylogeny of Dinosauria. We exclude avialean theropods from consideration because of their radically different lifestyle (flight) and generally small body size. The main sampling location in all studies considered was the mid-shaft cross section of large long bones such as humeri and femora.

Basal Dinosauromorpha had highly vascularized fibrolamellar bone with cyclical lines of arrested growth (LAGs). This histology was retained by Theropoda outside of Avialae and by basal Sauropodomorpha. Both retain a large open medullary cavity, limiting Haversian bone development, as explained by the Three Front Model (Mitchell and Sander 2014). Functionally, the loss of the open medullary cavity is linked to graviportality (Houssaye et al. 2015). Spinosaurs have very dense bone tissue with abundant Haversian bone and lacking a medullary cavity, presumably representing bone mass increase as an adaptation to an aquatic lifestyle (Aureliano et al. 2018).

Basal Sauropodomorpha have thinner laminae in their laminar cortical bone than other dinosaurs. Sauropoda evolved thicker laminae than other dinosaurs and lost growth mark expression before late ontogeny. Sauropoda possess a small medullary cavity filled by trabecular bone and show extensive Haversian replacement at senescence. A unique bone tissue type, possibly synapomorphic to Saurischia, is pneumosteum, which is seen in secondary trabeculae associated with postcranial skeletal pneumaticity of the axial and girdle skeleton in sauropods and avian theropods (Lambertz et al. 2018, Aureliano et al. 2020). Interestingly, sauropod histological characters may be strongly modified in dwarfed taxa such as Europasaurus (Sander et al. 2006) and Magyarosaurus (Stein et al. 2010). Many titanosaurs show modified laminar bone in which the laminar vacular architecture is retained but the bone matrix is parellel-fibered, lacking woven-fibered matrix (Klein et al. 2012).

Among Ornithopoda, Stegosauria either have fibrolamellar bone with longitudinal canals and well developed LAGs (Stegosaurus) or laminar to plexiform fibrolamellar bone (Kentrosaurus). As in Sauropoda, Stegosaur medullary cavities are small as in Sauropoda. Primary cortical bone of Ankylosauria resembles that of Stegosaurus but remains incompletely known because of the early onset of Haversian remodeling. Ankylosaur primary and, uniquely among dinosaurs, secondary tissue is rich in structural fibers. These are also the dominant component of ankylosaur armor. Ornithopods also retained the plesiomorphic histology but have a smaller medullary cavity and accordingly show more remodeling. Ceratopsian histology is least studied among major dinosaur clades, but it is most similar to that of ornithopods and theropods. These patters of microanatomy and sequence of bone tissues are explained by the Three Front Model of cortical bone growth (Mitchell and Sander 2014). Originally developed for Sauropodomorpha, the model is generally applicable to all amniote long bones, vertebral centra and ribs.

Examples of the practical application of paleohistology to identify fragmentary remains include the first dinosaur recorded from Sicily, a theropod long bone from Cretaceous marine rocks exposed in a cave (Garilli et al. 2009), the first dinosaur from Norway, a plateosaurid bone cross section from the Triassic section of a drill core offshore Norway (Hurum et al. 2012), and the rejection of the hypothesis that the very bone shafts from the famous Late Triassic Aust Cliff bonebeds represent sauropodomorphs (Redelstorff et al. 2014). Current work suggests that the specimens pertain to giant ichthyosaurs instead. Future work will incorporate histological and microanatomical characters into phylogenetic analyses of Dinosauria to develop an apomorphy-based approach to such data.

References

Aureliano, T., A.M. Ghilardi, P.V. Buck, M. Fabbri, A. Samathi, R. Delcourt, M.A. Fernandes, P.M. Sander, (2018): Semi-aquatic adaptations in a spinosaur from the Lower Cretaceous of Brazil. *Cretaceous Research*, 90, 283-295.

Aureliano, T., A.M. Ghilardi, J.C.G.S. Junior, A.G. Martinelli, L.C.B. Ribeiro, T. Marinho, M.A. Fernandes, F. Ricardi-Branco, P.M. Sander (2020): Influence of taphonomy on histological evidence for vertebral pneumaticity in a Late Cretaceous titanosaur from South America. *Cretaceous Research*(108), 1-8.

Buffrénil, V. d., A. d. Ricqlès, L. Zylberberg, K. Padian (2021): Vertebrate Skeletal Histology and Paleohistology. 838 pp. CRC Press, Boca Raton.

Garilli, V., N. Klein, E. Buffetaut, P.M. Sander, F. Pollina, L. Galletti, A. Cillari, D. Guzzetta (2009): First dinosaur bone from Sicily identified by histology and its paleobiogeographical implications. *Neues Jahrbuch für Geologie und Paläontologie – Abhandlungen,*(252), 207-216.

Houssaye, A., K. Waskow, S. Hayashi, R. Cornette, A.H. Lee, J.R. Hutchinson (2015): Biomechanical evolution of solid bones in large animals: a microanatomical investigation. Biological *Journal of the Linnean Society,*(117), 350-371.

Hurum, J.H., M. Bergan, R. Müller, J.P. Nystuen, N. Klein (2006): A Late Triassic dinosaur bone, offshore Norway. *Norwegian Journal of Geology* 86.

Klein, N., P.M. Sander, K. Stein, J.L. Loeuff, J.L. Carballido, B. Eric. 2012. Modified laminar bone in *Ampelosaurus atacis* and other titanosaurs (Sauropoda): implications for life history and physiology. *PLoS ONE* 7, e36907.

Lambertz, M., F. Bertozzo, P.M. Sander (2018): Bone histological correlates for air sacs and their implications for understanding the origin of the dinosaurian respiratory system. *Biology Letters,*(14),1-5.

Mitchell, J., P.M. Sander (2014): The three-front model: a developmental explanation of long bone diaphyseal histology of Sauropoda. *Biological Journal of the Linnean Society*, London (112),765-781.

Padian, K., H. Woodward (2021): Archosauromorpha: Avemetatarsalia –dinosaurs and their relatives.; pp. 511-549 *i*n V. d. Buffrénil, A. d. Ricqlès, L. Zylberberg, and K. Padian (eds.), Vertebrate Skeletal Histology and Paleohistology. CRC Press, Boca Raton.

Redelstorff, R., P. M. Sander, P.M. Galton (2014): Unique bone histology in partial, large bone shafts from Aust Cliff (England, Upper Triassic): An early independant experiment in gigantism. *Acta Palaeontologica Polonica,*(59), 607-615.

Sander, P.M., Klein, N.(2006): An unusual bone histology and growth pattern in *Ampelosaurusatacis*, a titanosaurid sauropod from South France. *Journal Vertebrate Paleontology*, (26), 85A.

Stein, K., Z. Csiki, K.C. Rogers, D.B. Weishampel, R. Redelstorff, P.M. Sander (2010): Small body size and extreme cortical bone remodeling indicate phyletic dwarfism in *Magyarosaurus dacus* (Sauropoda: Titanosauria). Proceedings of the National Academy of Sciences, USA,(107), 9258-9263.

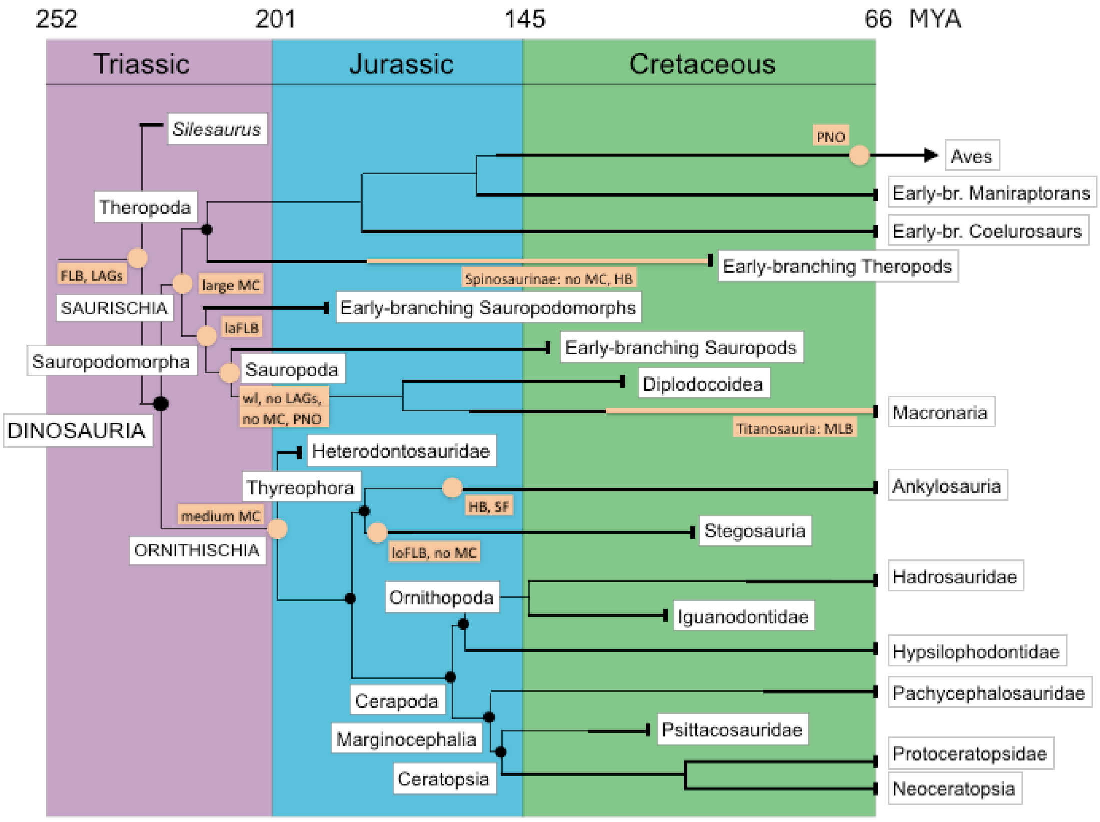

Figure 1: Microanatomy and histology mapped onto the dinosaurian tree. Abbreviations: FLB, fibrolamellar bone; HB, abundant Haversian bone; LAGs, lines of arrested growth; laFLB, laminar bone; loFLB, FLB with longitudinal canals; MC, medullary cavity; MLB, modified laminar bone; PNO, pneumosteum; SF, structural fibers; wl, wide laminae.

COMUNICACIONES

Carbonatic rocks in the quarry of La Corte-Campanedda, Nurra, Sardinia N-W: sedimentological, stratigraphic analysis and palaeoenvironmental reconstruction

Basso, A[1].

[1] *Graduate Università degli Studi di Sassari, Gestione dell'Ambiente e del Territorio, Sassari, Italy*
angi.basso@gmail.com

Keywords: Nurra, Jurassic, Tethys, stratigraphy, palaeontology, palaeoenviroment.

Introduction

Palaeontological, sedimentological, stratigraphic and geodynamic works allow us to interpret the Jurassic and Cretaceous outcrops of the Nurra, Sardinia North-West (Carannante & Simone, 1998, 2002; Cherchi & Schroeder, 2002), in a broader framework that includes the Sardinian-Corsican (Orsini et al., 1980; Oggiano et al., 2009), the Provençal-Pyrenean system (Chabrier & Fourcade, 1975; Chabrier &Mascle, 1975; Fauré & Peybernès, 1983; Dercourt et al., 1994), and the Iberian and Catalonian Mountain ranges (Ziegler et al., 2001). This work aims to make a further contribution to the understanding of the Southern European Mesozoicthrough the collection of soil data and their interpretation in terms of palaeoecological, sedimentological and stratigraphic evolution.

In the quarries of La Corte and Campanedda localities, stratigraphic series were identified. Four columns comprising the units referable to the Mesozoic were realized. Systematic sampling has allowed us to identify the main litho-stratigraphic units, from which selected thin sections have been prepared and used for detailed sedimentological, palaeontological and micro-palaeontological analysis (Fig. 1).

The formations include from the bottom-up: 1) partially dolomitized mudstone-wackstone, formed by well-stratified levels characterized by parallel and crossed laminations, and thin marly layers; 2) yellowish, massive, oolitic wackestone; 3) well-stratified, fossiliferous, limestones, mudstone and wackestone with peloids, intra-clasts and bioclasts, with dark muddy levels of lagoon habitat; 4) biomicrite with peloids, light yellow in colour, from massive to well-stratified intercalated to thin marly levels. The sedimentological features and the fossil content consistently indicate an hemipelagic depositional environment that goes from the coastal lagoon to the shallow carbonate platform, occasionally protected by coralline bars, often sterile or slightly fossiliferous.

Methodology

The working methodology was divided into well-defined phases:

1) Identification of the stratigraphic successions useful to create four columns including the outcropping units and referable to the Mesozoic limestones; measurement, sampling and macroscopic description of each lithostratigraphic unit, writing down the sampling of each sample with an alphanumeric system, and schematizing the position in the field notebook and then reporting the data correctly to the stratigraphic column and on a photographic image of the outcrop.

2) Preparation sections of selected samples; observation and description of sedimentological and micro-palaeontological elements.

3) Palaeontological analysis of the macro- and micro-fossils identified. This part of the work required cleaning and study of fossils, observation and identification of microfossils, high magnification photography, description, taxonomy, ecology, reference age, based on the comparative observation of the distinctive elements of the different species, as well as on the reading of manuals. and specific bibliography for each taxon identified.

4) Stratigraphic and sedimentological analysis of the identified type sections, in order to reconstruct the palaeoenvironmental conditions.

Results and discussion

This work was born with the aim of being able to date some Mesozoic outcrops of Nurra on micro-palaeontological bases, using biostratigraphic, palaeoecological methods and the correlation with similar studies carried out in equivalent areas (D’Argenio et al., 1985; Bernoulli & Jenkyn, 2009). The collection of sedimentological and palaeontological data made it possible to reconstruct the depositional environments in a fairly detailed manner. These environments range from a carbonate platform of low sea and medium-high energy, recognizable in the disused quarry at La Corte, to an epicontinental area of shallow sea, characterized by coastal lagoons and coral reefs (Poignant et al., 1982) with algal vegetation (Yilmaz, 1998), recognizable in the lower quarry in Campanedda. The oolithic limestones with marly intercalations and thin clayey levels of the upper quarry of Campanedda are attributable to an intermediate platform area with flysh-type terrigenous contributions.

The age attributed in the literature (D’Argenio et al., 1985; Cherchi & Schroeder, 2002) to the fossils (Poignant et al., 1982; Kroh & Smith, 2010; Gaillard et al., 2011; Kollmann, 2014) and microfossils (Schönfeld, J., 1990; Rogl, 1995; Miller, 2005) found in the lithofacies analysed, also made it possible to identify the lower and upper chronological limit of the emerging successions. Limits that are situated in a range between the Bathonian (Sotak & Misik, 1993), species association of *Salpingoporella annulata*, *Diplocidaridae and Thecosmilia annularis,* and the Tithonian/Berriasian species association of *Choffatella decipiens* (Schlumberger, 1905) *and Gyrodinoides nitida*(Schroeder et al., 2010).

Furthermore, it has been possible to identify a fossiliferous formation from the upper Jurassic period corresponding to a phase of the lagoon palaeoenvironment. This formation lends itself to further investigations to look for and discover new and more interesting fossils.

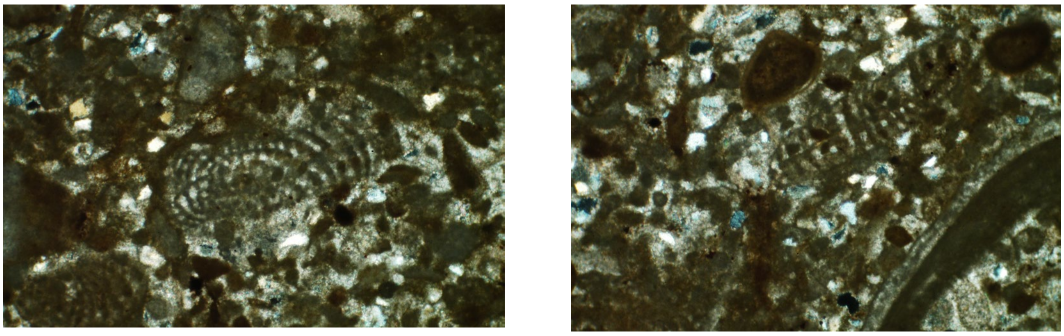

Figure 1. *Choffatella decipiens*, planar and longitudinal section of two different individuals.

References

Bernoulli, D., Jenkyn, H.C. (2009): Ancient oceans and continental margins of the Alpine- Mediterranean Tethys: deciphering clues from Mesozoic pelagic sedimentsand ophiolites. *Sedimentology*, (56), 149–190.

Carannante, G., Simone, L. (1988): The fate of Foramol (temperate type) carbonate plataforms. *SedimentaryGeology*, (60), 347–354.

Carannante, G., Simone, L. (2002): Late Cretaceous Foramol carbonate factories of The Nurra region (North-Western Sardinia, Italy). In: Cherchi, A., Corradini, C., Putzu, M.T. (eds.), Sardinia Field Trip - Paleontology & Stratigraphy. *Società Paleontologica Italiana*, (1), 135–140.

Chabrier, G., Fourcade, E. (1975): Sur le Crétacé du Nord-Ouest de la Sardaigne (présence de Valanginien à faciès pyrénéo-provençal). *Comptes Rendus de l’Académie des Sciences Paris* D, (280), 563-566.

Chabrier, G., Mascle, G. (1975): Comparaison des évolutions géologiques de la Provence et de la Sardaigne.*Revue de Géographie physique et de Géologie dynamique*, (17), 121–136.

Cherchi, A., Schroeder, R. (2002): Jurassic and Cretaceous biostratigraphy of Nurra Region (NW Sardinia, Italy).Palaeobiogeographical remarks. *Reporting Società Paleontologica Italiana*, (1), 119–133.

D'Argenio, B., Simone, L., Carannante., G. (1985): *Se*dimentary evolution of the Northwestern Sardinia. Jurassic and Cretaceous Carbonates. In: *19th European Micropaleontological Colloquium*, Guide Book, AGIP, Sardinia, 57-65.

Dercourt, J., Fourcade, E., Cecca, F., Azema, J., Enay, R., Bassoullet, J.P., Cottereau, N. (1994): Palaeoenvironment of the Jurassic system in the Western and Central Tethys (Toarcian, Callovian, Kimmeridgian, Tithonian): an overview. 3ème Symposium International de Stratigraphie du Jurassique. *Géobios*, (Mém. Spec. 17), 625–644.

Fauré, P. & Peybernès, S. (1983): Le Lias de la Nurra (Sardaigne Nord-Occidentale). Implications paléobiogéographiques. *Comptes Rendus de l'Académie des Sciences Paris*, 296, 1799–1802.

Gaillard, C., Néraudeau, D., Thierry, J. (2011): *Tithonia oxfordiana*, a new irregular echinoid associated with Jurassic seep deposits in south-east France. *Palaeontology*, (54, 4), 735–752.

Kollmann, H.A. (2014): The extinct Nerineoidea and Acteonelloidea (Heterobranchia, Gastropoda): a palaeobiological approach. *Geodiversitas*,(36, 3), 349–383.

Kroh, A., Smith, A.B. (2010): The phylogeny and classification of post-Palaeozoic echinoids. *Journal of Systematic Palaeontology*, (8, 29), 147–212.

Miller, W. (2005): Giant *Bathysiphon* (Astrorhizina: Foraminifera) from the Late Cretaceous Hunters Cove Formation, Southwestern Oregon. *Journal of Paleontology*, (79, 2), 389–394.

Oggiano, G., Funedda, A., Carmignani, L., Pasci, S. (2009): The Sardinia–Corsica microplate and its role in the Northern Apennine Geodynamics: new insights from the Tertiary intraplate strike-slip tectonics of Sardinia. *Italian Journal of Geosciences*, (128, 2), 527–541.

Orsini, J.B., Coulon, C., Cocozza, T. (1980) : Derive cénozoique de la Corse et de la Sardaigne et ses marqueurs géologiques. *Geologie en Mijnbow*, (59), 385–396.

Poignant A.F., Cherchi, A., Schroeder, R. (1982): Les Corallinacées crétacées du Nord-Ouest de la Sardaigne.*Révue de Micropaléontologie*, (24), 244–252.

Rogl, F. (1995): A Late Cretaceous Flysch-type Agglutinated Foraminifera fauna from the *Trochamminoides proteus* Type Locality (Wien-Hiitteldorf, Austria). In: Kaminski, M.A., Geroch, S. & Gasinski, M.A. (eds.). Proceedings of the Fourth International Workshop on Agglutinated Foraminifera, Krakow Poland, September 12-19, 1993. Grzybowski Foundation, (Spec. Publ. 3), 249–263.

Schlumberger, C. (1905): Note sur le genre *Choffatella* n.g. *Bulletin de la Société Géologique de France*. (Sér. 4, 4), 763-764

Schönfeld, J. (1990): Die Maastricht-Stufe in NW-Deutschland, Teil 9: Zur Stratigraphie und Ökologie benthischer Foraminiferen im Schreibkreide-Richtprofil von Lägerdorf/Holstein. *Geologisches Jahrbuch* A, (117), 3–151.

Schroeder, R., Cherchi, A., van Buchem, S.P., Baghbani, D., Vincent, B., Immenhauser, A., Granier, B. (2010): Revised orbitolinid biostratigraphic zonation for the Barremian–Aptian of the eastern Arabian Plate and implications for regional stratigraphic correlations. *GeoArabia Special Publication*, (4, 1), 49–96.

Sotak, J., Misik, M. (1993): Jurassic and Lower Cretaceous dasycladalean Algae from the Western Carpathians. In: Barattolo, F., de Castro, P., Parente, M. (eds). Studies on Fossil Benthic Algae. *Bolletino de la Società Paleontologica Italaniana*, (Spec. Vol. 1), 383–404.

Yilmaz, U. (1998): Taxonomic and Paleogeographic Approaches to the Dasyclad Algae in the Upper Jurassic (Kimmeridgian) Upper Cretaceous (Cenomanian) Peritidal Carbonates of the Fele (YassÝbel) Area (Western Taurides, Turkey).*Turkish Journal of Earth Sciences*,(8), 81–101.

Ziegler, P.A., Stampfli, G.M., Borel, G.D., W. Cavazza, W., Mosar, J. (2001): Palaeotectonic and palaeogeographic evolution of the western Tethys and PeriTethyan domain. *Episodes*, (24, 4), 222–228.

Ziegler, P.A., Stampfli, G.M., Borel, G.D., W. Cavazza, W., Mosar, J. (2001): Palaeotectonic and palaeogeographic evolution of the western Tethys and PeriTethyan domain. *Episodes*, (24, 4), 222–228.

Reigniting Stromer's crocodyliforms from the Bahariya Formation (Cenomanian, Late Cretaceous, North Africa)

Blanco, A.[1,2], Pol, D.[3], Rauhut, O.W.M.[2]

1: Departamento de Física e Ciencias da Terra, Universidade da Coruña, Rúa da Fraga 10, 15008, A Coruña, Spain. alejandro.blancoc@udc.es

2: SNSB, Bayerische Staatssammlung für Paläontologie und Geologie, Richard-Wagner-Strasse 10, 80333 München, Germany. rauhut@snsb.de

3: Museo Paleontológico Egidio Feruglio, CONICET, Av. Fontana 140, U9100, Trelew, Argentina. cacopol@gmail.com

Keywords: *Libycosuchus*, *Aegyptosuchus*, Eusuchia, Notosuchia, Gondwana, digitization.

Introduction

The German palaeontologist Prof. Ernst Stromer discovered a striking bizarre vertebrate fauna during his expeditions into the Western Desert of Egypt at the beginning of the 20th century. Amongst his findings at the Gebel el Dist site were three different crocodyliforms described by him: *Libycosuchus brevirostris*, *Aegyptosuchus peyeri* and *Stomatosuchus inermis* (Stromer, 1914, 1925, 1933). The first taxon is represented by an almost complete, articulated skull, complete lower jaws and four vertebrae. Remains referred to *Aegyptosuchus* are a skull table, isolated teeth and some cervical, thoracic, lumbar, sacral and caudal vertebrae. *Stomatosuchus* was based on a partial skull, a well-preserved right lower jaw, an isolated right articular and one cervical vertebra. These three taxa are known from single specimens (their respective holotypes), but *Stomatosuchus* was destroyed during the bombing of Munich in WW II (1944), so that only the original description and drawings remain as unique evidence for this taxon.

When first described, anatomical comparisons of these species were limited, and they were compared to *Notosuchus*, *Alligatorellus*, *Theriosuchus*, goniopholids, *Bernissartia* and/or Crocodylia. Thus, *Libycosuchus* was initially considered a "highly-specialized form with ancestral features" closely related to *Notosuchus* and *Theriosuchus* and placed in its own genus and family (Stromer, 1914). Regarding *Aegyptosuchus*, the first comparative studies considered this taxon to be related to *Stomatosuchus*, placing both in the eusuchian family Stomatosuchidae (Carroll, 1988; Krause et al., 2006). Since then, a vast number of newly discovered taxa has increased the complexity in the systematics of the Notosuchia and Eusuchia, resulting in different interpretations of the position of *Libycosuchus* and *Aegyptosuchus*,respectively, although there seems to be a general consensus that the former is a member of the Notosuchia, whereas the latter is generally placed in the Eusuchia (Ortega et al., 2000; Carvalho et al., 2004; Pol & Apesteguia, 2005; Fiorelli & Calvo, 2008; Sereno & Larsson, 2009; Holliday & Gardner, 2012). Our aim is to update comparisons of these northern Gondwanan crocodyliforms, and to discuss their phylogenetic relationships.

Methodology

We performed a CT -scan of the skull remains of *Libycosuchus* and *Aegyptosuchus* with a medical Siemens Somatom Force CT scanner at the *Deutsches Herzzentrum München*.Dicom files were processed in Amira (5.6) software in the *Bayerische Staatssammlung für Paläontologie und Geologie*. Final 3D reconstructions allowed improved morphological descriptions for these two crocodyliform taxa.

Preliminary results and future research

The skull of *Libycosuchus* is well preserved, but damaged at several points (right orbit and postorbital bar, left jugal, right pterygoid and palatines), which have been reconstructed. In general shape, it is anteroposteriorly short, with a short antorbital region and a postorbital region that is almost as wide transversely as the skull is long. It is dorsoventrally higher and laterally wider at the posterior end, with a marked slope and narrowing towards the snout. An antorbital fossa is present on each side. The nares are anteriorly oriented and are separated by a robust premaxillary bar. Alveoli are not completely separated, forming a tooth-bearing groove. The lateral alveolar wall is well developed, but the medial border is confluent with the palatal surface. Teeth are lost except for two large caniniforms. The alveoli suggest that, excluding caniniforms and adjacent teeth, other teeth were small in size.

The lower jaw of *Libycosuchus* is formed by two short mandibular rami with strong divergent angle and articulated in a short symphysis. The anterior ends of both dentaries are damaged, and the area around the left mandibular fenestra is broken and reconstructed. Teeth are lost, but alveoli group in the anterior dentary region and indicate small teeth.

The skull roof of *Aegyptosuchus* includes the frontal, parietal, both postorbitals, both squamosals, the supraoccipital and left exoccipital bones. The posterodorsal margins of the orbits are preserved. The supratemporal fenestrae are constricted and widely separated from each other. The ventral end is anteriorly oriented. This taxon is especially noteworthy for its very thick and massive dorsal skull roof.

Forthcoming analyses will be focused on the segmentation and reconstruction of the inner structures of both *Libycosuchus* and *Aegyptosuchus*. Comparisons with other notosuchian and eusuchian taxa respectively will be performed, and phylogenetic relationships for the studied taxa will be tested.

References

Carroll, R.L. (1988): *Vertebrate Paleontology and Evolution.* W.H. Freeman and Company, New York.

Carvalho, I.S., Ribeiro, L.C.B., Avilla, L.S. (2004): *Uberabasuchus terrificus* sp. n., a new Crocodylomorpha from the Bauru Basin (Upper Cretaceous). *Gondwana Research*, 7, 975–1002.

Fiorelli, L.E., Calvo, J.O. (2008): New remains of *Notosuchus terrestris* Woodward, 1896 (Crocodyliformes: Mesoeucrocodylia) from the Late Cretaceous of Neuquén, Patagonia, Argentina. *Arquivos do Museu Nacional Rio de Janeiro*, 66, 83 – 124.

Holliday, C.M., Gardner, N.M. (2012): A new eusuchian crocodyliform with novel cranial integument and its significance for the origin and evolution of Crocodylia. *PLoS ONE*, 7(1), e30471.

Krause, D.W., O'Connor, P.M., Curry Rogers, K., Sampson, S.D., Buckley, G.A., Rogers, R.R. (2006): Late Cretaceous terrestrial vertebrates from Madagascar: implications for Latin American biogeography. *Annals of the Missouri Botanical Garden,* 93(2), 178 – 208.

Ortega, F., Gasparini, Z., Buscalioni, A.D., Calvo, J.O. (2000): A new species of *Araripesuchus* (Crocodylomorpha, Mesoeucrocodylia) from the Lower Cretaceous of Patagonia (Argentina). *Journal of Vertebrate Paleontology*, 20, 57 – 76.

Pol, D., Apesteguia, S. (2005): New *Araripesuchus* remains from the early Late Cretaceous (Cenomanian-Turonian) of Patagonia. *American Museum Novitates*, 3490, 1 – 38.

Sereno, P.C., Larsson, H.C.E. (2009): Cretaceous crocodyliforms from the Sahara. *ZooKeys*, 28, 1 – 143.

Stromer, E. (1914): Ergebnisse der Forschungsreisen Prof. E. Stromers in den Wüsten Ägyptens. II. Wirbeltier-Reste der Baharîje-Stufe (unterstes Cenoman). 1. Einleitung und 2. *Libycosuchus*. *Abhandlungen der Königlich Bayerischen Akademie der Wissenschaften, Mathematisch-Physikalische Klasse,* 27, 1 – 16.

Stromer, E. (1925): Ergebnisse der Forschungsreisen Prof. E. Stromers in den Wüsten Ägyptens. II. Wirbeltier-Reste der Baharije-Stufe (unterstes Cenoman). 7. *Stomatosuchus inermis* Stromer, ein schwach bezahnter Krokodilier. und 8. Ein Skelettrest des Pristiden *Onchopristis numidus* Huag sp. *Abhandlungen der Königlich Bayerischen Akademie der Wissenschaften, Mathematisch-naturwissenschaftliche Abteilung,*30, 1 – 22.

Stromer, E. (1933): Ergebnisse der Forschungsreisen Prof. E. Stromers in den Wüsten Ägyptens. II. Wirbeltierreste der Baharîje-Stufe (unterstes Cenoman). 12. Die procölen Crocodilia. *Abhandlungen der Bayerischen Akademie der Wissenschaften Mathematisch-naturwissenschaftliche Abteilung, Neue Folge* 15, 1 – 55.

First record of a probable squamate reptile from the Cenomanian of Algora (Guadalajara, Central Spain)

Cabezuelo Hernández, A.[1*], Pérez-García, A.[1]

1: Grupo de Biología Evolutiva, Dpto. de Física Matemática y de Fluidos, Facultad de Ciencias, UNED, Avda Esparta s/n, 28232, Las Rozas (Madrid, Spain). paleo.alb@gmail.com; a,perez.garcia@ccia.uned.es

Keywords: Reptilia, Squamata, vertebra, Upper Cretaceous, Iberian Peninsula

The Cenomanian (basal Late Cretaceous) vertebrate fossil record of Europe is relatively poorly known due to the scarcity of remainscompared to those of other geological stages. The Cenomanian record is essential for the understanding of the faunal turnover that took place between the Early and Late Cretaceous, since the European latest Cretaceous faunas were radically different from those of the Early Cretaceous ecosystems. In this sense, the palaeontological area of Algora (Guadalajara, Central Spain) represents the first location with a high concentration of macrovertebrate remains from the Cenomanian of Europe. The Algora fossil site has yielded numerous vertebrate fossil remains, increasing the knowledge about the faunal taxa from this transitional period.In this context, the European oldest or youngest record of certain lineages previously thought to be extinct at the Early Cretaceous or not yet present at the Late Cretaceous has been identified. The faunal assemblage of Algora is so far representedby an osteichthyan, stem and pleurodiran turtles, an indeterminate elasmosaurian, two neosuchian crocodiles, a theropod, and a sauropod. Recent finds in this locality, hitherto unpublished, allow us to recognize several previously unidentified taxa. In addition, a vertebra of a probable squamate reptile has been recognized. Its detailed systematic study is performed here, in addition to a comparison with fossil remains from other Cenomanian sites and from other stages of the Early and Late Cretaceous.

New data on the appendicular skeleton of the simosaurid *Paludidraco multidentatus* holotype (Eosauropterygia) from the Upper Triassic of El Atance (Guadalajara, Spain)

Cabezuelo Hernández, A.[1*], De Miguel Chaves, C.[1], Ortega, F.[1], Pérez-García, A.[1]

1: Grupo de Biología Evolutiva, Dpto. de Física Matemática y de Fluidos, Facultad de Ciencias, UNED, Avda Esparta s/n, 28232, Las Rozas (Madrid, Spain). paleo.alb@gmail.com; carlos.miguelchaves@gmail.com; fortega@ccia.uned.es; a.perez.garcia@ccia.uned.es

Keywords: Sauropterygia, Simosauridae, appendicular elements, Late Triassic, Iberian Peninsula

Simosauridae is a clade of Triassic eosauropterygians ranging from the Anisian or Ladinian (Middle Triassic) to the Carnian (Late Triassic) of the Middle East and Europe. Simosauridae was erected by Huene in 1948 after the description of *Simosaurus gaillardoti* (from the Ladinian of France and Germany) made by Meyer in 1842, this taxon being the type species for the group and the only known valid representative of the clade until recently. Nevertheless, a new eosauropterygian (i.e., *Paludidraco multidentatus*) was described by de Miguel Chaves et al. (2018) from the Carnian fossil site of El Atance (Guadalajara, Central Spain), being recognized as a member of Simosauridae. Despite the holotype of the Spanish taxon corresponds to a relatively complete skeleton preserving several of the appendicular elements, its postcranium has not yet been studied in detail. Appendicular elements of *S. gaillardoti* are relatively well-known, especially based on the information provided by Rieppel (1994). *Simosaurus gaillardoti* was recognized as an active predator whereas *Paludidraco multidentatus*shows non-appendicular anatomical features associated to a significantly different lifestyle (e.g., slender mandibles with numerous and small comb-like teeth, and pachyostotic ribs and vertebrae), suggesting adaptations for slow movement near the marine bottom. In this context, a detailed description of the appendicular elements preserved in the holotype of *P. multidentatus* is performed here, in addition to an anatomical comparative study with those of its sister taxon *S. gaillardoti*. The functional implications and locomotion modes previously proposed for both taxa will be reevaluated considering the different character states between their appendicular skeletons.

Acknowledgements. This research was funded by the FPU Grant FPU20/01945 (Spanish Ministry of Universities).

References

De Miguel Chaves, C., Ortega, F., Pérez-García, A. (2018): New highly pachyostotic nothosauroid interpreted as a filter feeding Triassic marine reptile. *Biology Letters*, (14), 20180130.

Huene, F.v. (1948): *Simosaurus* and *Corosaurus*. *American Journal of Science*, (246), 41-43.

Meyer, H. von (1842): *Simosaurus*, die Stumpfschnauze, ein Saurier aus dem Muschelkalke von Luneville. *Neues Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefakten-Kunde*, (1842), 184-197.

Rieppel, O. (1994): Osteology of *Simosaurus gaillardoti* and the relationships of stem-group Sauropterygia. *Fieldiana: Geology*, (28), 1-85.

Los Corrales del Pelejón tracksite (Lower Cretaceous, Galve) revisited: track preservation and ichnotaxonomy

Castanera, D.[1, 2,*], Bádenas, B.[1], Aurell, M.[1], Canudo, J. I.[1], Cuenca-Bescós, G.[1], Gasca, J. M.[1,3]

1: Aragosaurus—IUCA, Paleontología, Facultad de Ciencias, Universidad de Zaragoza, 50009 Zaragoza, Spain; dcastanera@hotmail.es;

2: Institut Català de Paleontologia Miquel Crusafont, Universitat Autònoma de Barcelona, c/ Escola Industrial 23, 08201 Sabadell, Barcelona, Spain.

3: Departamento de Geología, Universidad de Salamanca, 37008, Salamanca, Spain.

Keywords: dinosaur footprints, Theropoda, Ornithopoda, Galve Formation, Galve subbasin, Maestrazgo basin

Introduction

Los Corrales del Pelejón (CP) tracksite (Galve, Teruel province) was the first documented tracksite with dinosaur footprints in the Maestrazgo Basin (northeastern Spain). At the beginning of the eighties, a few isolated theropod footprints were described in this outcrop (Casanovas et al., 1983-84). Posteriorly, the track-bearing bed of the site was cleaned and excavated, and new trackways were exposed. Seven trackways were identified, six of them attributed to theropod dinosaurs and the seventh to an ornithopod (Cuenca et al., 1993). Despite the high quantity of dinosaur tracksites in several geological units of the Maestrazgo Basin this is the only dinosaur tracksite in the alluvial, red-mudstone-dominated Galve Formation (Berriasian-Valanginian, Aurell et al., 2016).

Methodology

The CP tracksite has been documented with photogrammetric techniques. A total of 585 photographs were taken to create a 3D model of the whole surface. Besides, 3D models of individual footprints have been also created with sets of about 12-20 pictures per footprint. The 3D models have been built using the software Agisoft Photoscan Standard edition. In addition, a detailed analysis of the stratigraphy of the tracksite has been carried to understand track preservation either as (1) true tracks, preserved in the layer were the dinosaurs walked on, that is the tracking surface, or (2) undertracks preserved in a lower stratigraphic layer of the tracking surface. Morphological quality preservation (MP) has been independently analyzed of each footprint using the numerical scale proposed by Marchetti et al. (2019).

Results

A total of six clear trackways and a possible seventh can be identified in the tracksite as reported by Cuenca et al. (1993). The orientation of the dinosaur trackways plotted in a rose diagram provides a general multidirectional pattern although the theropod trackways show a rather bimodal pattern with a NE-SW direction trend. Stratigraphically, four cm-thick fine to very fine-grained sandstone layers can be distinguished on the surface of the tracksite (Fig. 1). Many of the tracks and trackways (CP3-CP10) are preserved in the lowest layer of the surface (layer 1), which is mostly exposed in the eastern area of the tracksite. On the other hand, trackways CP1 and CP2 located in the western side are mainly preserved in the uppermost layers but locally some of the tracks also in lower layers. All the trackways show a considerable intratrackway variation in MP, with values of each footprint that varies from 0.5 to 2.5. All the tracks are preserved as concave epirreliefs. Three different theropod morphotypes can be distinguished according to their size: a small-sized (CP4, Footprint length (FL) = around 15 cm), a medium-sized (CP1, CP5, CP8, CP9, CP10; FL = 25-30 cm) and a large theropod (CP2, CP3 and CP6, FL around 35-38 cm). The tracks are typically tridactyl theropod tracks, some of them with clear claw impressions. The three different morphotypes have slightly variations in FL/FW ratio and mesaxony according to the different size classes with smaller specimens showing higher values of FL/FW and mesaxony. Some of the footprints show a characteristic large and rounded metatarsophalangeal pad impression. CP7 is the only trackway attributed to ornithopods. The tracks show a low MP preservation value but CP7.4 is a tridactyl track, slightly longer than wide with low mesaxony, and with rounded digit impressions and no evidence of claw impressions.

Discussion

The absence of layers 2, 3 and 4 in some areas of the tracksite makes difficult to interpret how the tracks were preserved, and to properly understand which layer was the tracking surface. Since CP1 and CP2 were mainly preserved in the uppermost layers in the western area and some of the footprints show the highest MP values, one hypothesis could be that layer 4 was the only tracking surface and these two trackways were mainly preserved as true tracks (and some footprint as a shallow undertrack). Thus, the uppermost layers (2-4) were eroded in the eastern area of the tracksite, and what we are currently seeing are shallow undertracks of the other trackways (CP3-CP10) preserved in layer 1. Another hypothesis could be that the trackways in the eastern and western areas were produced at different surfaces, and thus CP3-CP10 could have been produced before CP1-CP2, so the ichnoassemblage would not be coeval. The former hypothesis could have more support if the MP values would show a considerable difference, i.e. true tracks would have better MP than shallow undertracks. There is not a considerable difference although tracks in CP1 show the highest MP values and preserved fine anatomical details such as claw marks and possible phalangeal pad impressions.

The theropod tracks from Los Corrales del Pelejón have not been previously assigned to any ichnotaxa. Casanovas et al. (1983-84) compared the tracks (from trackways CP3 and CP6) with different ichnotaxa such as *Eubrontes*, *Eutynichnium*, *Megalosauropus* and *Bueckeburgichnus*. Certainly, some of these tracks resemble *Eubrontes*-like tracks, a theropod ichnotaxa typical from the Late Triassic-Early Jurassic but also identified in the Lower Cretaceous of Asia (Xing et al., 2021). Some of the other medium and large-sized theropod tracks are also similar to *Megalosauripus* tracks, especially to *Megalosauripus transjuranicus* described from the Late Jurassic and the Jurassic/Cretaceous transition (Tithonian-Berriasian) of Europe (e.g. Belvedere et al., 2019), due to the large rounded heel pad impression. Nonetheless, this feature is also typical of *Asianopodus* from the Lower Cretaceous of Asia (Xing et al., 2014). Finally, the small-sized theropod (CP4) resemble tracks included in Grallatoridae and the ornithopod tracks (CP7) resembles *Iguanodontipus*-like tracks. Both ichnotaxa have been described in Late Jurassic and Berriasian tracksites in Europe (e.g.: Castanera et al., 2016; 2022). Further work is needed to properly understand the preservation of the tracks in this site and thus interpret whether the morphological variations seen among the tracks might be ichnotaxonomic, preservational-related or both so we can clarify the number of theropod ichnotaxa present in the site. This will help to understand the differences between *Eubrontes*, *Megalosauripus* and *Asianopodus*-like tracks in the Lower Cretaceous. The ichnotaxonomic affinities of the tracks are very significant to elucidate whether the ichnoassemblage is more similar to Late Jurassic or to Lower Cretaceous ichnofaunas, thus representing (or not) the faunal change occurred across the Jurassic/Cretaceous transition.

References

Aurell, M., Bádenas, B., Gasca, J. M., Canudo, J. I., Liesa, C. L., Soria, A. R., ... & Najes, L. (2016): Stratigraphy and evolution of the Galve sub-basin (Spain) in the middle Tithonian–early Barremian: implications for the setting and age of some dinosaur fossil sites. *Cretaceous Research*, 65, 138-162.

Belvedere, M., Castanera, D., Meyer, C. A., Marty, D., Mateus, O., Silva, B. C., ... & Cobos, A. (2019): Late Jurassic globetrotters compared: A closer look at large and giant theropod tracks of North Africa and Europe. *Journal of African Earth Sciences*, 158, 103547.

Casanovas-Cladellas, M.L., Santafe-Llopis, Y.U., Sanz, J.L. (1983-1984): Las Icnitas de «Los Corrales del Pelejón» en el Cretácico inferior de Galve, Teruel, España. *Paleontología i Evolució*, 18, 173-176.

Castanera, D., Piñuela, L., & García-Ramos, J. C. (2016). *Grallator* theropod tracks from the Late Jurassic of Asturias (Spain): ichnotaxonomic implications. *Spanish Journal of Palaeontology*, 31(2), 283-296.

Castanera, D., Bádenas, B., Aurell, M., Canudo, J. I., & Gasca, J. M. (2022). New ornithopod tracks from the Lower Cretaceous El Castellar Formation (Spain): Implications for track preservation and evolution of ornithopod footprints. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 591, 110866.

Cuenca, G., Ezquerra, R., Pérez, F., Soria, A.R. (1993): Las Huellas de dinosaurios (icnitas) de Los Corrales del Pelejón. Diputación General de Aragón. Departamento de Cultura y Educación. 14 pp.

Marchetti, L., Belvedere, M., Voigt, S., Klein, H., Castanera, D., Díaz-Martínez, I., ... & Farlow, J. O. (2019): Defining the morphological quality of fossil footprints. Problems and principles of preservation in tetrapod ichnology with examples from the Palaeozoic to the present. *Earth-Science Reviews*, 193, 109-145.

Xing, L. D., Niedźwiedzki, G., Lockley, M. G., Zhang, J. P., Cai, X. F., Persons IV, W. S., & Ye, Y. (2014): *Asianopodus*-type footprints from the Hekou Group of Honggu District, Lanzhou City, Gansu, China and the "heel" of large theropod tracks. *Palaeoworld*, 23(3-4), 304-313.

Xing, L. D., Lockley, M. G., Klein, H., Zhang, L. J., Romilio, A., Scott Persons, W., ... & Wang, M. Y. (2021): The new ichnotaxon *Eubrontes nobitai* ichnosp. nov. and other saurischian tracks from the Lower Cretaceous of Sichuan Province and a review of Chinese *Eubrontes*-type tracks. *Journal of Palaeogeography*, 10(1), 1-19.

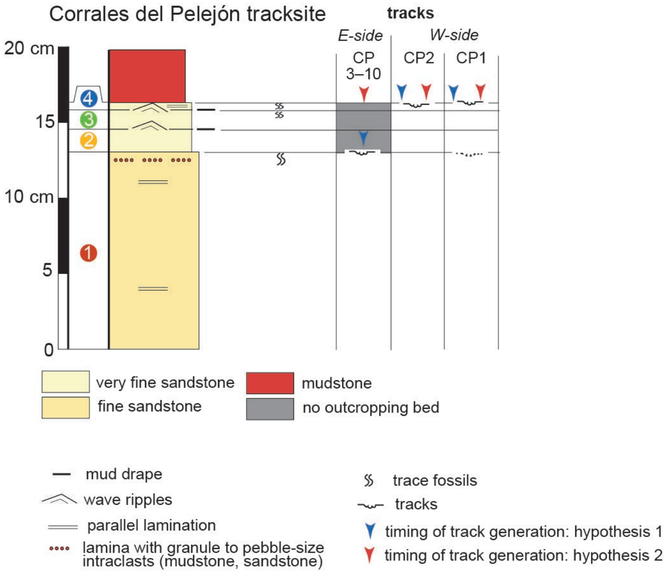

Figure 1.- Detailed stratigraphic log of the Los Corrales del Pelejón tracksite, showing the layers in which, the tracks are preserved and the possible time intervals of track generation.

Nodosaurids osteoderms from the Late Maastrichtian (Late Cretaceous) of Southern Pyrenees

Castillo-Visa, O.[1], Vicente, A.[2,3], Sellés, A.[1,4]

1: Museu de la Conca Dellà, C/del Museu, 4, 25650, Isona (Lleida, Spain).oscarcasvi25@gmail.com

2: Departament de Dinàmica de la Terra i de l'Oceà, Institut de Recerca de la Biodiversitat-IRBio, Facultat de Ciències de la Terra, Universitat de Barcelona-UB, 08028, Barcelona, Catalonia, Spain. albavr@geologia.unam.mx

3: Estación Regional del Noroeste. Instituto de Geología, Universidad Nacional Autónoma de México-UNAM, Blvd. Luis Donaldo Colosio S/N Campus UNISON, 83000, Hermosillo, Sonora, Mexico

4: Institut Català de Paleontologia Miquel Crusafont, Universitat Autònoma de Barcelona, Carrer Escola Industrial 23, 08201 Sabadell (Barcelona), Catalonia, Spain albert.selles@icp.cat

Keywords: Osteoderms, Nodosauridae, Maastrichtian.

Introduction

By the end of the Cretaceous, armored dinosaurs become relatively diverse and abundant in both Western America and Eastern Asia, where the two main clades, Ankylosauridae and Nodosauridae, were present. In contrast, nodosaurids were a minor faunal component of the dinosaur communities that once roamed along the ancient Cretaceous European archipelago.

Latest Cretaceous nodosaurids were present in Portugal, Spain, France, Austria, Hungary, and Romania, being unevenly represented (Csiki-Sava et al., 2015). The Iberian record is strikingly scarce, limited to fragmentary remains from the upper Campanian deposits of Laño (Pereda Suberbiola, 1999), and from the early Maastrichtian beds of Chera (Company, 2004). Regarding the ankylosaurian record from Southern Pyrenees, it includes a single humerus from the Barranc dels Cantals (formerly and erroneously reported from Suterranya-Mina de lignit locality, see Vila, 2022) (Martín Jiménez et al., 2017) and some isolated teeth from the Fontllonga-6, Biscarri and Julí sites (Álvarez-Sierra et al., 1994; López-Martínez et al., 2000; López-Martínez, 2003). In addition, Santafé et al. (1997) documented the occurrence of one osteoderm from the late Early Maastrichtian Els Nerets site (Pallars Jussà), which were never described. Here, we describe for the first time the remains of dermal armor elements attributed to nodosaurid struthiosaurinis from Els Nerets site (Southern Pyrenees).

Methodology

We provide a preliminary description of three isolated osteoderms from els Nerets site, following the nomenclatural terminology of Ösi & Makadi (2009), and Arbour et al. (2014). All elements are housed in the Museu de la Conca Dellà (MCD, Isona, Pallars Jussà, Catalonia, Spain).

Results

MCD-5035 is a well-preserved left pectoral osteoderm. The dermal element is divided in two distinctive lobes by a vascular channel that bestows a characteristic kidney-lake shape to the armor plate. The external surface is of hummocky type with a uniform rugosity distribution (based on Hieronymus et al., 2009). A low, narrow, and straight keel runs anterioposteriorly along the sagittal plane of the osteoderm. In lateral view, the base is convex with its maximum curvature placed at the level of the basal neurovascular channel.

MCD-0074 isa partial right sacral spike. Most of the medial and posterior margins, and the spine are missing. In dorsal view, the element is squared, with curved anterior margin. The base of the spine, which is located near the lateral margin, is wither latero-medially than thick antero-posteriorly. In lateral view, the base of the spine is slightly tilted anteriorly. Ventrally, an elongated neurovascular foramen is in the posterior region of the element.

MCD-8822is a small sub-conical osteoderm. Despite most of the margins are eroded, in dorsal view the element seems that could had displayed a subrombical shape. The keel, which is relatively tall and lacks its posterior margin, curves posteromedially. In anterior view, the base is slightly convex.

Histological thin sections were performed in MCD-0074. It shows an external cortex that displays abundant secondary osteons, which locally obliterate most of the primary fibrolamellar tissue. The basal cortex is absent. In its place a poorly organized woven bone tissue extends deep into the basal part of the bone. Large trabecular cavities cover most of the inner cortex and the core of the osteoderm. The CT scan analyses on MCD-5035 revealed similar histological configuration, with a disorganized basal region and an inner cortex full of large cavities, which may correlate to trabeculae vacuities.

Discussion

Integument ossifications (osteoderms) are among the most common fossil remains of ankylosaurs worldwide. They can be distinguished from osteoderms of crocodiles, and titanosaurs based on the different texture exhibited in titanosaurs (elements typically having an irregular surface with nodules, fibers, and grooves (Vidal et al., 2014)) and crocodyliforms (a surface with several subcircular pits and covered by a smooth texture). Furthermore, the attribution of the studied osteoderms in the present work to testudines seems unlikely due the asymmetry of the studied elements, the presence of spines and vascular channels ventrally, and the lack of sutural marks along the surface and margins.

Burns and Currie (2014) noted that nodosaurid osteoderms are characterized by having a dense external fibered cortex and poor-developed basal cortex. These histological features are observed in some of the osteoderms from Els Nerets (MCD-0074 and MCD-5035), confirming their ascription to Nodosauridae. Given that osteoderms are relatively common in the fossil record, several authors have made a significant effort to identify anatomical treats that could allow their taxonomic classification (e.x. Ford, 2000; Pereda-Suberbiola and Galton, 2001). In this regard, Kirkland et al. (2013) proposed that the presence of "erect sacral osteoderms with flat bases" was a synapomorphic feature of the tribe Struthiosaurini (*sensu*Madzia et al., 2021). This feature is at least present in the sacral spike plate from Els Nerets (MCD-0074). Consequently, this element is tentatively attributed to an indeterminate species belonging to the tribe Struthiosaurini. On the other hand, the morphology and location of the neurovascular channel of MCD-5035 seems to be only reported in struthiosaurini *Struthiosaurus austriacus* (Pereda-Suberbiola & Galton, 2001) and *Europelta carbonensis* (Kirkland et al., 2013), supporting the hypothesis that the specimens from Els Nerets belong to the tribe Struthiosaurini.

References

Álvarez-Sierra, M.A., Arribas, M.E., Ardévol, L., Civis, J., Daams, R., Krauss, S., López-Martínez, N., de la Peña, A., Soler, R., Vianey-Liaud, M., Lacasa, A., Marandat, B., Peláez-Campomanes, P., Sevilla, P., Sigé, B. (1994): El límite Cretácico-Terciario en la sección de Fontllonga (cuenca de Ager, provincia de Lérida). In: *II Congreso del Grupo Español de Terciario*. (Dpto. de Ciencias de la Tierra, Universidad de Zaragoza, Ed.), 23-26.

Arbour, V.M., Burns, M.E., Bell, P.R., Currie, P.J. (2014): Epidermal and dermal integumentary structures of ankylosaurian dinosaurs. *Journal of Morphology*, 275 (1), 39-50.

Burns, M.E., Currie, P.J. (2014): External and internal structure of ankylosaur (Dinosauria, Ornithischia) osteoderms and their systematic relevance. *Journal of Vertebrate Paleontology*, 34 (4), 835-851.

Company, J. (2004): Vertebrados continentales del Cretácico superior (Campaniense-Maastrichtiense) de Valencia (*Doctoral dissertation*, Universitat de València)

Csiki-Sava, Z., Buffetaut, E., Ősi, A., Pereda-Suberbiola, X., Brusatte, S.L. (2015): Island life in the Cretaceous-faunal composition, biogeography, evolution, and extinction of land-living vertebrates on the Late Cretaceous European archipelago. *ZooKeys*, (469), 1-161.

Ford, T. (2000): A review of ankylosaur osteoderms from New Mexico and a preliminary review of ankylosaur armor. In: Lucas, S.G., Heckert, A.B. (eds). Dinosaurs of New Mexico. *New Mexico Museum of Natural History and Science Bulletin*, (17), 157.

Hieronymus, T.L., Witmer, L.M., Tanke, D.H., Currie, P.J. (2009): The facial integument of centrosaurine ceratopsids: morphological and histological correlates of novel skin structures. *The Anatomical Record: Advances in Integrative Anatomy and Evolutionary Biology: Advances in Integrative Anatomy and Evolutionary Biology*, 292 (9), 1370-1396.

Kirkland, J.I., Alcala, L., Loewen, M.A., Espilez, E., Mampel, L., Wiersma, J.P. (2013): The basal nodosaurid ankylosaur *Europelta carbonensis* n. gen., n. sp. from the Lower Cretaceous (lower Albian) Escucha Formation of northeastern Spain. *PLoS One*, 8 (12), e80405.

López-Martínez, N., Moratalla, J.J., Sanz, J.L., (2000): Dinosaurs nesting on tidal flats. *Palaeogeography, Palaeoclimatology, Palaeoecology* , 160, 153–163.

López-Martínez, N., 2003. La extinción de los dinosaurios y su registro en los Pirineos meridionales. In: *II Jornadas de Paleontología de Dinosaurios y su Entorno.* (Colectivo Arqueológico–Paleontológico de Salas, Ed.) Salas de los Infantes, 71–98.

Madzia, D., Arbour, V.M., Boyd, C.A., Farke, A.A., Cruzado-Caballero, P., Evans, D.C. (2021): The phylogenetic nomenclature of ornithischian dinosaurs. *PeerJ*, 9, e12362.

Martin Jiménez, M., Sánchez-Chillón, B., Escaso, F., Mocho, P., Narvaez, I., Ortega, F., Perez-Garcia, A. (2017): Systematic study of the historical material of Upper Cretaceous reptiles from the Tremp Basin (Catalonia, Spain) housed at the Museo Nacional de Ciencias Naturales (Madrid). *Journal of Iberian Geology*, 43 (2), 217-233.

Ősi, A., Makádi, L. (2009): New remains of *Hungarosaurus tormai* (Ankylosauria, Dinosauria) from the Upper Cretaceous of Hungary: skeletal reconstruction and body mass estimation. *Paläontologische Zeitschrift*, 83 (2), 227-245.

Pereda-Suberbiola, X. (1999): Ankylosaurian dinosaur remains from the Upper Cretaceous of Laño (Iberian Peninsula). *Estudios del Museo de Ciencias Naturales de Alava*, 14 (1), 273-288.

Pereda-Suberbiola, X. Galton, P. (2001): Reappraisal of the nodosaurid ankylosaur *Struthiosaurus austriacus* Bunzel from the Upper Cretaceous Gosau Beds of Austria. In: Carpenter, K. (eds). *The Armored Dinosaurs*. Bloomington, Indiana: Indiana University Press, 173–210.

Santafé, J.V., Casanovas, M.L. Llompart, C. (eds) (1997): *Els Dinosaures i el seu entorn geològic*. Diputació de Lleida, 1-69.

Vidal, D., Ortega, F., Sanz, J.L. (2014): Titanosaur osteoderms from the Upper Cretaceous of Lo Hueco (Spain) and their implications on the armor of Laurasian titanosaurs. *PLoS One*, 9 (8), e102488.

Vila, B. (2022): Walter Georg Kühne (1911-1991) and the discovery of the first semi-articulated titanosaurian sauropod from Europe. *Historical Biology*, https://doi.org/10.1080/08912963.2022.2100771

Review of the theropod teeth from the Upper Maastrichtian Molí del Baró-1 locality (Southwestern Pyrenees)

Castillo-Visa, O.[1], Serrano, J.[1], Baiano, M. A.[2, 4, 5], Vila, B[1, 3]

1: Museu de La Conca Dellà, c/ Museu 4, 25650 Isona, Lleida, Spain. jfsp@gmail.com, oscarcasvi25@gmail.com

2: Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina. mbaiano@unrn.edu.ar

3: Institut Català de Paleontologia Miquel Crusafont, Universitat Autònoma de Barcelona, Carrer Escola Industrial 23, 08201 Sabadell (Barcelona), Catalonia, Spain.. bernat.vila@icp.cat

4: Área Laboratorio e Investigación, Museo Municipal "Ernesto Bachmann", Dr. Natali s/n, Villa El Chocón (Q8311AZA), Neuquén, Argentina

5: Universidad Nacional de Río Negro (UNRN), Isidro Lobo 516, General Roca (8332), Río Negro, Argentina

Introduction

Non-avian theropod dinosaurs were pivotal components of Mesozoic ecosystems, spanning a wide array of trophic niches that lead to the diversification of tooth shape and dental morphologies (Torices et al., 2018; Hendrickx et al., 2019). In Europe, the Upper Cretaceous theropod fossil record mainly consists of isolated teeth and fragmentary bone remains that concentrate in Spain, Portugal, France, Romania, and Austria (Csiki-Sava et al., 2015; Ösi et al., 2019). The isolated nature of tooth remains has hampered their taxonomic identification beyond family level (e.g. Marmi et al., 2015). However, recent studies have greatly improved theropod taxonomic identification based on qualitative and quantitative dental features (Hendrickx et al., 2019, 2020).

In this regard, the Iberian record, despite being mainly based on isolated teeth and ootaxa, is diverse enough to contribute to the theropod paleobiodiversity and paleobiogeography studies (Isasmendi et al., 2022). In the southern Pyrenees, the theropod fossil record consists of isolated teeth (Prieto-Márquez et al., 2000; Canudo et al., 2016; Torices et al., 2015), eggs and eggshells (López-Martínez and Vicens, 2012; Sellés et al., 2014), and a single appendicular bone (Sellés et al., 2021).

In the present study, we review the theropod remains of the Molí del Baró-1 locality (Isona i Conca Dellà, Catalonia, Spain), from the fluvial deposits of the Talarn Formation or 'Lower red Garumnian' of the Tremp Group (C29r magnetochron-upper Maastrichtian; Fondevilla et al., 2019). This fossil locality has yielded plants (charophytes, sporomorphs, angiosperm leaves, seeds, and logs), invertebrates (mollusc shells, partial insect exoskeletons and eggs) and vertebrates (mainly shed teeth, bones, and eggshells of dinosaurs and crocodylomorphs) remains (Marmi et al., 2015).

Among the vertebrate remains, the theropod material of Molí del Baró-1 consists of five teeth that might represent a remarkable taxonomic diversity (Marmi et al., 2015), although until now their taxonomic classification remained poorly resolved. In this context, our aim is to improve the systematics of these teeth using quantitative and qualitative approaches and anatomical and nomenclature terminology previously proposed by Hendrickx et al. (2015, 2019).

Results

The specimen MCD-5033, previously classified as Theropoda indet. (Marmi et al., 2015), is here assigned to Velociraptorinae and recognized as a lateral tooth. The new assignment is based on the combination of the following dental features proposed by Hendrickx et al. (2019) for this clade: 1) presence of a ziphodont dentition with serrated mesial and distal carinae in at least some lateral teeth; 2) lateral tooth with ridged carinae; 3) absence of a constriction between the root and the crown base; 4) a strongly concave distal margin; and, 5) an eight-shaped cross section of the crown base. It is remarkable that condition 3 and 4 are considered unambiguous synapomorphies for Dromaeosauridae, whereas condition 5 is present in all velociraptorines other than *Deinonychus* (Hendrickx et al., 2019). The PCA analysis (based on Isasmendi et al., 2022 data matrix) shows a relatively close position of MCD-5033 with the teeth of *Velociraptor mongoliensis*.

The specimen MCD-5579 was previously classified as a Dromaeosauridae indet. (Marmi et al., 2015). However, in the present study we assign it to Troodontidae based on the presence and combination of the following dental features: 1) relatively short crown height; 2) unserrated mesial carina; 3) concave surface adjacent to carinae; 4) distal carina centrally positioned or slightly displaced (crown sub-symmetrical); 5) small number of large distal denticles in lateral teeth (i.e. fewer than 15 denticles on the carina); 6) hooked denticles; 7) absence of marginal undulations and 8) presence of interdenticular sulci and transverse undulations (as in *Troodon*). Because of its partial preservation, no PCA analysis was performed on MCD-5579.

The specimen MCD-5583, previously identified as a Theropoda indet. (Marmi et al., 2015), is here recognized as a tooth from the mesial part of the snout and assigned to Dromaeosaurinae indet. The new assignment is based on the presence of a J-shaped cross section of the crown base, which is considered an unambiguous synapomorphy of Dromaeosauridae (Hendrikx et al., 2019).

The revision of this material, despite its preliminary state, considerably improves the taxonomic resolution of the teeth studied and highlights a higher theropod diversity in the Molí del Baró-1 fossil site than previously known.

References

Canudo, J.I., Oms, O., Vila, B., Galobart, À., Fondevilla, V., Puértolas-Pascual, E., Sellés, A.G., Cruzado-Caballero, P., Dinarès-Turell, J., Vicens, E., Castanera, D., Company, J., Burrel, L., Estrada, R., Marmi, J., Blanco, A. (2016): The Upper Maastrichtian dinosaur fossil record from the southern Pyrenees and its contribution to the topic of the Cretaceous–Palaeogene mass extinction event. *Cretaceous Research*, 57, 540-551.

Csiki, Z., Vremir, M., Brusatte, S.L., Norell, M.A. (2010): An aberrant island-dwelling theropod dinosaur from the Late Cretaceous of Romania. *Proceedings of the National Academy of Sciences*, 107 (35), 15357-15361.

Csiki-Sava, Z., Buffetaut, E., Ősi, A., Pereda-Suberbiola, X., Brusatte, S.L. (2015): Island life in the Cretaceous-faunal composition, biogeography, evolution, and extinction of land-living vertebrates on the Late Cretaceous European archipelago. *ZooKeys*, 469, 1-161.

Fondevilla, V., Riera, V., Vila, B., Sellés, A.G., Dinarès-Turell, J., Vicens, E., Gaete, R., Oms, O., Galobart, A. (2019): Chronostratigraphic synthesis of the latest Cretaceous dinosaur turnover in south-western Europe. *Earth-Science Reviews*, 191, 168-189.

Hendrickx, C., Mateus, O., Araújo, R. (2015): A proposed terminology of theropod teeth (Dinosauria, Saurischia). *Journal of Vertebrate Paleontology*, 35 (5), e982797.

Hendrickx, C., Mateus, O., Araujo, R., Choiniere, J. (2019): The distribution of dental features in non-avian theropod dinosaurs: Taxonomic potential, degree of homoplasy, and major evolutionary trends. *Palaeontologia Electronica*, 22 (3), 1-110.

Hendrickx, C., Tschopp, E., d Ezcurra, M. (2020). Taxonomic identification of isolated theropod teeth: the case of the shed tooth crown associated with Aerosteon (Theropoda: Megaraptora) and the dentition of Abelisauridae. *Cretaceous Research*, 108, 104312.

Isasmendi, E., Torices, A., Canudo, J.I., Currie, P.J., Pereda-Suberbiola, X. (2022): Upper Cretaceous European theropod palaeobiodiversity, palaeobiogeography and the intra-Maastrichtian faunal turnover: new contributions from the Iberian fossil site of Laño. *Papers in Palaeontology*, 8 (1), e1419.

López-Martínez, N., Vicens, E. (2012): A new peculiar dinosaur egg, *Sankofa pyrenaica* oogen. nov. oosp. nov. from the Upper Cretaceous coastal deposits of the Aren Formation, south-central Pyrenees, Lleida, Catalonia, Spain. *Palaeontology*, 55 (2), 325-339.

Marmi, J., Blanco, A., Fondevilla, V., Dalla Vecchia, F.M., Sellés, A.G., Vicente, A., Martín-Closas, C., Oms, O., Galobart, A. (2015): The Molí del Baró-1 site, a diverse fossil assemblage from the uppermost Maastrichtian of the southern Pyrenees (north-eastern Iberia). *Cretaceous Research*, 57, 519-539.

Ortega, F., Bardet, N., Barroso Barcenilla, F., Callapez, P.M., Domingo Martínez, L. (2015): The biota of the Upper Cretaceous site of Lo Hueco (Cuenca, Spain). *Journal of Iberian Geology*, 41 (1), 83-99.

Ősi, A., Szabó, M., Kollmann, H., Wagreich, M., Kalmar, R., Makádi, L., Szentesi, Z., Summesberger, H. (2019): Vertebrate remains from the Turonian (Upper Cretaceous) Gosau Group of Gams, Austria. *Cretaceous Research*, 99, 190-208.

Prieto-Marquez, A., Gaete, R., Galobart, A., Ardévol, L. (2000): A Richardoestesia-like theropod tooth from the Late Cretaceous foredeep, south-central Pyrenees, Spain. *Eclogae Geologicae Helvetiae*, 93 (3), 497-502.

Sellés, A.G., Vila, B., Galobart, A. (2014): Diversity of theropod ootaxa and its implications for the latest Cretaceous dinosaur turnover in southwestern Europe. *Cretaceous Research*, 49, 45-54.

Sellés, A.G., Vila, B., Brusatte, S.L., Currie, P.J., Galobart, À. (2021): A fast-growing basal troodontid (Dinosauria: Theropoda) from the latest Cretaceous of Europe. *Scientific reports*, 11 (1), 1-12.

Torices, A., Currie, P.J., Canudo, J.I., Pereda-Suberbiola, X. (2015): Theropod dinosaurs from the Upper Cretaceous of the South Pyrenees Basin of Spain. *Acta Palaeontologica Polonica*, 60 (3), 611–626.

Torices, A., Wilkinson, R., Arbour, V.M., Ruiz-Omeñaca, J.I., Currie, P.J. (2018): Puncture-and-pull biomechanics in the teeth of predatory coelurosaurian dinosaurs. *Current Biology*, 28 (9), 1467-1474.

Cranial and mandibular material from a hadrosauriform dinosaur from the Lower Cretaceous of Los Terreros-Altollano I site (Salas de Los Infantes, Burgos, Spain)

Escanero-Aguilar, D.[1]; Torcida Fernández-Baldor, F.[2], Pereda-Suberbiola, X.[3]

1: Diego Escanero-Aguilar, 50007 Zaragoza, Spain. d.escanero88@gmail.com

2: Museo de Dinosaurios de Salas de los Infantes y Colectivo Arqueológico y Paleontológico de Salas; 09600 Salas de los Infantes (Burgos), Spain. fideltorcida@hotmail.com

3: Universidad del País Vasco / Euskal Herriko Unibertsitatea, Apartado 644, 48080 Bilbao, Spain. Xabier.pereda@ehu.es

Keywords: Barremian-Aptian, Castrillo de la Reina Formation, Ornithopoda, iguanodontia

Introduction

The surroundings of the Burgos town of Salas de los Infantes is especially rich in fossil remains, whether bone, ichnological or oological records (Torcida Fernández-Baldor, 2006), from the Upper Jurassic to the Lower Cretaceous. Most of the sites with dinosaur remains date from the Lower Cretaceous, from the Hauterivian-Aptian interval, in which two formations have been established, Pinilla de los Moros (upper Hauterivian-lower Barremian) and Castrillo de la Reina (upper Barremian-Aptian), both of them of fluvial origin (Martín-Closas & Alonso-Millán, 1998) and included in the Urbión Group, within the western sector of the Cameros Basin.

The Terreros-Altollano I site is located in the Castrillo de la Reina Formation. This lithostratigraphic unit is defined by alternating layers of sandstone and red shales with carbonate nodules. They have been interpreted as sediments from an alluvial plain with long periods of very low sedimentation rate (Martín-Closas & Alonso-Millán, 1998). These deposits are very rich in fossils, having been found dinosaur remains (Torcida Fernández-Baldor, 2006; Pereda-Suberbiola et al., 2012).

The cranial and mandibular ornithopod material (MDS-LTASI) described here was found in 2008 over the surface layers. The present work focuses on the description of the material, and investigates the possible relationship with other Iberian or English taxa.

Description

The predentary is incomplete, with only two fragments not articulated with each other. The largest one (MDS-LTASI,2) corresponds to the distal end of the left lateral wall of the predentary. In dorsal and caudal views, a rectilinear and slightly curved profile can be seen, which would give it a "V" shape on its rostral margin if the piece was complete. The other fragment (MDS-LTASI,3) corresponds to the left wall of the ventral process. The rostral region is a little concave with a striated rostromedial surface, while the ventral face is slightly convex and smooth. In dorsal view, the reconstruction of this process would have a bifurcated and bilobed “heart-shaped” morphology. The walls would project towards the caudal region, embracing the ventral part of the curved symphysis of the dentary.

The MDS-LTASI,1 left dentary (Figure 1) shows great preservation, without deformation. It is practically complete, except for the dorsorostral area, the rostral part of the symphysis, and the caudoventral area, which would articulate with the surangular bone of the mandible. The dorsal margin is rectilinear and the diastema is not preserved. The ventral margin is concave and parallel in the caudal region to the dorsal margin, but in the middle part the ventral margin begins to curve towards the symphysis. Two series of neurovascular foramina can be seen.

In medial view, the lingual alveolar wall has not been preserved. There are 18 alveolar positions, reaching the base of the coronoid process. The shape of the alveolar cavities is straight, with the septa of the alveoli straight and parallel to each other. The buccal platform presents a rectilinear contour parallel to the dorsal margin of the dentary.

In rostral view, the predentary groove can be seen, which extends from the dorsal margin, curving dorsoventrally towards the ventral margin, in contact with the symphysis. The coronoid process presents an obtuse angle with respect to the horizontal axis of the dentary, and there is no platform between it and the dental row.

Four right maxillary teeth have been recovered, of which only two preserve the complete crown and root. Two of them (MDSLTASI,4; MDS-LTASI,5) have suffered erosion and mechanical transport, but the existence of a primary ridge delimited by two concave (mesial and distal) surfaces can be seen. The other two teeth (MDS-LTASI,6; MDS-LTASI,7) are “leaf-shaped” with a denticulate margin and denticles arranged as tiles, and in some cases, with a mamelon between them.

Discussion

The curvature of the ventral margin of the dentary towards the rostral region and the symphysis is not a common character in iguanodontians which usually present practically straight and parallel dorsal margins. Derived iguanodontians such as Mantellisaurus atherfieldensis (Norman, 1986) have more curved margins. The deviation of the ventral margin of MDS-LTASI,1 is approximately 17º, an angle similar to the 16º of Brighstoneus simmondsi (Lockwood et al., 2021) and the 18º of Proa valdearinnoaensis (McDonald et al., 2012).

The last alveolar position located at the base of the coronoid process is a synapomorphic character of hadrosaurids (sensu Horner et al., 2004). The straight shape of the alveoli septa and their parallelism to each other differs from other non-hadrosaurid hadrosauriforms, whose teeth are not arranged in alveoli but in a kind of continuous groove and supported by alveolar parapets (Norman, 1986). Proa also has an alveolar row extended to the base of the coronoid process, but it presents a greater curvature of the alveolar wall (McDonald et al., 2012). This rectilinear and parallel morphology of the alveoli is typical of more derived hadrosauriforms.

The coronoid process shows an obtuse angle with respect to the horizontal axis of the dentary. There is no a platform between the base of this and the teeth row. This is a plesiomorphic character in iguanodontians and in hadrosauriforms known prior to the Aptian. However, this character appears in the most Albian iguanodonts (Lockwood et al., 2021).

The maxillary dental crowns show a low number (1-2) or absence of secondary ridges, unlike the multiple ones thar are known in Proa or Brighstoneus. However, it is a more common character among non-iguanodontian hadrosauriforms and hadrosaurids (Horner et al., 2004). The absence or very diffuse presence of secondary ridges could be considered as an autapomorphy in MDS-LTASI,1.

Analysis and Conclusions

A phylogenetic analysis has been done using the character matrix generated by Madzia et al. (2020), which presents a total of 75 taxa and 153 characters, of which 19 have been coded in MDS-LTASI. The resulting tree places The Terreros-Altollano I specimen as a basal hadrosauriform, differentiating it from iguanodontians such as *Iguanodon bernissartensis* and other more derived hadrosauriforms such as *Altirhinus kurzanovi*.

In conclusion, MDS-LTASI shows a mixture of primitive and derived characters, with some anatomical similarities to the taxa *Proa* and *Brighstoneus*. Faunal similarities have been recognised in dinosaurs from the Lower Cretaceous of Burgos (Spain) and those found in the Wealden Group of southern England (Martill & Naish, 2001).

References

Horner, J.R., Weishampel, D.B., Forster, C.A. (2004): "Hadrosauridae". In: Weishampel, D. B., Podson, P. and Osmólska, H. (Eds), *The Dinosauria: Second Edition*. University of California Press, Berkeley, 438-463.

Lockwood, J.A.F., Martill, D.M., Maidment, S.C.R. (2021):A new hadrosauriform dinosaur from the Wessex Formation, Wealden Group (Early Cretaceous), of the Isle of Wight, southern England. *Journal of Systematic Palaeontology*, (19,12), 847-888.

Madzia, D., Jagt, J., Mulder, E. (2020): Osteology, phylogenetic affinities and taxonomic status of the enigmatic late Maastrichtian ornithopod taxon *Orthomerus dolloi* (Dinosauria, Ornithischia). *Cretaceous Research,* (108), 104334.

Martill, D.M., Naish, D. (2001): *Dinosaurs of the Isle of Wight.*Palaeontological *Association*, London. Field Guide to Fossils 10, 433 pp.

Martín-Closas C., Alonso-Millán A. (1998): Estratigrafía y bioestratigrafía (Charophyta) del Cretácico Inferior en el sector occidental de la Cuenca de Cameros (Cordillera Ibérica). *Revista de la Sociedad Geológica de España* (11), 253-269.

McDonald, A.T., Espílez, E., Mampel, L., Kirkland, J.I., Alcalá, L. (2012):An unusual new basal iguanodont (Dinosauria: Ornithopoda) from the Lower Cretaceous of Teruel, Spain. *Zootaxa,* (3595), 61-76.

Norman, D.B. (1980): On the ornithischian dinosaur *Iguanodon bernissartensis* of Bernissart (Belgium). *Mémoires de l'Institut Royal des Sciences Naturelles de Belgique*, (178), 1-105.

Norman, D.B. (1986): On the anatomy of *Iguanodon atherfieldensis* (Ornithischia: Ornithopoda). *Bulletin de L'institut Royal des Sciences Naturelles de Belgique, Sciences de la Terre*, (56), 281-372.

Pereda-Suberbiola, X., Ruiz-Omeñaca, J.I., Canudo, J.I., Torcida, F., Sanz J.L. (2012): Dinosaur Faunas from the Early Cretaceous (Valanginian-Albian) of Spain. In: *Bernissart Dinosaurs and Early Cretaceous Ecosystems*, 378-407.

Torcida Fernández-Baldor F. (2006): Restos directos de dinosaurios en Burgos (Sistema Ibérico): un balance provisional. In: Torcida Fernández-Baldor F, Huerta P coord, eds. *Actas de las III Jornadas Internacionales Sobre Paleontología de Dinosaurios y su Entorno*. Salas de los Infantes: Colectivo Arqueológico y Paleontológico de Salas, 105-128.

Torcida Fernández-Baldor, F., Canudo, J.I., Huerta, P., Moreno-Azanza, M., Montero, D. (2017): *Europatitan eastwoodi*, a new sauropod from the lower Cretaceous of Iberia in the initial radiation of somphospondylans in Laurasia, *PeerJ* (5), e3409.

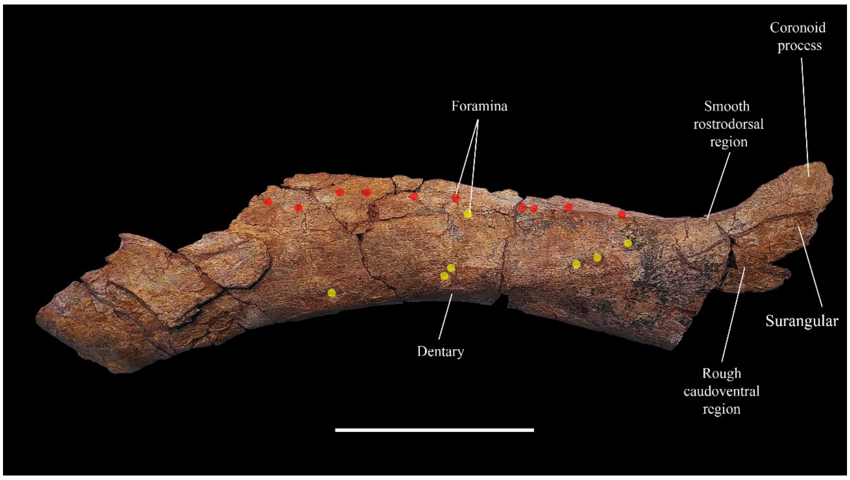

Figure 1. MDS-LTASI,1. Lateral View. Scale: 10 cm.

Infecciones en vértebras caudales de saurópodos titanosaurios del Cretácico Superior de Patagonia, Argentina

Filippi, L. S.[1], González-Dionis, J.[2,3], Cruzado-Caballero, P.[*2,3,4,5]

[1]*Museo Municipal "Argentino Urquiza", Chos Malal 1277, 8319, Rincón de los Sauces, Neuquén, Argentina.* lsfilippi@gmail.com

[2]*Consejo Nacional de Investigaciones Científicas y Tecnológicas (CONICET).*jagondi1@gmail.com, pcruzado@ull.edu.es

[3]*Instituto de Investigación en Paleobiología y Geología (IIPG CONICET-UNRN), Av. Roca 1242, 8332, General Roca, Río Negro, Argentina.*

[4]*Grupo Aragosaurus-IUCA, Facultad de Ciencias, Universidad de Zaragoza, C/ Pedro Cerbuna, 12, 50009 Zaragoza, Spain.*

[5]*Área de Paleontología, Facultad de Ciencias, Universidad de La Laguna, Av. Astrofísico Francisco Sánchez, 2, 38206, San Cristóbal de La Laguna, Santa Cruz de Tenerife, Spain*

**corresponding autor*

Palabras claves: patología, saurópodo, Gondwana, cola

Introducción

Los estudios paleopatológicos están demostrando ser importantes en los estudios paleobiológicos y paleoecológicos de las faunas fósiles por los datos que aportan. Estos son muy valiosos, ya que por un lado nos dan información acerca de la biología, como por ejemplo los procesos de cura desencadenados tras una lesión (traumas) o patologías, y la paleoecología en la medida que la lesión o enfermedad afectó a las relaciones con otros organismos (ver referencias en Cruzado-Caballero et al., 2020, 2021). Pero, también, las patologías nos muestran nuevos datos de momentos importantes en la evolución de los vertebrados como, por ejemplo, como afectó al esqueleto de los primeros tetrápodos el pasar de un medio acuático a un medio terrestre (Bishop et al., 2015).

En el presente trabajo presentamos dos vértebras caudales patológicas de dos taxones de saurópodos titanosaurios indeterminados procedentes de los yacimientos Loma de los Jotes (MAU-Pv-LJ-472/1, Fm. Sierra Barrosa, Coniaciense, Cretácico superior) y La Invernada (MAU-Pv-LI-601, Fm. Bajo de la Carpa, Santoniense, Cretácico superior) de la provincia de Neuquén (Argentina). MAU-Pv-LJ-472/1 es una vértebra caudal de la sección media (Fig. 1. A) de la cola. En su centro vertebral se puede observar una importante reacción periostial del tejido óseo (formación de tejido patológico) asociada a una posible estructura de drenaje de pus (cloaca). Con respecto a MAU-Pv-LI-601, esta es una vértebra caudal anterior (Fig. 1. B) que al igual que MAU-Pv-LJ-472/1 presenta una reacción periostial, en este caso de menor desarrollo, localizada en la zona de articulación con los arcos hemales. En ambos casos la superficie subperióstica tiene un aspecto rugoso y está cubierta de fosas poco profundas e irregulares.

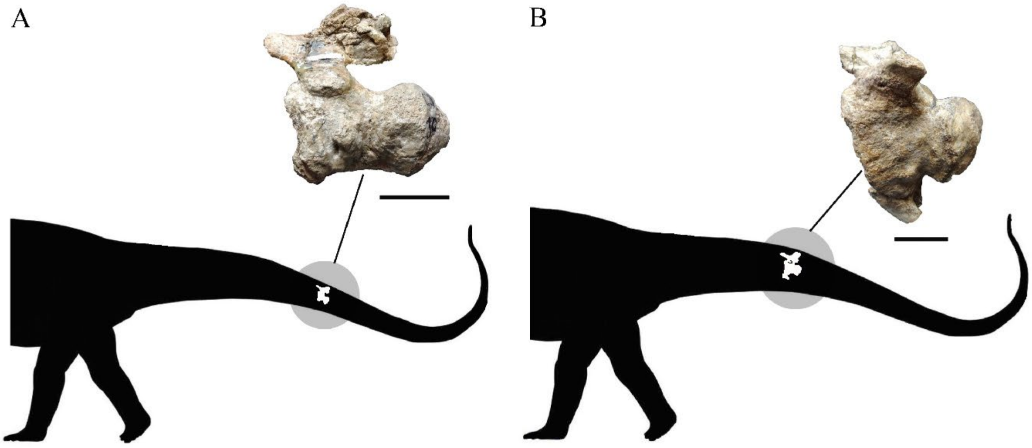

Fig. 1.- A) MAU-Pv-LJ-472/1, vértebra caudal media con estructura de drenaje para la infección, B) MAU-Pv-LI-601, vértebra caudal con arcos hemales fusionados al centro vertebral. Escala: 5 cm (A) y 5 cm (B).

La presencia de un área de sobrecrecimiento óseo en ambas vértebras sugiere la presencia de una infección, la cual pudo ser debida a una herida en el tejido blando o estar asociada a una fractura ósea. En el caso de MAU-Pv-LJ-472/1 la presencia de una cloaca apoyaría la diagnosis patológica de una infección piogénica o supurativa, mientras que la ausencia de cloaca en MAU-Pv-LI-601 indicaría una infección no piogénica o no supurativa. Cuando la infección afecta al hueso se denomina osteítis (es decir, inflamación del hueso) u osteomielitis (es decir, inflamación de la médula ósea; Anné et al., 2015), por lo que MAU-Pv-LI-601 y MAU-Pv-LJ-472/1 corresponderían a dos casos de osteomielitis en saurópodos titanosaurios.

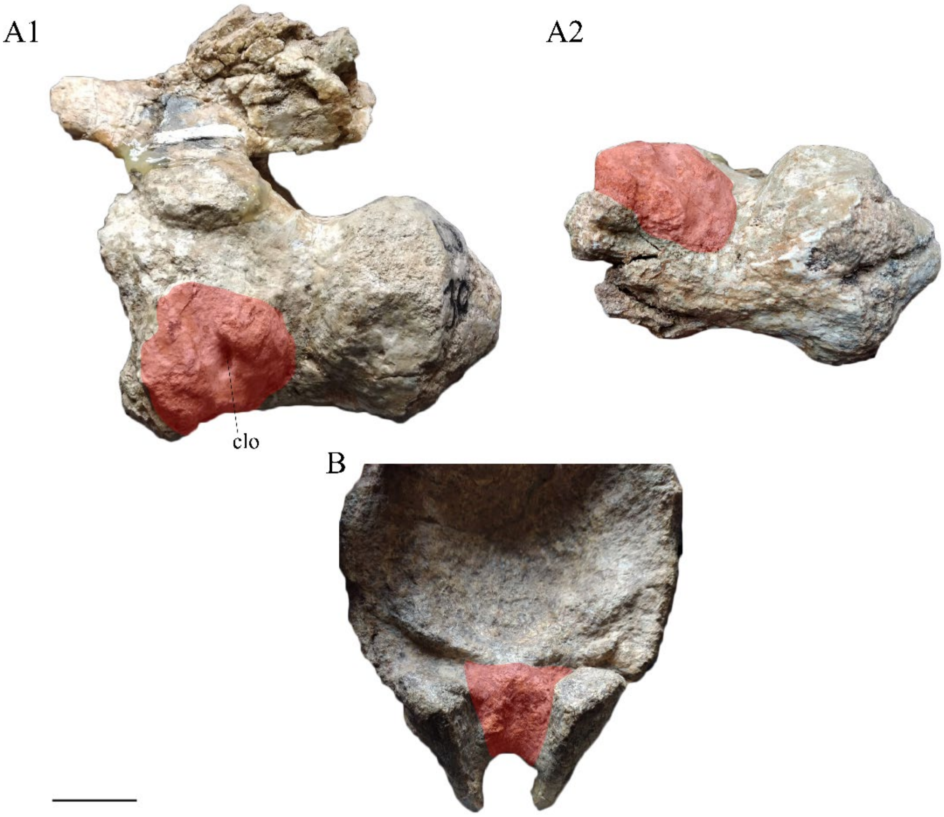

Fig. 2.- Región patológica en A) MAU-Pv-LJ-472/1 en vista lateral y ventral; B) MAU-Pv-LI-601 en vista anterior. Escala: 3 cm. Abreviaciones: clo: cloaca

La presencia de patologías infecciosas en las vértebras caudales de los saurópodos suelen estar asociadas a traumatismos que afectan a los tejidos blandos o al hueso (ver referencias en Cruzado-Caballero et al., 2021). Actualmente se están analizando las imágenes tomográficas realizadas a las vértebras en busca de la presencia o ausencia de una fractura asociada al hueso patológico.

Referencias

Anné, J., Garwood, R.J., Lowe, T., Withers, P.J., Manning, P.L., (2015): Interpreting pathologies in extant and extinct archosaurs using micro-CT. PeerJ 3, e1130.

Bishop, P. J., Walmsley, C. W., Phillips, M. J., Quayle, M. R., Boisvert, C. A., &McHenry, C. R. (2015): Oldestpathology in a tetrapod bone illuminates the origin of terrestrial vertebrates. PLoSOne, 10(5), e0125723.

Cruzado-Caballero, P., Díaz-Martínez, I., Rothschild, B., Bedell, M., Pereda-Suberbiola, X. (2021): A limping dinosaur in the Late Jurassic: pathologies in the pes of the neornithischian *Othnielosaurus consors* from the Morrison Formation (Upper Jurassic, USA).Historical Biology, 33(9), 1753-1759.

Cruzado-Caballero, P., Lecuona, A., Cerda, I., Díaz-Martínez, I. (2021): Osseous paleopathologies of *Bonapartesaurus rionegrensis* (Ornithopoda, Hadrosauridae) from Allen Formation (Upper Cretaceous) of Patagonia Argentina.*Cretaceous Research*,124, 104800.

Análisis tafonómico de los límites de secuencia de la Formación Picofrentes (Cretácico Superior) en Segovia

Franco, R[1].

[1] *Universidad Complutense de Madrid, C/ José Antonio Novais, 12, 28040, (Madrid, España). rfranc01@ucm.es*

Keywords: Sistema Central, Rampa Castellana, paleoecología, Turoniense, tafocenosis, biofacies.

Introdución

Los trabajos realizados en los materiales Turonienses (Cretácico Superior) de Villaverde de Montejo (Segovia) han sido fundamentales para la comprensión de la geología de este piso. Sin embargo son pocos los trabajos que abordan con detalle su contenido paleontológico. En este estudio se describen los patrones de conservación fósiles de los límites de las secuencias de quinto orden de la Formación Calizas y margas de Picofrentes, donde abundan fósiles *in situ*. Estos permiten identificar con mayor detalle los procesos que han sufrido los restos durante su producción.

Los primeros trabajos en la zona son Alonso (1981) y Gil-Gil (2002) interpretando la unidad como una plataforma externa carbonática, con edad Turoniense Medio.

Según Gil-Gil *et al.* (2006), la asociación fósil de la unidad indica influencia de los dominios oceánicos Atlántico al Noroeste y del Tethys al Sureste. Debido a cambios de buzamiento en la microplaca de Iberia, durante la rotación antihoraria de la placa, dando la apertura del Golfo de Vizcaya.

La asociación fósil de los afloramientos es parecida a la que Barroso-Barcenilla *et al.* (2018) encuentran en el área de Tamajón, con bivalvos como *Ceratostreon flabellatum, Rhynchostreon suborbiculatum, Plicatula auressensis*, gasterópodos del género *Drepanocheilus* y equinoideos de simetría radial como *Tetragramma variolare*.

Resultados

Se estudia el afloramiento al oeste de Villaverde de Montejo, levantando siete columnas estratigráficas en tres unidades estratigráficas que dan resalte (Fig. 1). La primera unidad C7, en la segunda C1 y C4-6 y en la tercera unidad las columnas C2 y C3.

En C7 (Fig. 2) se observan calizas *wackstone* nodulosas amarillas de bivalvos (*Ceratostreon flabellatum* y *Rhynchostreon suborbiculatum*) y equinoideos con simetría bilateral. Los bivalvos están reorientados siguiendo los ejes antero/posteriores de los individuos y fragmentados. Los equinoideos presentan elipsoides de deformación tridimensionales.

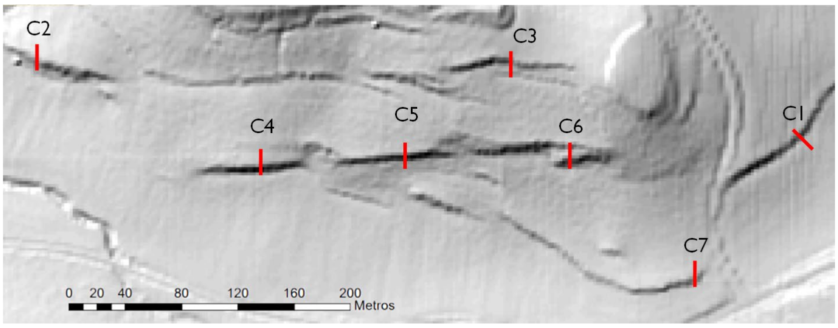

Figura 1. Situación de las columnas en los afloramientos.

La segunda unidad presenta dos tramos a lo largo de las columnas, el primero con calizas nodulosas *mudstone*-*wackstone* cuya potencia oscila entre 26-81 cm, con restos de *Ceratostreon flabellatum*, *Rhynchostreon suborbiculatum, Plicatula auressensis*, gasterópodos del género *Drepanocheilus* y equinoideos como *Tetragramma variolare* y equinoideos con simetría bilateral, cuyas abundancias varían según la sección.

El segundo tramo presenta calizas con nodulización más intensa, con texturas *wackstone-packstone*, y potencias variables, con asociación fósil de *Ceratostreon flabellatum, Rhynchostreon suborbiculatum, Plicatula auressensis* y fragmentos de bivalvos.

La tercera unidad presenta un cambio lateral de facies, con dos tramos de areniscas en la columna C3 (Fig. 2), que presentan fragmentos de bivalvos y el primero de estos restos vegetales carbonosos. Al oeste la unidad pasa a carbonatos (C2, Fig. 3) más potentes con restos de bivalvos (*Rhynchostreon suborbiculatum* y *Ceratostreon flabellatum)* y equinoideos con simetría bilateral.

Se reconocen procesos fosildiagenéticos, en los equinoideos con silicificaciones y elipsoides de deformación tridimensionales. Algunos ejemplares de bivalvos, presentan silicificaciones (Fig. 3a). Son frecuentes los procesos bioestratinómicos, con bioerosiones en forma de *borings* (Fig. 3b) y la desarticulación de las valvas, en algunos casos *Rhynchostreon suborbiculatum*, se puede encontrar relleno sedimentario y cementaciones algales.

Se han realizado dos láminas delgadas, en C6 y C3 (C2-B3). El tramo dos de C6 presenta packstones bioclásticos, trimodal con recristalizaciones de calcita en los restos de bivalvos, placas de equinodermos micritizadas.

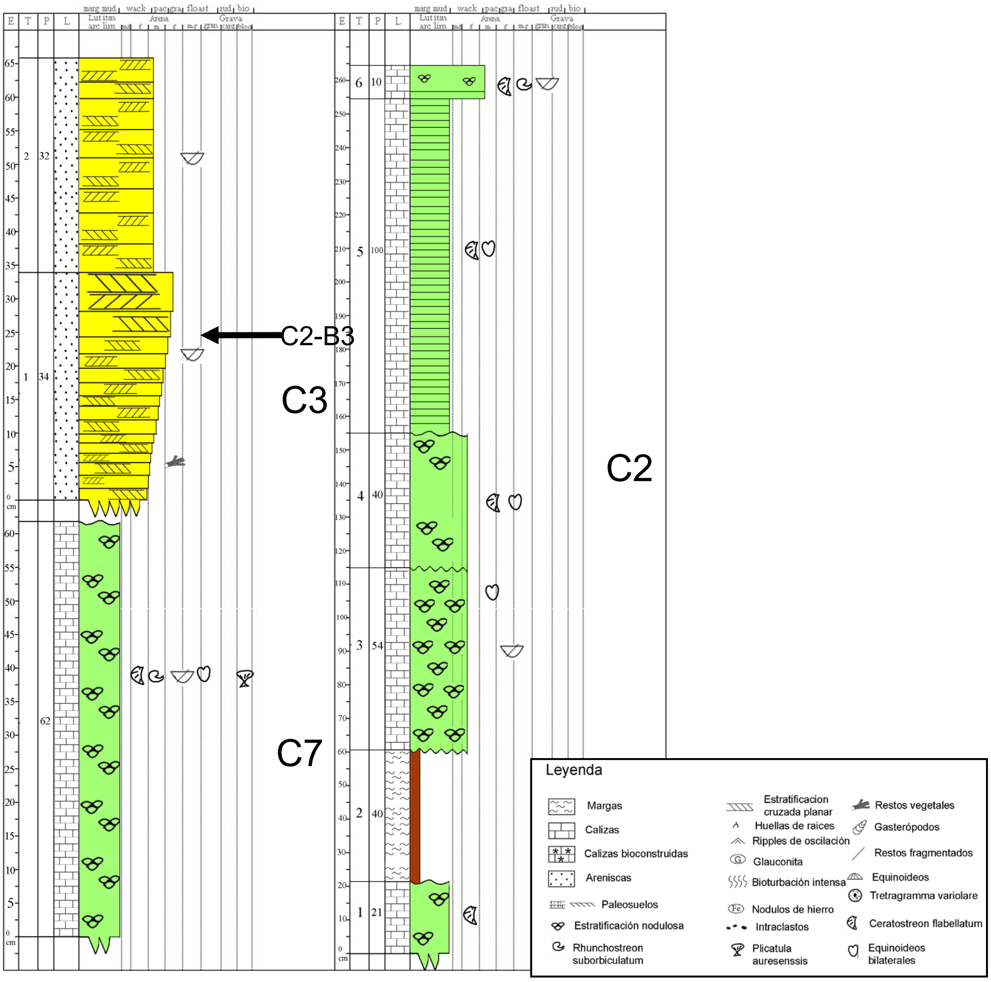

Figura 2. Columnas estratigráficas de la unidad 1 y unidad 3. Con la situación de la muestra C2-B3.

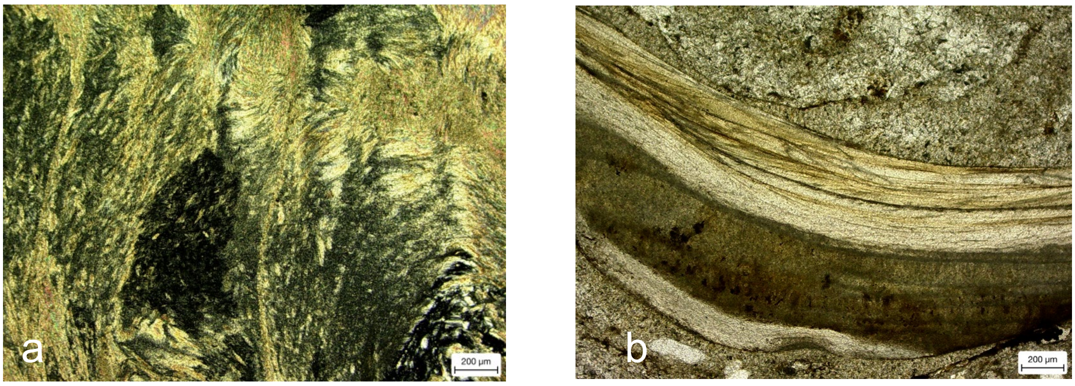

Figura 3. 3a) Lámina del ejemplar silicificado. 3b) Lámina C2-B3.

La lámina C2-B3, (posición estratigráfica en Figura 2), presenta bivalvos centimétricos con micritización por *microborings* y neomorfismo (Fig. 3b). Los bivalvos se encuentran orientados siguiendo su eje antero/posterior.

Se ha realizado dos secciones de un ejemplar de Ceratostreon flabellatum (Fig. 3a), donde se observan silicificaciones destructivas siguiendo los anillos de crecimiento o creando nódulos destruyendo por completo la microestructura. Estas silicificaciones solo se encuentran en los restos esqueléticos.

Discusión

La primera unidad se interpreta como un episodio de alta energía en la cuenca (tempestita), atrapando a la fauna reorientándola en su deposición, la segunda unidad también se interpreta como el mismo proceso, con cambios en el espacio de acomodación en la cuenca, lo cual indica una cuenca heterogénea e irregular.

La tercera unidad presenta al oeste el mayor espesor de todas las unidades estudiadas, con un primer episodio de profundización pasando a margas y una posterior somerización con calizas nodulosas que pasan a tableadas. Se puede observar que el espacio de acomodación disminuye rápidamente como indica el tramo 6 constituido por *packstones*. Al este disminuye aún más su profundidad y recibe aportes de sedimento continental.

Las microfacies indican un ambiente tranquilo para el desarrollo de la micritización, con una comunidad fósil abundante, con episodios de mayor energía que conservan los restos, que son silicificados y recristalizados destruyendo su textura. Por ello se le asigna a la formación un ambiente de plataforma interna somera.

Conclusión

El registro fósil, paleobiológico y tafonómico, aporta información paleogeográfica y estratigráfica sobre la que apoyar interpretaciones paleoambientales. En este caso pasando de una plataforma externa a interna con aportes del continente

Referencias

Alonso, A. (1981): El Cretácico de la provincia de Segovia. Tesis Doctoral, Univ. Complutense de Madrid, 320 p.

Barroso-Barcenilla, F., Audije-Gil, J., Berrocal-Casero, M., Callapez, P.M., Carenas, B., Comas-Renjifo, M.J., García-Joral, F., García-Hidalgo, J.F., Gil-Gil, J., Goy, A., Ozkaya de Juanas, S. A., Rodríguez-García, S., dos Santos, V.F., Segura, M. y Sevilla, P. (2018): El Cenomaniense-Turoniense de Tamajón (Guadalajara, España): contexto geológico, contenido fósil e interpretación paleoambiental. *Boletín de la Real Sociedad Española de Historia Natural*, Sección Geología, 111: 67-84.

Gil-Gil, J. (2002): Estratigrafía de alta resolución en el Turoniense Superior-Coniaciense Inferior de la Cordillera Ibérica Septentrional. Tesis Doctoral, Universidad Complutense de Madrid, 226 p.

Gil-Gil, J., García-Hidalgo, J.F., Segura, M., García, A. y Carenas, B. (2006): Stratigraphic architecture, palaeogeography and sea-level changes of a third order depositional sequence: The late Turonian-early Coniacian in the northern Iberian Ranges and Central System (Spain). *Sedimentary Geology*, 191: 191-225.

3D reconstructions of evidence of insect galleries in gymnosperm trunks from the Lower Cretaceous of the Pinilla de los Moros Formation (Salas de los Infantes, Burgos, Spain)

García-Ávila, M.[1,2*], Santos, A. A. [1,2], López-Periago, J. E.[3], Wappler, T. [4], Torcida Fernández-Baldor, F. [5,6], Diez, J. B. [1,2]

*1: Departamento de Xeociencias Mariñas e Ordenación do Territorio, Facultade de Ciencias do Mar, Universidade de Vigo, 36310 Vigo, Spain. * manugarcia@uvigo.es*

2: Centro de Investigación Mariña, Universidade de Vigo (CIM-UVIGO), 36310 Vigo, Spain.

3: Departamento de Bioloxía Vexetal e Ciencias do Solo, Facultade de Ciencias, Universidade de Vigo, 32004 Ourense, Spain.

4: Department of Natural History, Hessisches Landesmuseum Darmstadt, Friedensplatz 1, 64283, Darmstadt, Germany.

5: Museo de Dinosaurios, Salas de los Infantes, Burgos, Spain.

6: Colectivo Arqueológico-Paleontológico Salense, Salas de los Infantes, Burgos, Spain.

Keywords: Barremian, xylophages, Curculionidae, microCT, plant-insect interactions.

Introduction

Record of Mesozoic plant-arthropod interactions in the Iberian Peninsula are very scarce compared to other regions. However, in the last four years, these type of studies have experienced notable advances in this area, with the publication of the first Mesozoic interactions in Cycadales / Bennettitales leaves from the Aalenian (Jurassic) (Santos *et al*. 2021) and angiosperms from the Albian-Aptian (Cretaceous) (Sender *et al*. 2022).

In this symposium we will show the preliminary results of a computed X-ray tomography study on two specimens of fossil wood of gymnosperms found in the deposits of Fuentezarza-II and Peñuquillo located in the Ledanías de Salas de los Infantes, Castrillo de la Reina, Hacinas and Monasterio de la Sierra (Burgos). The geologic context is the Cameros Basin, western sector, in the Pinilla de los Moros Formation, dated as upper Hauterivian-lower Barremian (Martín-Closas and Alonso Millán, 1998).

Objectives

The main objective is to examine, in a non-destructive way, the inner structures of two specimens of fossil wood of gymnosperms (ID-50 and ID-87) to describe and study the internal galleries in the wood. The second objective is the creation of 3D models that are suitable for the analysis of the specimens, as well as the dissemination of the same and the information obtained. The third objective is to deduce the possible culprits of these galleries and understand their reproductive and feeding behaviour (in progress).

Methodology and results

For the data collection of the interior and exterior of the pieces, they were scanned with an FF20-CT tomograph at a resolution of 52 µm. The image was segmented with AVIZO3D using the feature adaptive thresholding method. These procedures allowed the elaboration of a high-resolution 3D model and images, observing different types of galleries within the specimens. The process described above provides very precise information on the pieces; however, it does not allow us to obtain color data. For this reason, to document the external appearance of the trunks (their color), two photogrammetric models were made using a Canon PowerShot SX700 HS camera and Agisoft Metashape software.

On the one hand, the high resolution and large size of the 3D models obtained with the tomograph (several Gigabytes) made it necessary to post-process each model to reduce its weight and get files that could be handled fluently by our computers. Once achieved, to show the pieces and the galleries they contain, we worked with the free software Blender.

On the other hand, the photogrammetric models were also post-processed, applying an optimization process, which allows us to obtain models with less geometry, therefore less heavy, but visually identical to the high-resolution ones.

The final result has been a collection of high-resolution 3D models, which allow us to study each piece as if it were the original, in addition to other models intended for dissemination, which can be viewed freely, free of charge, from any device, and anywhere in the world from the virtual museum of the Iberian Paleobotany Group, on the Sketchfab platform.

Discussion

The application of microCT on the trunks with galleries allows the detailed observation of the different types of galleries: egg and larvae galleries, feeding tunnels, and possible pellets inside the galleries, which provides clues for the deduction of the potential producers of the galleries (preliminary attributed to the Curculionidae family, and Scolytinaede subfamily) as well as on their reproductive and feeding behavior.

The interactions studied here represent the first Barremian records from the Iberian Peninsula and the first evidence of galleries made by Coleopteran insects in wood in the fossil record of this area.

Acknowledgements

Aid Competitive Reference Group Xunta de Galicia Nº CN2012/301. The FF20-CT unit on the Auga-Uvigo Campus was acquired with funds from the State I+D+I Plan EQC2018-004965-P FEDER. Santos, A. is supported by a predoctoral fellowship (Xunta de Galicia - European Social Fund).

References

Martín-Closas C. y Alonso Millán A. (1998): Estratigrafía y bioestratigrafía (Charophyta) del Cretácico Inferior en el sector occidental de la Cuenca de Cameros (Cordillera Ibérica). *Revista de la Sociedad Geológica de España* 11:253–269.

Santos, A. A., Sender, L. M., Wappler, T., Engel, M. S., Diez, J. B. (2021): A Robinson Crusoe story in the fossil record: Plant-insect interactions from a Middle Jurassic ephemeral volcanic island (Eastern Spain). *Palaeogeography, Palaeoclimatology, Palaeoecology*, *583*, 110655.

Sender, L. M., Wappler, T., García-Ávila, M., Santos, A. A., & Diez, J. B. (2022): First plant-insect interactions on Cretaceous caytoniales (genus *Sagenopteris*) from the Lower Cretaceous (Albian) of Spain. *Cretaceous Research*, 105295.

An overview of the dinosaur faunas from the El Castellar Formation (upper Hauterivian-lower Barremian, Lower Cretaceous) of Teruel, Spain

García-Cobeña, J.[1], Verdú, F. J.[1], Cobos, A.[1].

1: Fundación Conjunto Paleontológico de Teruel-Dinópolis/Museo Aragonés de Paleontología, Av. Sagunto s/n, 44002 Teruel, (Spain). josuegarcia140394@gmail.com, verdu@fundaciondinopolis.org, cobos@dinopolis.com

Keywords: Palaeodiversity, Natural casts, Saurischia, Ornithischia, Maestrazgo Basin.

Nowadays, more than thirty new dinosaur species have been erected in Spain, which turns it into a worldwide hot spot for the knowledge of the Upper Jurassic-Upper Cretaceous dinosaurs. In particular, about a third of these defined dinosaurs have been described for the first time in the Teruel Province, and eight of them were found in Lower Cretaceous deposits. The upper Hauterivian-lower Barremian (Lower Cretaceous) section in this province, which lies within the Maestrazgo Basin (Salas and Guimerà, 1996), includes several continental lithostratigraphic units that have yielded highly diverse dinosaur bones and tracks. Here, we present the most relevant discoveries of dinosaurs found in one of these units, the Areniscas y Calizas de El Castellar Formation, in the southwest margin of the Maestrazgo Basin.

The El Castellar Formation (Salas, 1987) outcrops extensively along this sector of the Maestrazgo Basin, in the so-called Peñagolosa and Galve sub-basins (Salas and Guimerà, 1996; Mas *et al*., 2004). This lithostratigraphic unit is divided into two stages, a lower one more detrital, with shales, evaporites and sandstones, and an upper one composed by limestones and marlstones (e.g. Cobos *et al*., 2012); both deposited in a coastal wetland system (see García-Cobeña *et al*., 2022). Martín-Closas (1989) dated this formation as upper Hauterivian-lower Barremian trough an association of charophytes.

Respect to dinosaur direct remains, isolated vertebral centra, teeth and bone fragments are the most frequent skeletal elements found in the El Castellar Formation. Despite this, our current knowledge on dinosaur faunas in this formation suggests a remarkable regional diversity. Among the saurischians, theropods are represented by basal tetanurans such as Allosauroidea? indet. (Ruiz-Omeñaca, 2006), Spinosauridae indet. (Gasca *et* *al.*,2018), Baryonychinae indet. (Gasca *et al.*,2008, 2009a, b) and aff. *Baryonyx* sp. (Gasca *et al.*,2018), and small coelurosaurs, including Maniraptoriformes indet. (Ruiz-Omeñaca, 2006; Gasca *et al.*, 2009a, b) Maniraptora indet., Velociraptorinae indet. and '*Prodeinodon*' sp. (Ruiz-Omeñaca, 2006); and sauropods by neosauropods as Camarasauridae? indet. (Ruiz-Omeñaca, 2006), '*Pleurocoelus valdensis*' (Ruiz-Omeñaca, 2006; Ruiz-Omeñaca and Canudo, 2005) and *Oplosaurus armatus* (Royo-Torres and Cobos, 2007). On the other hand, ornithischians comprise basal forms such as Heterodontosauridae indet. (Ruiz-Omeñaca, 2006), thyreophorans as Ankylosauria indet. (Gasca *et al.*, 2009b) and other remains attributed to Stegosauria indet. (Pereda-Suberbiola *et al.*, 2005) which, however, Royo-Torres *et al.* (2009) suggested that they come from the underlying Villar del Arzobispo Formation, and ornithopods. This latter group is represented in this unit by fossils of small basal ornithopods such as Hypsilophodontidae indet. (Ruiz-Omeñaca, 2001, 2006; Gasca *et al.*, 2009a, b) and those more common of large styracosternans, for instance Styracosterna indet. (Cobos *et al.*, 2012; Guerrero and Cobos, 2017; Verdú *et al.*, 2019; García-Cobeña *et al.*, 2022), Iguanodontoidea indet. (Luque *et al.*, 2006; Gasca *et al.*, 2009a), cf. *Iguanodon* sp. (Ruiz-Omeñaca, 2006) and *Iguanodon* cf. *galvensis* (García-Cobeña *et al.*, 2022).

Recently, the first reports about dinosaur tracks in the El Castellar Formation of the Peñagolosa (García-Cobeña *et al.*, 2022) and Galve (Castanera *et al.*, 2022) sub-basins have been published. In both cases, all the tracks are preserved as natural casts with a different anatomical definition, and related to large ornithopod trackmakers, mainly to styracosternans. These tracks were assigned to Iguanodontopodidae indet. and *Caririchnium*-like (García-Cobeña *et al.*, 2022), and *Caririchnium magnificum*. (Castanera *et al.*, 2022).

The dinosaur faunal association recorder in the El Castellar Formation in the southwest Maestrazgo Basin resembles others for the same age in Spain and outside this basin, such as that of the Golmayo Formation of Soria Province (Fuentes-Vidarte *et al.*, 2005, 2016; Pereda-Suberbiola *et al.*, 2007; Royo-Torres *et al.*, 2017).

As conclusion, we infer that large ornithopod styracosternans were frequent inhabitants of the lacustrine-palustrine environments developed in a coastal wetland system during the late Hauterivian-early Barremian in the southwest sector of the Maestrazgo Basin.

They shared these ecosystems with large tetanurans and small coelurosaurs, huge neosauropods, ankylosaurs, and small basal ornithopods.

References

Castanera, D., Bádenas, B., Aurell, M., Canudo, J.I., Gasca, J.M. (2022): New ornithopod tracks from the Lower Cretaceous El Castellar Formation (Spain): implications for track preservation and evolution of ornithopod footprints. *Palaeogeography, Palaeoclimatology, Palaeoecology*, (591), 110866. doi:10.1016/j.palaeo.2022.110866.

Cobos, A., Royo-Torres, R., Alcalá, L. (2012): Restos postcraneales de ornitópodo en el Cretácico Inferior de El Castellar (Subcuenca de Peñagolosa, Teruel). *Geogaceta*, (52), 181-184.

Fuentes-Vidarte, C., Meijide-Calvo, M., Meijide-Fuentes, F., Meijide-Fuentes, M. (2005): Fauna de vertebrados del Cretácico Inferior del yacimiento de "Zorralbo" en Golmayo (Soria, España). *Spanish Journal of Palaeontology,* (20, 3), 83-92.

Fuentes-Vidarte, C., Meijide-Calvo, M., Meijide-Fuentes, F., Meijide-Fuentes, M. (2016): Un nuevo dinosaurio estiracosterno (Ornithopoda: Ankylopollesia) del Cretácico Inferior de España. *Spanish Journal of Palaeontology,* (31, 2), 407-446.

García-Cobeña, J., Verdú, F.J., Cobos, A. (2022): Abundance of large ornithopod dinosaurs in the El Castellar Formation (Hauterivian-Barremian, Lower Cretaceous) of the Peñagolosa sub-basin (Teruel, Spain). *Journal Iberian Geology*, (48), 107-127. doi:10.1007/s41513-021-00185-w.

Gasca, J.M., Canudo, J.I., Moreno-Azanza, M. (2009a): Dientes aislados de dinosaurio de la Formación El Castellar en Miravete de la Sierra (Cretácico Inferior, Teruel, España). In: *Actas de las IV JornadasInternacionales sobre Paleontología de Dinosaurios y su Entorno.* (Colectivo Arqueológico y Paleontológico de Salas, Ed.). Salas de los Infantes, 221-234.

Gasca, J.M., Díaz-Martínez, I., Moreno-Azanza, M., Canudo, J.I., Alonso, A. (2018): A hypertrophied ungual phalanx from the lower Barremian of Spain: implications for the diversity and palaeoecology of Spinosauridae (Theropoda) in Iberia. *Cretaceous Research*, (84), 141-152.

Gasca, J.M., Moreno-Azanza, M., Canudo, J.I. (2008): Dientes de dinosaurios terópodos espinosáuridos de la Formación El Castellar (Cretácico Inferior, Teruel). *Paleontologica Nova, SEPAZ, 8*, 233-234.

Gasca, J.M., Moreno-Azanza, M., Canudo, J.I. (2009b): The dinosaur assemblage of the El Castellar Formation (upper Hauterivian-lowermost Barremian, Teruel, Spain). In: *Darwin-Bernissart Meeting*. (Godefroit, P., Lambert, O., Eds.). Brussels, (9, 13), 43.

Guerrero, A., Cobos, A. (2017): Nuevos fósiles de dinosaurios cretácicos del yacimiento La Balsa 2 (El Castellar, Teruel, España). In: *Abstract book of the XV Encuentro de Jóvenes Investigadores en Paleontología.* (Barrios de Pedro, S., Blanco-Moreno, C., de Celis, A., Colmenar, J., Cuesta, E., García-Martínez, D., Gascó, F., Facinto, A., Malafaia, E., Martín Jiménez, M., de Miguel Chaves, C., Mocho, P., Pais, V., Páramo Blázquez, A., Pereira, S., Serrano Martínez, A., Vidal, D., Eds.). Pombal, 15-19.

Luque, L., Espílez, E., Cobos, A., Alcalá, L., Royo-Torres, R., Aberasturi, A., Mampel, L., González, A. (2006): Iguanodóntidos y otros vertebrados cretácicos de Miravete de la Sierra (Teruel). *Teruel*, (91, 1), 57-87.

Martín-Closas, C. (1989): *Els caròfits del Cretaci Inferior de les conques perifèriques del Bloc de l'Ebre*. PhD thesis, University of Barcelona, 581 pp.

Mas, R., García, A., Salas, R., Meléndez, A., Alonso, A., Aurell, M., Bádenas, B., Benito, M.I., Carenas, J.F., García-Hidalgo, J., Gil, J., Segura, M. (2004): Segunda fase de rifting: Jurásico Superior-Cretácico Inferior. In: Vera, J. A. (ed.). *Geología de España*. SGE-IGME, Madrid, 503-510.

Pereda-Suberbiola, X., Fuentes, C., Meijide, M., Meijide-Fuentes, F., Meijide-Fuentes, M. (2007): New remains of the ankylosaurian dinosaur *Polacanthus* from the Lower Cretaceous of Soria, Spain. *Cretaceous Research*, (28, 4), 583-596.

Pereda-Suberbiola, X., Galton, P.M., Ruiz-Omeñaca, J.I., Canudo, J.I. (2005): Dermal spines of stegosaurian dinosaurs from the Lower Cretaceous (Hauterivian-Barremian) of Galve (Teruel, Aragón, Spain). *Geogaceta*, (38), 35-38.

Royo-Torres, R., Cobos, A. (2007): Teeth of *Oplosaurus armatus* (Sauropoda) from El Castellar (Teruel, Spain).In: *Abstract book of the 5th annual meeting European Association of Vertebrate Palaeontologists*. (Le Loeuf, J., Ed.). Carcassonne, 52-55.

Royo-Torres, R., Cobos, A., Luque, L., Aberasturi, A., Espílez, E., Fierro, I., González, A., Mampel, L., Alcalá, L. (2009): High European sauropod dinosaur diversity during Jurassic-Cretaceous transition in Riodeva (Teruel, Spain). *Palaentology*, (52), 1009-1027.

Royo-Torres, R., Fuentes, C., Meijide, M., Meijide-Fuentes, F., Meijide-Fuentes, M. (2017): A new Brachiosauridae Sauropod dinosaur from the lower Cretaceous of Europe (Soria Province, Spain). *Cretaceous Research*, (80), 38-55.

Ruiz-Omeñaca, J.I. (2001): Dinosaurios hipsilofodóntidos (Ornithischia: Ornithopoda) en la Península Ibérica. In: *Actas de las I Jornadas Internacionales sobre Paleontología de Dinosaurios y su Entorno.* (Colectivo Arqueológico-Paleontológico de Salas, Ed.). Salas de los Infantes, 175-266.

Ruiz-Omeñaca, J.I. (2006): *Restos directos dedinosaurios (Saurischia, Ornithischia) en el Barremiense(Cretácico Inferior) de la Cordillera Ibérica en Aragón(Teruel, España)*. PhD thesis. University of Zaragoza, 584 pp.

Ruiz-Omeñaca, J.I., Canudo, J.I. (2005): "*Pleurocoelus*" *valdensis* Lydekker, 1889 (Saurischia, Sauropoda) en el Cretácico Inferior (Barremiense) de la Península Ibérica. *Geogaceta*,(38), 43-46.

Salas, R. (1987): *El Malm i el Cretaci inferior entre el Massif de Garraf i la Serra d´Espadà. Anàlisi de conca*. PhD thesis. University of Barcelona, 365 pp.

Salas, R., Guimerà, J. (1996): Rasgos estructurales principales de la cuenca Cretácica Inferior del Maestrazgo (Cordillera Ibérica oriental). *Geogaceta* (20), 1704-1706.

Verdú, F.J., Cobos, A., Royo-Torres, R., Alcalá, L. (2019): Diversity of large ornithopod dinosaurs in the Upper Hauterivian-Lower Barremian (Lower Cretaceous) of Teruel, Spain: a morphometric approach. *Spanish Journal of Palaeontology*, (34, 2), 269-288. doi:10.7203/sjp.34.2.16116.

Shell anomalies of the Spanish Cenomanian bothremydid turtle *Algorachelus peregrina*

Guerrero, A[1]., Pérez-García, A[1].

1: Grupo de Biología Evolutiva, Facultad de Ciencias, UNED, Avda. Esparta s/n, Las Rozas, 28232 Madrid, Spain. guerbach@gmail.com; a.perez.garcia@ccia.uned.es

Keywords: Pleurodira, Late Cretaceous, Algora, intraspecific variability, anatomical deviations.

The Cenomanian (basal Late Cretaceous) pleurodiran turtle *Algorachelus peregrina* is the oldest representative of the Bothremydidae clade currently described in Europe. This species has been defined in the uppermost middle-lowermost upper Cenomanian site of Algora (Guadalajara, Central Spain), being subsequently identified in the middle Cenomanian locality of Nazaré (West Central Portugal). The *Algorachelus peregrina* material found in its type locality (i.e., the Algora site) represents the largest concentration of remains of a bothremydid member recorded in Europe. The availability of numerous specimens as well as their generally good preservation has allowed us, in previous studies, to provide a preliminary characterization of the shell of this taxon at an intraspecific level (e.g., individual variability and sexual dimorphism). Likewise, a few examples of the extreme cases of morphological variation (i.e., anomalies) have also been previously documented in *Algorachelus peregrina*; however, these have not been characterized in detail. In this context, the detailed study of the shell anomalies of *Algorachelus peregrina* is carried out herein. The evaluation of hundreds of shell remains (i.e., both disarticulated and articulated plates as well as complete shells) allow us to determine the frequency and distribution of these anatomical deviations providing, for the first time, detailed data regarding the manifestation of this type of intraspecific variation for a member of Bothremydidae. Also, the morphogenetic cause of each typology of anomaly is discussed herein. As a result, a relatively broad spectrum of anomalies is reported for *Algorachelus peregrina*.

Palinoestratigrafía del yacimiento de dinosaurios de Los Ganchos (Fm. Villar del Arzobispo, Alpuente, Valencia)

López-Fernández, P.[1]*, Santos, A. A.[1,2], Suñer, M.[3], Santisteban, C.[4], Diez, J.B[1,2]

1: Departamento de Geociencias Marinas, Universidad de Vigo, Campus As Lagoas-Marcosende, Vigo, España. patlopez@alumnos.uvigo.es

2: Centro de Investigación Mariña, Universidade de Vigo (CIM-UVIGO), Vigo, España

3: Museo Paleontológico de Alpuente. Av. San Blas, 17, 46178, Alpuente, Valencia, España.

4: Departamento de Botánica y Geologia. Universitat de València. Av. Dr. Moliner, 50, 46100 Burjassot, Valencia, España

Keywords: Palinología, Paleoambiente, SE Cordillera Ibérica, Kimmeridgiense-Berriasiense

Introducción

Este estudio tiene como objetivo la datación palinoestratigráfica y reconstrucción paleoambiental del yacimiento fósil de “Los Ganchos” en materiales de la Formación Villar del Arzobispo del área de Alpuente en la comarca de Los Serranos (Valencia).

La formación se extiende por la Cuenca Suribérica y presenta un amplio registro de fósiles de dinosaurios, macroflora e invertebrados. Estudios recientes con foraminíferos le asignan una edad de Kimmeridgiense-Tithoniense o tránsito Jurásico-Cretácico para la Fm. Villar del Arzobispo (Campos-Soto et al. 2019). Aunque en el área de Galve se le llega a asignar una edad Berriasiense inferior (Santos et al. 2018).

Los estudios palinológicos del Jurásico Superior y límite J/K son muy escasos (Mohr 1989, Santos et al. 2018, Rodríguez-Barreiro et al. 2022). En el área de Alpuente no se han publicado hasta el momento asociaciones palinológicas, lo que contrasta con el amplio conocimiento de vertebrados en la zona, especialmente dinosaurios, incluyendo restos de Sauropoda, Stegosauria, Ornithopoda y Theropoda (Suñer et al. 2021, Sánchez-Fenollosa et al. 2022).

El yacimiento de Los Ganchos está emplazado en el relleno sedimentario de un cauce encajado en materiales de un delta dominado por procesos de oleaje y sometido a eustatismo relativo. Los depósitos muestreados se pueden situar en el cortejo sedimentario transgresivo de una secuencia deposicional con carácter transgresivo – regresivo.

Material y métodos

Las muestras han sido tomadas en el yacimiento de Los Ganchos, recogiendo un total de cinco muestras de los niveles con abundante materia orgánica, próximos a zona de aparición de restos fósiles (LG-A, LG-B, LG-03, LG-pre04 y LG-04). Las técnicas utilizadas para el procesamiento de las muestras en el laboratorio son las técnicas palinológicas estándar HCl-HF-HCl descritas por Wood et al. (1996).

Tras el análisis se montaron varias láminas delgadas y rosetas de SEM y se realizaron fotografías de los palinomorfos encontrados en el microscopio óptico (Leica DM 2000 LED) y en el microscopio electrónico de barrido (JEOL-6010LA).

Resultados

Tras examinar cuatro láminas de los cuatro niveles muestrados se han identificado un total de 43 morfoespecies pertenecientes a 25 morfogéneros incluyendo esporas, granos de polen y hongos.

Se observó una mayor diversidad de esporas con respecto a granos de polen (15 morfogéneros de esporas frente a cuatro de granos de polen), aunque la abundancia relativa de estos últimos era mayor, destacando la marcada dominancia de *Spheripollenites*. En lo que respecta a los hongos su abundancia y diversidad varía notablemente entre niveles, identificándose 4 morfogéneros diferentes.

Discusión

En la asociación palinológica están presentes varios taxones con un amplio rango de aparición, siendo comunes en más de un periodo geológico. Sin embargo, aparecen también taxones con un rango temporal más limitado. Entre ellos destaca el género *Cicatricosisporites*, cuya FAD en Europa y África se sitúa en el Kimmeridgiense (Filatoff 1975, Dettmann y Clifford 1992, Santos et al. 2021), por lo que su presencia nos indica que la muestra no podría tener una edad anterior al Kimmeridgiense (157.3±1.0Ma). La presencia de *Cicatricosisporites* spp. junto con *Concavissimisporites montuosus*, *Contignisporites fornicatus*, *Polycingulatisporites crenulatus* y *Klukisporites neovariegatus* sugiere una edad Kimmderidgiense-Berriasiense inferior para el yacimiento de Los Ganchos.

Palinomorfo	Afinidad botánica
Alisporites	Pinaceae; Podocarpaceae
Auracariacites	Araucariaceae
Baculatisporites	Osmundaceae
Cicatricosisporites	Schizaeaceae
Concavissimisporites	Cyatheaceae; Dipteridaceae; Matoniaceae
Contignisporites	Schizaeaceae
Cyathidites	Cyatheaceae; Dipteridaceae; Matoniaceae
Ischyosporites	Schizaeaceae
Klukisporites	Schizaeaceae
Leptolepidites	Lycopodiaceae; Selaginellaceae
Polycingulatisporites	Sphagnaceae
Spheripollenites	Taxodiaceae; Cheirolepidiaceae
Todisporites	Osmundaceae

Tabla 1. Tabla que relaciona a los géneros de pólenes y esporas más abundantes en Los Ganchos con las familias o géneros actuales con los que guardan relación.

Como se observa en la Tabla 1, los grupos de plantas dominantes en las tafocenosis del área de Alpuente son gimnospermas de porte arbóreo relacionadas con las familias Cheirolepidiaceae/Taxodiaceae y Pinaceae relacionadas algunas de ellas con climas secos y costeros (e.g., Abbink et al. 2004). Sin embargo, la diversidad de familias de helechos encontrada en la asociación palinológica (como Cyatheaceae, Dipteridaceae, Matoniaceae, Osmundaceae o Schizaeaceae) evidencia también la presencia de zonas húmedas y favorables para el desarrollo de estos grupos de pteridofitas, esta elevada variedad de familias de helechos ya fue observada en la macroflora y asociación palinológica de la Fm. Villar del Arzobispo en el área de Galve (Santos et al. 2018) de una edad similar.

References

Abbink, O. A., Van Konijnenburg-Van Cittert, J. H. A., Visscher, H. (2004):. A sporomorph ecogroup model for the Northwest European Jurassic-Lower Cretaceous: concepts and framework. *Netherlands Journal of Geosciences*, 83(1), 17-31.

Campos-Soto, S., Benito, M. I., Cobos, A., Caus, E., Quijada, I. E., Suarez-Gonzalez, P., Mas, R., Royo-Torres, R. & Alcalá, L. (2019): Revisiting the age and palaeoenvironments of the Upper Jurassic–Lower Cretaceous? Dinosaur-bearing sedimentary record of eastern Spain: implications for Iberian palaeogeography. *Journal of Iberian Geology*, 45(3), 471-510.

Dettmann, M. E., & Clifford, H. T. (1992): Phylogeny and biogeography of *Ruffordia*, *Mohria* and *Anemia* (Schizaeaceae) and *Ceratopteris* (Pteridaceae): evidence from in situ and dispersed spores. *Alcheringa*, 16(4), 269-314.

Filatoff, J. (1975): Jurassic Palynology of the Perth Basin, Western Australia. *Palaeontographica Bd., 154*

Mohr, B. R. (1989): New palynological information on the age and environment of Late Jurassic and Early Cretaceous vertebrate localities of the Iberian Peninsula (eastern Spain and Portugal).

Rodríguez-Barreiro, I., Santos, A. A., Arribas, M. E., Mas, R., Arribas, J., Villanueva-Amadoz, U., Torcida, F., & Diez, J. B. (2022): The Jurassic–Cretaceous transition in the West Cameros Basin (Tera Group, Burgos, Spain): Sedimentological and palynostratigraphical insights. *Cretaceous Research*, 105300.

Sánchez- Fenollosa, S., Verdú F.J., Suñer, M.C. de Santisteban (2022): Tracing Late Jurassic ornithopod diversity in the eastern Iberian Peninsula: *Camptosaurus*-like postcranial remains from Alpuente (Valencia, Spain). *Journal of Iberian Geology,* **48,** 65–78. https://doi.org/10.1007/s41513-021-00182-z

Santos, A. A., Villanueva-Amadoz, U., Royo-Torres, R., Sender, L. M., Cobos, A., Alcala, L., & Diez, J. B. (2018): Palaeobotanical records associated with the first dinosaur defined in Spain: Palynostratigraphy, taxonomy and palaeoenvironmental remarks. *Cretaceous Research*, 90, 318-334

Santos, A.A., Jain, S., & Diez, J. B. (2021): Upper Jurassic palynology from the Blue Nile Basin (Ethiopia). *Review of Palaeobotany and Palynology*, 285, 104361.

Suñer, M., Royo-Torres, R., Sánchez-Fenollosa, S., Marín-Monfort, M. D., Gamonal, A., Verdú, F. J. Santos, A. A., Castanera, D., Santos-Cubedo, A., Marquina-Blasco, R., Galobart, A., de Santisteban, C. (2021): 20 años de estudio del registro fósil de la Formación Villar del Arzobispo en la comarca de Los Serranos (Valencia, España). En: Libro *de resúmenes XXIV Bienal de la Real Sociedad Española de Historia Natural* (eds. García-Forner, A., Conejero-Ortega, N. & Díaz-Acha, Y.). Valencia, 232-234

Wood, D.G., Gabriel, A.M., Lawson, J.C., (1996): Palynologycal techniques – processing and microscopy. In: Jansonius, J., McGregor, D.C. (Eds.), *Palynology: Principles and applications*. AASP Foundation 1, 29-50.

Neuroanatomy of the bothremydid turtle *Zolhafah bella* (Pleurodira) from the Maastrichtian of Egypt

Martín-Jiménez, M.[1], Pérez-García, A.[1].

1: Grupo de Biología Evolutiva, Facultad de Ciencias, UNED, Avda. Esparta s/n, 28232, Las Rozas, (Madrid, Spain). mmartinjimenez@gmail.com; a.perez.garcia@ccia.uned.es

Keywords: Late Cretaceous, Dakla Formation, African record, Bothremydidae, 3D reconstruction.

Introduction

Zolhafah bella is a bothremydid turtle from the Maastrichtian Ammonite Hills (Dakla Formation) of Egypt. It is exclusively known by its holotype, corresponding to a nearly complete skull described by Lapparent de Broin and Werner (1998). Although it is attributed to the clade Bothremydini, its precise phylogenetic position is currently under debate. Thus, it has been interpreted as both a basal member of the clade Bothremydina (Gaffney et al., 2006), and a taxon occupying a basal position within Bothremydini (Martín-Jiménez and Pérez-García, 2021).A more precise anatomical analysis of the skull of this species will allow to improve our understanding of the phylogenetic relationships between the representatives of this clade. To carry out the detailed analysis of the holotype of *Zolhafah bella*, a CT scanning has been realized. The images obtained have been processed through specific three-dimensional segmentation software to reconstruct both the bony elements of the skull and the neuroanatomical structures (i.e., the cranial, nasal, and labyrinthic cavities, and the carotid and nervous canals). As a result, the first three-dimensional reconstruction of the neuroanatomical structures of *Zolhafah bella* is presented here, being one of the few available for Bothremydidae. The comparison with the neuroanatomy of other bothremydid taxa for which their complete or partial reconstruction had been performed, including most lineages of this clade (i.e., Cearachelyini, Bothremydini, and Taphrosphyini), is also accomplished here. The new information provided here for the bothremydid *Zolhafah bella* allows to improve the comparative neuroanatomy framework for this diverse clade, allowing to recognize synapomorphies for this group.

References

Gaffney, E. S., Tong, H., Meylan, P. E. (2006): Evolution of the side-necked turtles: The families

Bothremydidae, Euraxemydidae, and Araripemydidae. *Bulletin of American Museum of Natural History*, (300), 700 pp.

Lapparent de Broin, F., Werner, C. (1998): New late Cretaceous turtles from the Western Desert, Egypt. *Annales de Paléontologie*, (84), 131–214.

Martín-Jiménez, M., Pérez-García, A. (2021): Neuroanatomical study and three-dimensional reconstruction of the skull of a bothremydid turtle (Pleurodira) based on the European Eocene *Tartaruscola teodorii*. *Diversity*, (13, 298). https://doi.org/10.3390/d13070298.

One of the last dinosaur-bearing sites before the K/Pg boundary (Veracruz 1, NE Spain): a palynostratigraphical and paleoecological approach

Martínez de Espronceda, P.[1], Rodríguez-Barreiro, I.[1,2], Pérez-Pueyo, M.[3], Bádenas, B.[3], Canudo, J.I.[3], Puértolas-Pascual, E.[3,4], Sender L.M.[5], Diez, J.B.[1,2].

1: Departamento de Xeociencias Mariñas e Ordenación do Territorio, Facultade de Ciencias do Mar. Universidad de Vigo, 36310 Vigo, Spain. pilaresppronceda94@gmail.com

2: Centro de Investigación Mariña, Universidad de Vigo (CIM-UVIGO), 36310 Vigo, Spain.

3: Grupo Aragosaurus-IUCA, Facultad de Ciencias. Universidad de Zaragoza,50009 Zaragoza, Spain.

4. GeoBioTec, Departamento de Ciências da Terra, FCT, Universidad Nova de Lisboa. 2829-516. Caparica, (Setúbal, Portugal).

5. Área de Paleontología, Facultad de Ciencias. Edificio C, Universidad de Zaragoza, Zaragoza, Spain.

Keywords: Tremp Formation, Paleopalynology, Maastrichtian, K/Pg boundary, South-Central Pyrenees.

Introduction

The continental stratigraphic series in Europe including the K/Pg boundary are scarce. Some of the best examples are located in SW Europe, particularly in NE Iberian Peninsula. This is the case of the Tremp Formation outcropping in the South-Central Pyrenees in the so-called Tremp Basin, spanning from the end of the Cretaceous to the beginning of the Paleogene (Rosell et al., 2001). This formation is particularly interesting as it includes one of the most modern Cretaceous tetrapod fossil assemblages in Europe (Fondevilla et al., 2019; Pérez-Pueyo et al., 2021). The present work is a palynological study of the Veracruz 1 site within the Tremp Formation that provides a palynostratigraphic dating and new information to the paleoecological interpretation of the area.

Geographic and geological context

The study focused on the Veracruz 1 (VE1) site that is located in the surrounding area of Beranuy municipality in the northwestern sector of the Tremp Basin. This formation, in the studied area, has two informal units: Grey and Lower Red (Puértolas-Pacual et al., 2018). The VE1 site is within the lower part of the Tremp Formation (Grey Unit). The Grey Unit consists of mudstones and marly mudstones with some intercalations of cross-bedded sandstones and sandy limestones interpreted as a barrier-lagoon system (Rosell et al., 2001; Villalba-Breva and Martín-Closas, 2012). The Grey Unit is overlaid by the Lower Red Unit that is mainly composed by continental mudstones and sandstones. Both units are dated as late Maastrichtian in this sector of the basin, within the magnetochron C29r, where the K/Pg boundary is located (Puértolas-Pascual et al., 2018). The VE1 site has a rich fossil association, with foraminifera, charophytes, plants, bryozoans, gastropods, bivalves and decapod crustaceans, and also several groups of vertebrates, including fishes, amphibians, turtles, crocodylomorphs and dinosaurs (hadrosauroids and theropods).

Methodology

One marly mudstone sample was collected from the Grey Unit in the VE1 site. The standard palynological techniques described by Wood et al. (1996) were applied to the sample treatment.

Results

The palynological assemblage found has a good preservation and high diversity. A total of 41 fossil-genera were identified, including spores, pollen, dinoflagellates, algae, and fungi. The angiosperm pollen dominates the assemblage, especially *Liliacidites* and post-Normapolles group. A high continental character is observed, but freshwater/brackish algae and dinoflagellates indicate marine influence in the area.

Discussion

A late Maastrichtian age for the VE1 palynological assemblage can be deduced based on the following selected taxa: 1) the presence of *S. microconstans,* which is registered solely during the Maastrichtian; 2) the fact that the Last Occurrence (LO) of *C. insignis, L. dettmannae,* and *T. granulosus* is recorded in the late Maastrichtian so far; 3) the presence of the fossil-genera *Bacumorphomonocolpites* and *Rugulitriporites pflugii* whichhave their First Occurrence (FO) in the late Maastrichtian.

Previous dating of the Tremp Formation at basin-scale indicate that the unit accumulated in the interval period from the end-Cretaceous to the lowermost Paleogene, as it is shown by the magnetostratigraphic (Oms et al., 2007; Canudo et al., 2016; Fondevilla et al., 2016) and biostratigraphical studies (Díez-Canseco et al., 2014; Vicente et al., 2015). However, due to the existence of a lateral facies change between the Grey and Lower Red Units, depending on the geographic position of the studied section and due to diachronism, the Grey Unit may correspond to a different age within the Maastrichtian. The Grey Unit in the Beranuy-Serraduy area is within the magnetochron C29r (late Maastrichtian) according to combined magnetostratigraphical and biostratigraphical studies (Canudo et al. 2016; Puértolas-Pascual et al., 2018). All above agrees with our new age proposal obtained through palynological dating.

According to the dominant palynomorphs observed, the plant community will be mainly represented by a seaside forest of Jungladaceae/Myricaceae trees and shrubs (walnut and bayberry-like) with a flowering understory of Liliaceae herbs. The paleoenvironment of the area suggests a transitional background with continental and marine influence, due to the presence of freshwater fossil-taxa (*Chomotriletes fragilis, Ovoiidites springii*) and dinoflagellate cysts (*Sepispinula* sp., *Spiniferites* cf. *ramosus*), in agreement with the hypothesis proposed of the Grey Unit being a barrier-lagoon system (Rosell et al. 2001; Villalba-Breva and Martín-Closas, 2012).

A Gondwanan paleoecological influence has been observed. Although, the VE1 assemblage is dominated by palynomorphs from the Normapolles Province there is a significant presence of representatives from the Palmae Province (e.g., *Bacumorphomonocolpites*). This influence has been already observed during the late Maastrichtian, as Laurasian occurrences of *Bacumorphomonocolpites* in the late Maastrichtian of the Iberian Peninsula (Mayr et al., 1999) and the Netherlands (Herngreen et al., 1986).

Conclusions

The VE1 palynological assemblage belongs to the late Maastrichtian, representing a plant community dominated by Liliaceae herbs and Jungladaceae/Myricaceae trees and shrubs with Gondwanan influence. The presence of fresh-water algae and dinoflagellate cysts reinforces the hypothesis of the area as a barrier-lagoon type sedimentary environment.

References

Canudo, J.I., Oras, O., Vila, B., Galobart, A., Fondevila, V., Puértolas-Pascual, E., Sellés, A.G., Cruzado-Caballero, P., Dinarès-Turell, J., Vicens, E., Castanera, D., Company, J., Burrel, L., Estrada, R., Marmi, J., Blanco, A. (2016): The upper Maastrichtian dinosaur fossil record from the southern Pyrenees and its contribution to the topic of the Cretaceous-Palaeogene mass extinction event. *Cretaceous Research,* 57, 540-551. http://doi.org/10.1016/j.cretres.2015.06.013

Díez-Canseco, D., Arz, J.A., Benito, M.I., Díaz-Molina, M., Arenillas, I. (2014): Tidal influence in redbeds: a palaeoenvironmental and biochronostratigraphic reconstruction of the Lower Tremp Formation (South-Central Pyrenees, Spain) around the Cretaceous/Paleogene boundary. *Sedimentary Geology*, 312, 31-49. http://dx.doi.org/10.1016/j.sedgeo.2014.06.008.

Fondevilla, V., Dinarès-Turell, J., Oms, O. (2016): The chronostratigraphic framework of the South-Pyrenean Maastrichtian succession reappraised: implications for basin development and end-Cretaceous dinosaur faunal turnover. *Sedimentary Geology,* 337, 55-68. http://dx.doi.org/10.1016/j.sedgeo.2016.03.006.

Fondevilla, V., Riera, V., Vila, B., Sellés, A.G., Dinarès-Turell, J., Vicens, E., Gaete, R., Oms, O., Galobart, À. (2019): Chronostratigraphic synthesis of the latest Cretaceous dinosaur turnover in south-western Europe. *Earth Science Review,* 191, 168-189. http://doi.org/10.1016/j.earscirev.2019.01.007.

Herngreen, G.F.W., Felder, W.M., Kedves, M., Meessen, J.P.M.T. (1986): Micropaleontology of the Maestrichtian in Borehole Bunde, the Netherlands. *Review of Palaeobotany and Palynology*, 48, 1-70.

Mayr, C., Thümmler, B., Windmaier, G., Altenbach, A.V., Köhler, H., Tiedemann, R. (1999): New data about the maastrichtian/danian transition in the southern Pyrenees (Ager Basin, Catalonia, Spain) *Revista Española de Micropaleontología*, 31, 357-368.

Oms, O., Dinarès-Turell, J., Vicens, E., Estrada, R., Vila, B., Galobart, À., Bravo, A.M. (2007): Integrated stratigraphy from the Vallcebre Basin (southeastern Pyrenees, Spain): New inisghts on the continental Cretaceous-Tertiary transition in southwest Europe. *Palaeogeography, Palaeoclimatology, Palaeoecology,* 255, 35-47. http://doi.org/10.1016/j.palaeo.2007.02.039

Pérez-Pueyo, M., Cruzado-Caballero, P., Moreno-Azanza, M., Vila, B., Castanera, D., Gasca, J.M., Puértolas-Pascual, E., Bádenas, B., Canudo, J.I. (2021): The Tetrapod Fossil Record from the Uppermost Maastrichtian of the Ibero-Armorican Island: An Integrative Review Based on the Outcrops of the Western Tremp Syncline (Aragón, Huesca Province, NE Spain). *Geosciences,* 11, 162. http://doi.org/10.3390/geosciences11040162

Puértolas-Pascual, E., Arenillas, I., Arz, J.A., Calvín, P., Ezquerro, L., García-Vicente, C., Pérez-Pueyo, M., Sánchez-Moreno, E.M., Villalaín, J.J., Canudo, J.I. (2018): Cronostratigraphy and new vertebrate sites from the upper Maastrichtian of Huesca (Spain), and their relation with the K/Pg boundary. *Cretaceous Research,* 89, 36-59. http://doi.org/10.1016/j.cretres.2018.02.016

Rosell, J., Linares, R., Llompart, C. (2001): El "Garumniense" Prepirenaico. *Revista de la Sociedad Geológica Española,* 14, 47-56.

Vicente, A., Martín-Closas, C., Arz, J. A., Oms, O. (2015): Maastrichtian- basal Paleocene charophyte biozonation and its calibration to the Global Polarity Time Scale in the southern Pyrenees (Catalonia, Spain). *Cretaceous Research*, 52, 268-285. https://doi.org/10.1016/j.cretres.2014.10.004.

Villalba-Breva, S., Martín-Closas, C., (2013): Upper Cretaceous paleogeography of the Central Southern Pyrenean Basins (Catalonia, Spain) from microfacies analysis and charophyte biostratigraphy. *Facies*, 59, 319-345. http://doi.org/10.1007/s10347-012-0317-1.

Wood, G.D., Gabriel, A.M., Lawson, J.C., (1996): Palynological techniques-processing and microscopy. In: Jansonius J., McGregor D.C., (Eds.), Palynology: Principles and Applications, vol. 1. *American Association of Stratigraphic Palynologists*. Dallas, TX, 29-50.

New data about the Sauropoda record of the Blesa Formation (Lower Cretaceous) in northeast Spain

Medrano-Aguado, E.[1], Parrilla-Bel, J.[1], Canudo, J.I.[1]

[1]: Grupo Aragosaurus-IUCA, Paleontología, Facultad de Ciencias, Universidad de Zaragoza, C/Pedro Cerbuna, 12, 50009 Zaragoza, (Zaragoza, Spain). emedranoaguado@unizar.es

Keywords: Barremian, Maestrazgo basin, Teruel, Titanosauriformes,

Introduction

The dinosaur sauropods are the biggest terrestrial animals that have walked on Earth so their distribution and way of life are always under review. The presence of Titanosauriformes and rebbachisaurid sauropods at the Barremian of the Iberian Peninsula is well documented (Canudo et al., 2008; Royo-Torres et al., 2012, 2014, 2017; Torcida Fernández-Baldor et al., 2011; 2017). The Blesa Formation shows the start of the Cretaceous sedimentation (Barremian) in the Oliete subbasin, the most northwestern subbasin included in the Mesozoic Maestrazgo basin (Teruel). The dinosaur paleobiodiversity of the Lower Blesa Sequence (Aurell et al., 2018) is relatively well known due to the La Cantalera-1 site, where hundreds of fossils have been recovered, most of them isolated teeth (Canudo et al., 2010). The sauropod fossils are scarcer: two isolated teeth and fragments of one more, besides a fragmented cervical vertebra assigned to enigmatic Euhelopodidae indet. (Canudo et al., 2002). Until now, no sauropod remains were known in the Upper Blesa Sequence (Aurell et al., 2018). The objective of this work is to describe for the first time new sauropod remains recovered in the most modern part of the Blesa Formation in Alacón and Obón respectively.

Material and Methods

The anatomical nomenclature used in this study is what is common for Sauropoda. The fossil bones are stored at the Museo de Ciencias Naturales of the Universidad de Zaragoza, under the label MPZ (Canudo 2018). The material studied is a caudal vertebra (MPZ 2022/726) and a right ischium (MPZ 2019/262). Mechanical methods have been used for the preparation of MPZ 2022/726. The ischium MPZ 2019/262 was prepared with chemical and mechanical methods.

Results

MPZ 2022/726 is a middle-posterior caudal vertebra. It comes from a conglomeratic level that marks the start of the continental sedimentation of the Upper Blesa Sequence near Alacón locality. No more sauropod remains have been founded at the site. The centrum is broken and the left posterior half and the neural arc are practically lost, as well as the external surface in the union between the articular facets and the sides of the centrum. The suture of the neural arc with the centrum is totally closed, which, together with the size of the centrum, indicates that MPZ 2022/726 corresponds with an adult specimen. The vertebra is 170mm length, 110mm width and 100mm dorsoventrally in the anterior articular facet. MPZ 2022/726 is amphicoelous with both articular facets slightly concave. Anteroposteriorly the centrum is concave in both ventral and lateral surfaces and has a smooth ridge directed anteroposteriorly in the middle of the lateral surfaces. The internal structure of the centrum has relatively small cavities. The neural arc is located in an anterior position and lacks transverse process, just a smooth buldge in the lateral surface, indicative of the posterior caudal position of the vertebra.

MPZ 2019/262 is a small and mostly complete right ischium. It was recovered from the limestones near at the base of the Upper Blesa Sequence near Obón village. One strong predatory mark can see in the medial surface near the base of the ischial ramus. One more possibly tooth mark is located anterior to this one. The edges of the pubic peduncle and the base of the ischial ramus are slightly broken due to their slender end. The iliac peduncle and the end of the ischial ramus are not completely preserved. Its dorsoventral length is 45cm, the pubic peduncle length is 16cm (but its ventral end is broken) and the maximum length of the ischial shaft is 20cm. The iliac ramus is well differentiated, projected posteriorly and the outline has a conic morphology in posterior view, being widest in the proximal part although it is not complete. The acetabulum medial surface is slightly concave and has a narrow-broken margin so the contribution in the acetabulum is not clear. The pubic peduncle is expanded dorsoventrally and its margin is extremely thin. The medial surface of the main body is convex and the lateral surface is concave. The ischial ramus preserved (almost complete) is approximately equal to the rest of the ischium. It has triangular shape in cross-section. The ramus slightly twists towards itself with the medioventral surface turning into most ventral position, at the same time than the ramus turns posteroventrally, forming a concave lateral outline for the posterior edge of the ischium. The distal end of the ramus is not expanded. From the medial surface of the ramus emerges a strong ridge that ends in the middle of the main body of the ischium, near the posterior end.

Discussion

The general morphology of the MPZ 2022/726 allow us to assign it to the Titanosauriformes clade, with the neural arch moved to an anterior position and both articular facets concave (Salgado et al. 1997). The size of the centrum is similar to those of middle caudal vertebra of *Soriatitan golmayensis* (Royo-Torres et al., 2017) and probably to *Europatitaneastwoodi* (Torcida Fernández-Baldor et al. 2017), but no middle caudal vertebrae are preserved for this second.

The general morphology of MPZ 2019/262 is similar to the ischium of Titanosauriformes sauropod clade as *Europatitan eastwoodi* (Torcida Fernández-Baldor et al. 2017), *Soriatitangolmayensis* (Royo-Torres et al. 2017) or *Tastavinsaurus sanzi* (Canudo et al. 2008) more than to the Rebbachisauridae like *Demandasaurus darwini* (Torcida Fernández-Baldor et al. 2011). The morphology of the ischiadic blade, slender, with no expanded distal end and directed ventrally instead of posteriorly or posteroventrally is similar to the *Soriatitan* ischium more than to the *Tastanvinsaurus* and *Europatitan* ones. Due to the isolated state of the ischium and considering the characters described below we decide to assign it to Titanosauriformes indet.

Conclusions

In the current state of knowledge, the sauropod remains are scarcer in the Barremian Oliete subbasin in comparison with other Barremian areas of the Iberian Peninsula where sauropod material is more common (i.e., the Maestrazgo Basin or the Cameros basin). At the moment it cannot be affirmed that this particularity is the result of a preference of the Iberian sauropods for a particular environment scarce in the Oliete sub-basin, or simply due to the taphonomic and fossilization processes.

The new sauropod material of the Upper Blesa Sequence Blesa Formation is assigned to Titanosauriformes indet. probably closely related with *Soriatitan*. Basal Titanosauriformes are the most common group of sauropods in the Iberian Barremian, so their presence in the Oliete sub-basin is consistent.

The Titanosauriformes taxon present in the upper sequence of the Blesa Formation could be related to the Euhelopodidae cited in the lower sequence, which for some authors is a non-Titanosaurian Titanosauriformes. However, the great resemblance of MPZ 2022/726 and MPZ 2019/262 to *Soriatitan* makes us think that it is a different sauropod and therefore there would be two sauropods in the Blesa Formation: Euhelopodidae indet and aff. *Soriatitan*.

Acknowledgments

Juanita Alquézar Lázaro has donated MPZ 2022/726 to the Museo de Ciencias Naturales de la Universidad de Zaragoza. This research is supported by the PLEC2021-008203 project and by the Government of Aragón-FEDER 2014–2020 Construyendo Europa desde Aragón (Group E18: Aragosaurus: Recursos Geológicos y Paleoambientales). Eduardo Medrano-Aguado es beneficiario de un contrato predoctoral de formación de la DGA (Diputación General de Aragón).

References

Aurell, M., Soria, A.R., Bádenas, B., Liesa, C.L., Canudo, J.I., Gasca, J.M., Moreno-Azanza, M., Medrano-Aguado, E., Meléndez, A. (2018). Barremian synrift depositional sequence evolution in continental to restricted bay environments with high diversity of vertebrates (Blesa Formation, Oliete sub-basin, NE Spain). *Journal of Iberian Geology* 44(2), 285-308

Canudo, J.I. (2018). The collection of type fossils of the Natural Science Museum of the University of Zaragoza (Spain). *Geoheritage,* 10, 385–392.

Canudo, J. I., Ruiz-Omeñaca, J. I., Barco, J. L. & Royo-Torres, R. (2002). ¿ Saurópodos asiáticos en el Barremiense inferior (Cretácico Inferior) de España. *Ameghiniana*, 39(4), 443-452.

Canudo, J. I., Royo-Torres, R. & Cuenca-Bescós, G. (2008). A new sauropod: *Tastavinsaurus sanzi* gen. et sp. nov. from the Early Cretaceous (Aptian) of Spain. *Journal of Vertebrate Paleontology*, 28(3), 712-731.

Canudo, J.I., Gasca, J.M., Aurell, M., Badiola, A., Blain, H.-A., Cruzado- Caballero, P., Gómez-Fernández, D., Moreno-Azanza, M., Parrilla, J., Rabal, R. and Ruiz-Omeñaca, J.I. 2010. La Cantalera: an exceptional window onto the vertebrate biodiversity of the Hauterivian-Barremian transition in the Iberian Peninsula. *Journal of Iberian Geology*, 36(2):205–224.

Fernández-Baldor, F. T., Canudo, J. I., Huerta, P., Moreno-Azanza, M. & Montero, D. (2017). *Europatitan eastwoodi*, a new sauropod from the lower Cretaceous of Iberia in the initial radiation of somphospondylans in Laurasia. *PeerJ*, 5, e3409.

Royo-Torres, R., Alcalá, L. & Cobos, A. (2012). A new specimen of the Cretaceous sauropod *Tastavinsaurus sanzi* from El Castellar (Teruel, Spain), and a phylogenetic analysis of the Laurasiformes. *Cretaceous Research*, 34, 61-83.

Royo-Torres, R., Upchurch, P., Mannion, P. D., Mas, R., Cobos, A., Gascó, F., ... & Sanz, J. L. (2014). The anatomy, phylogenetic relationships, and stratigraphic position of the Tithonian–Berriasian Spanish sauropod dinosaur *Aragosaurus ischiaticus*. *Zoological Journal of the Linnean Society*, 171(3), 623-655.

Royo-Torres, R., Fuentes, C., Meijide, M., Meijide-Fuentes, F. & Meijide-Fuentes, M. (2017). A new Brachiosauridae sauropod dinosaur from the lower Cretaceous of Europe (Soria Province, Spain). *Cretaceous Research*, 80, 38-55.

Torcida Fernández-Baldor, F.., Canudo, J. I., Huerta, P., Montero, D., Suberbiola, X. P. & Salgado, L. (2011). *Demandasaurus darwini*, a new rebbachisaurid sauropod from the Early Cretaceous of the Iberian Peninsula. *Acta Palaeontologica Polonica*, 56(3), 535-552.

A sampling method to study the Titanosaurian pelvis with 3D Geometric Morphometrics

Páramo, A.[1,2], Mocho, P.[3,2,4], Vidal, D.[2,5], Marcos-Fernández, F.[2,6], Ortega, F.[2]

1: Centro de Interpretación Paleontológica de La Rioja, Government of La Rioja, Calle Mayor 10, 26525 Igea, La Rioja, Spain. paramoblazquez@gmail.com

2: Grupo de Biología Evolutiva, Facultad de Ciencias, Universidad Nacional de Educación a Distancia (UNED), Avda. Esparta s/n, 28232. Las Rozas. Madrid, Spain. fortega@ccia.uned.es

3: Instituto Dom Luiz, Faculdade de Ciências da Universidade de Lisboa, Edifício C6, Campo Grande, 1749-016 Lisboa, Portugal.

4:Dinosaur Institute, Natural History Museum of Los Angeles, 900 Exposition Blvd, 90007 Los Angeles, California, USA

5: Department of Organismal Biology and Anatomy, University of Chicago, 1027 East 57th Street, Chicago, Illinois, 60637, United States of America

6: Facultad de Bellas Artes, Universidad Complutense de Madrid, C. Pintor el Greco, 2, 28040 Madrid Spain

Keywords: Titanosauria, 3D-Geometric Morphometrics, Pelvis, Lo Hueco, Virtual Paleontology

Introduction

Sauropod pelvic girdles remain poorly understood, especially their three dimensional morphology in anatomical articulation due the incompleteness of the fossil record, the size of the elements and the general difficulty in handling the fossil specimens (e.g., Vidal et al., 2020a, b). In the case of geometric morphometric analyses, incompleteness of the fossil specimens and the lack of osteological features to sample landmarks adds to the previously commented issues.

Sauropod pelvic girdle elements exhibit few osteological features that can be identified as potential osteological characters (e.g., Mannion et al., 2019; Tschopp et al., 2015) suitable to identify and define type-I and type-II landmarks (Rohlf, 1999). These types of landmarks are desirable because they are restricted to a precise anatomical feature such as trochanters, protuberances the union of several joints or crests. which reduce potential sampling biases and errors.

In this study we define several landmarks and semilandmark curves in titanosaur ilia, pubes and ischia and propose a multi-platform sampling workflow useful for including titanosaur pelves in landmark-based 3D geometric morphometric (3D-GMM) analyses.

Methodology

In order to define a template of landmarks and semilandmark curves, as well as to assess the usefulness of the sampling method, we compared *Lohuecotitan pandafilandi* (HUE-EC-01) and the other pelvic elements (e.g., HUE-EC-04) from Lo Hueco fossil site (Upper Cretaceous. Cuenca, Spain), with other Upper Cretaceous titanosaur taxa. While up to four potential morphotypes based on caudal morphology has been noticed in Lo Hueco (Mocho et al., 2022; Vidal et al., 2017), the taxonomic affinities of the so far undescribed specimens of Lo Hueco, such as HUE-EC-02, HUE-EC-04 or HUE-EC-13, are currently unknown. Also, while phylogenetic relationships of Ibero-Armorican titanosaurs are still debated, previous studies noticed for the presence of some morphological features that are being used the characterize the members of the Aeolosaurini clade (e.g., Mocho et al., 2022).

We sampled the ilia, pubes and ischia of seven titanosaur species (including *Lohuecotitan pandafilandi*), cf. *Neuquensaurus* and "*Neuquensaurus robustus*" (Otero, 2010) which taxonomical status is uncertain and the pelvis of an indeterminate titanosaur of Lo Hueco (HUE-EC-04) via stereophotogrammetry. All sampled titanosaurs have at least one element of each pelvic bone except for cf. *Neuquensaurus* and "*N. robustus*" morphotypes which are fragmentary but were included to calculate potential 'intra-specific' variance within *Neuquensaurus*. The titanosaur *Aeolosaurus* sp. lacks an ilium, but was also included to assess the usefulness of our sampling method allowing a comparison between Lo Hueco titanosaurs and *Aeolosaurus* sp. pubes and ischia.

Our landmark and semilandmark curve proposals include several supporting type-III landmarks. The main landmarks are type-I and type-II, but type-III is unavoidable as several features (e.g., boundaries of the ischiatic peduncle of the ilium) are not restrained enough by other osteological features. Supporting landmarks on the other hand are placed in sampling software like IDAV Landmark Editor (Wiley et al., 2005), '*geomorph'* R-package (Adams et al., 2019), Stratovan® Checkpoint®, or NURB curve placement (e.g., Molnar et al., 2012) when defining a semilandmark curves. We sampled these landmarks as an easy way to deploy reference points from our template that can be easily replicated in other studies and by other authors with a multi-platform capability. The support landmarks and semilandmark curves were placed in a similar way as defining an outline in lateral, anterior and dorsal view of the specimen in anatomical position. With this strategy we tried to solve the problematic of semilandmark curve sampling in a complex morphology as a sauropod pelvic bone, as the outline will pass through the most external edge of the specimen.

The incomplete specimens were virtually restored with the workflow proposed by Páramo et al. (2022) but this time the support landmarks were excluded both from the estimation and analysis pipeline within R. The support landmark role was left merely as guides for the curve midpoints and joints as for now. The complete landmark and semilandmark curve databases were then analyzed with generalized procrustes analyses (GPA) and principal component analyses (PCA) of the GPA-aligned coordinates.

Results and Discussion

Our method has allowed us to compare the morphology of the Lo Hueco titanosaurs and several Upper Cretaceous Gondwanan titanosaurian taxa. Virtual restoration could be carried out with only two to three completed specimens with our current template of landmarks and semilandmark curves. The mesh reconstruction via thin-plate spline projection from the template ("atlas") mesh to the incomplete specimen 3D mesh following Páramo et al. (2022) has enabled to reconstruct and visualize of the pelvic bones of fragmentary specimens. The resulting meshes and landmark and semilandmark curves configurations recovered even the extremely gracile and narrow blade surfaces of the specimens from rinconsaurian titanosaurs, despite an unbiased sample toward the extremely robust and laterally deflected elements of the Saltasauridae, especially on the ilia database.

Our analyses allow to differentiate between Rinconsauria and Saltasauridae pelvic bones. There are few similarities between *Aeolosaurus* sp. and Lo Hueco titanosaurs but our current sample is limited to test whether this morphological disparity is related with the absence of phylogenetic affinities. Morphological differences between the pelvis of HUE-EC-04 and *Lohuecotitan pandafilandi* are far greater than 'intraspecific' variance among rinconsaurian and saltasaurid taxa, including *Neuquensaurus* spp. Therefore, it is likely that *Lohuecotitan pandafilandi* and HUE-EC-04 represent two different taxa as previous comparative analyses suggested. Relationships between HUE-EC-04 and the proposed appendicular morphotypes (Páramo et al. 2022) remain still unknown. The inclusion of more pelvic elements (especially the ones associated to other partial skeletons recovered in Lo Hueco, such as HUE-EC-13 or HUE-EC-02) in future analyses landmark-based 3D

GMM analyses will be important to test the presence of more than two pelvic morphotypes, and eventually, the presence of more than two taxa.

Acknowledgements

This research was funded by the Ministerio de Ciencia e Innovación of Spain (PID2019-111488RB-I00) and, especially, by the Consejería de Educación, Cultura y Deportes, Junta de Comunidades de Castilla-La Mancha (SBPLY/21/180801/000045).

References

Adams, D.C., Collyer, M.L., Kaliontzopoulou, A., (2019): Geomorph: Software for geometric morphometric analyses. R package version 3.1.0.

Mannion, P.D., Upchurch, P., Schwarz, D., Wings, O., (2019): Taxonomic affinities of the putative titanosaurs from the Late Jurassic Tendaguru Formation of Tanzania: phylogenetic and biogeographic implications for eusauropod dinosaur evolution. *Zoological Journal of the Linnean Society,* (185), 784-909.

Mocho, P., Escaso, F., Marcos-Fernández, F., Páramo, A., Vidal, D., Ortega, F., (2022): Lo Hueco quarry (Upper Cretaceous, Cuenca, Central Spain), a puzzle of articulated titanosaurian tails. 19th EAVP Annual Meeting, Benevento, Abstract book.

Molnar, J.L., Pierce, S.E., Clack, J.A., Hutchinson, J.R., (2012): Idealized landmark-based geometric reconstructions of poorly preserved fossil material: a case study of an early tetrapod vertebra. *Palaeontologia Electronica*, (15), 18.

Otero, A., (2010): Comments on the taxonomic status of *Neuquensaurus robustus* (Huene) (Sauropoda, Titanosauria), in: *X Congreso Argentino de Paleontología y Bioestratigrafía - VII Congreso Latinoamericano de Paleontología*.

Páramo, A., Escaso, F., Mocho, P., Marcos-Fernández, F., Sanz, J.L., Ortega, F., (2022): 3D Geometric morphometrics of the hind limb in the titanosaur sauropods from Lo Hueco (Cuenca, Spain). *Cretaceous Research* 105147.

Rohlf, F.J., (1999): Shape statistics: Procrustes superimpositions and tangent spaces. *Journal of Classification,* (16), 197-223.

Tschopp, E., Mateus, O., Benson, R.B.J., (2015): A specimen-level phylogenetic analysis and taxonomic revision of Diplodocidae (Dinosauria, Sauropoda). *PeerJ* 3, e857.

Vidal, D., Mocho, P., Aberasturi, A., Sanz, J.L., Ortega, F., (2020a): High browsing skeletal adaptations in Spinophorosaurus reveal an evolutionary innovation in sauropod dinosaurs. *Scientific Reports,* (10), 6638.

Vidal, D., Ortega, F., Sanz, J.L., (2020b): Sauropodomorph skeletal mounts as scientific devices for testing hypotheses. *Journal of Iberian Geology*, 337-342.

Vidal, D., Sanz, J.L., Mocho, P., Páramo, A., Escaso, F., Marcos-Fernández, F., Ortega, F., (2017): The titanosaur tails from Lo Hueco (Cuenca, Spain): Four different ways to shake?, in: Farke, A.A., Mackenzie, S.A., Miller Camp, J. (eds.), 77th Annual Meeting of the Society of Vertebrate Paleontology. Calgary, 208.

Wiley, D.F., Amenta, N., Alcantara, D.A., Ghosh, D., Kil, Y.J., Delson, E., Harcourt-Smith, W., Rohlf, F.J., St John, K., Hamann, B., (2005): Evolutionary morphing, in: IEEE Visualization, 2005. VIS 05. Presented at the IEEE Visualization, 2005. VIS 05, 431-438.

Crocodylomorph diversity in Barranco del Hocino-1 site (Barremian, Lower Cretaceous) in Estercuel (Teruel, Spain)

Parrilla-Bel, J.[1], Medrano-Aguado, E.[1], Puértolas-Pascual, E.[1], Canudo, J.I.[1 2]

1: Grupo Aragosaurus-IUCA, Paleontologia, Facultad de Ciencias, Universidad de Zaragoza, C/Pedro Cerbuna, 12, 50009 Zaragoza, (Zaragoza, Spain) jarapbel@gmail.com

2: Museo de Ciencias Naturales de la Universidad de Zaragoza, Ed. Paraninfo, Pl. Basilio Paraíso, 4, 50005 Zaragoza (Zaragoza, Spain)

Keywords: Lower Cretaceous, Maestrazgo basin, Goniopholididae, teeth, Blesa Formation.

Introduction

The Barremian Blesa Formation was deposited in the Oliete sub-basin (north-western Maestrazgo basin, East Spain) overlying Jurassic units unconformably. This formation is divided into three genetic sequences: The lower Blesa sequence, characterized by distal alluvial to palustrine marls/clays which grade upward to palustrine–lacustrine limestones; the middle Blesa sequence, characterized by oyster-rich limestones and marls deposited in a shallow restricted bay, grading to distal alluvial and palustrine–lacustrine marls/clays and limestones towards the marginal areas of the basin, and upper Blesa sequence, characterized by distal alluvial fan environments to palustrine and lacustrine carbonates and marls/clays upwards (Aurell et al., 2018).

Blesa Formation is a very fossiliferous formation with abundant vertebrate remains through the sub-basin extension and across the three sequences. More than 20 fossiliferous sites have been located and more than 30 vertebrate taxa have been identified. Most of the vertebrate fossils are fragmentary material not classifiably at generic or specific level, but there are dinosaurs (sauropods, theropods, ornithopods, thyreophors), pterosaurs, plesiosaurs, squamates, chelonians, amphibians, mammals (multituberculates), fishes (osteichthyes and chondrichthyes) and crocodylomorphs (Canudo et al., 2010; Aurell et al., 2018 and references therein, Holgado et al., 2019, Medrano-Aguado et al., 2019).

The most common taxa in the lower Blesa sequence are crocodylomorphs. They are mainly represented by small isolated teeth found in La Cantalera-1 site (Puértolas-Pascual, et al., 2015). The teeth may correspond to goniopholidids, bernissartiids, atoposaurids and ziphodont crocodylomorphs, an assemblage of continental crocodylomorphs similar to other European Lower Cretaceous sites. In the middle Blesa sequence there are some cranial remains of probably marine longirostrine crocodylomorphs (Parrilla-Bel & Canudo, 2018). The upper Blesa sequence was the less fossiliferous of the three sequences. However, several new sites have been found in recent years, most of them located in the municipality of Estercuel (Teruel).

In the article by Aurell et al., 2018, crocodylomorph remains are cited in Barranco del Hocino 1 (Estercuel, Teruel), in the upper sequence of the Blesa Formation, but no study has been carried out on them. Here we present a preliminary study of the crocodylomorphs association from Barranco del Hocino 1 describing for the first time crocodylomorph remains from this sequence.

Material and methods

The material included in this study was recovered in several field campaigns since 2015 to 2019. All teeth from Barranco del Hocino-1 were collected during the excavation process. A small sample of sediment has been washed and sieved and no crocodylomorph teeth have been found. The fossils are housed in the Museo de Ciencias Naturales de la Universidad de Zaragoza with labered MPZ (Canudo, 2018).

Results

Three different teeth morphotypes are present:

Morphotype 1.

The material referred to this morphotype is: 9 teeth, MPZ 2022/740 to MPZ 2022/748

They are generalist conical teeth, with subcircular cross-section, medium to high crowns and acute apex slightly lingually curved. The transition between the crown and the root is unconstricted. Total crown height ranges from 5 to 10 mm only exceeding this size MPZ 2022/745 (17 mm) and MPZ 2022/742 (15 mm).The diameter of the base of the tooth crown is less than one half of its height. The labial and lingual surfaces are separated by smooth carinae with different degrees of development. The enamel is ornamented with longitudinal ridges, parallel or slightly convergent towards the apex. The ridges are more numerous, well-marked and packed on the lingual side. The number of ridges in this side is smaller than 10, with the only exception of MPZ 2022/744 and MPZ 2022/748.

Morphotype 2.

The material referred to this morphotype is: 7 teeth, MPZ 2022/749 to MPZ 2022/755.

This morphotype also corresponds with a generalist form described to morphotype 1 but differs from it in teeth proportions and enamel ornamentation: medium height crowns, with the diameter of the base of the crown greater than one half of its height. The labial and lingual surfaces are separated by carinae with different degrees of development and a small crenulation (false ziphodont) in some specimens. Both surfaces are ornamented with numerous longitudinal ridges, parallel or slightly convergent towards the apex. The ridges are more numerous (more than 10) and packed on the lingual surface.

Morphotype 3.

The material referred to this morphotype is: MPZ 2022/756 and MPZ 2022/757.

They are small conical teeth (crown high less than 5 mm), medium to high crowns, with the diameter of the base of the crown equal or greater than one half of its height and subcircular section. They are distally and lingually curved. The labial and lingual surfaces are separated by serrated carinae (true ziphodont pattern) and the enamel lacks ornamentation.

Discussion

The assemblage of Barranco de Hocino-1 is characterized by the absence of large crocodylomorph remains. Three morphotypes of teeth can be recognized, but the generalist morphology and the heterodonty jaws of crocodylomorphs makes difficult the assignation of isolated teeth to a generic or even family level. Morphotypes 1 and 2 could be assigned to Goniopholididae? indet. These morphotypes 1 and 2 represent the typical generalist conical morphologies that are usually assigned to goniopholidids given the abundance of this clade in most sites with vertebrates from the Upper Jurassic and the Lower Cretaceous of Europe. Differences between both morphotypes can represent teeth in different dental placements,from more anterior to posterior positions respectively. Morphotype 3 has been assigned to Mesoeucrocodylia indet. This type of conical teeth with serrated carinae by denticles (true zyphodonty) are typical of some terrestrial and amphibian crocodylomorphs such as notosuchians, and some paralligatorids (*Wannchampsus*) and crocodylians (e.g., Planocraniidae, *Quinkana*) (Ősi et al., 2015). However, the presence of these clades in the Early Cretaceous of Europe is unknown and, therefore, this Morphotype 3 has been more openly assigned to Mesoeucrocodylia indet. A comparison between La Cantalera-1 (lower Blesa sequence) and Barranco del Hocino 1 (upper Blesa sequence) sites, shows a lower crocodylomorph diversity in the second one: two different morphotypes assigned to goniopholidids and a third morphotype of some indeterminate mesoeucrocodylian appear at Barranco del Hocino-1 site. On the contrary, other clades such as bernissartiids or atoposaurids found in La Cantalera-1 (lower Blesa sequence), and common in the Lower Cretaceous, are not represented here. The amount of sediment washed in the La Cantalera-1 site is much greater than in the Barranco del Hocino-1, however, in the sediment sample that has already been washed and sieved, no small-sized crocodylomorph teeth have appeared. Barranco del Hocino-1 represents an environment with higher energy than La Cantalera-1. The differences between both fossil sites could be due to taphonomic processes, to the preference of small taxa for a lower energy environment like that of La Cantalera-1, or to a specialization in the faunas after the environmental change: continental-transitional-continental that occurred along the depositional sequences of the Blesa Formation in that region.

References

Aurell, M., Soria, A. R., Bádenas, B., Liesa, C. L., Canudo, J. I., Gasca, J. M., Moreno-Azanza, M., Medrano-Aguado, E.& Meléndez, A. (2018): Barremian synrift sedimentation in the Oliete sub-basin (Iberian Basin, Spain): palaeogeographical evolution and distribution of vertebrate remains. *Journal of Iberian Geology*, *44*(2), 285-308.

Canudo, J.I. (2018): The collection of type fossils of the Natural Science Museum of the University of Zaragoza (Spain). *Geoheritage,* 10, 385-392.

Holgado, B., Pêgas, R. V., Canudo, J. I., Fortuny, J., Rodrigues, T., Company, J., & Kellner, A. W. (2019): On a new crested pterodactyloid from the Early Cretaceous of the Iberian Peninsula and the radiation of the clade Anhangueria. *Scientific reports*, *9*(1), 1-10.

Medrano-Aguado, E., Germán, A. A., Parrilla-Bel, J. P., Canudo, J.I. (2019):. Paleobiodiversidad de vertebrados de la secuencia media de la Formación Blesa (Cretácico Inferior, Teruel). *Zubía*, (31), 205-210.

Ősi, A., Rabi, M., & Makádi, L. (2015): An enigmatic crocodyliform tooth from the bauxites of western Hungary suggests hidden mesoeucrocodylian diversity in the Early Cretaceous European archipelago.*PeerJ*,*3*, e1160.

Parrilla-Bel, J., & Canudo, J. I. (2018): New longirostrine crocodylomorph remains from the Blesa Formation (Barremian) in the Iberian Peninsula (Spain). *Journal of Iberian Geology*. https://doi.org/10.1007/s41513-017-0043-1

Puértolas-Pascual, E., Rabal-Garcés, R., & Canudo, J.I. (2015): Exceptional crocodylomorph biodiversity of “La Cantalera” site (lower Barremian; Lower Cretaceous) in Teruel, Spain (pp. 1–16). *Paleontologica Electronica*, 18.2.28a.

Was *Aragochersis* the only helochelydrid turtle that lived in the Spanish Albian area of Ariño?

Pérez-García, A.[1], Espílez, E.[2], Mampel, L.[2]

1: Grupo de Biología Evolutiva, Facultad de Ciencias, UNED, Avda. Esparta s/n, 28232 Las Rozas, Madrid, Spain. a.perez.garcia@ccia.uned.es

2: Fundación Conjunto Paleontológico de Teruel-Dinópolis (Museo Aragonés de Paleontología), Avda. Sagunto s/n, E-44002 Teruel, Spain. espilez@fundaciondinopolis.org, mampel@fundaciondinopolis.org

Keywords: Stem turtles, Helochelydridae, Early Cretaceous, Teruel, Spain.

Helochelydridae is recognized as the most abundant clade of terrestrial basal turtles (i.e., Testudinata belonging to the stem group of Testudines) for both the uppermost Jurassic to the uppermost Cretaceous record of Europe, and the Lower to the Upper Cretaceous record of North America. Several representatives have been defined for the European record. The two most complete European skeletons for this lineage have recently been recognized in the lower Albian fossiliferous levels of the Santa María Quarry, in Ariño (Teruel, Aragon, Spain). They were attributed to a single form, identified as a new taxon, *Aragochersis lignitesta*. Additional material of Helochelydridae has been found at this fossiliferous locality. Some of these remains have been prepared for study, but they remain unpublished until now. Anatomical elements of juvenile and adult individuals are recognized. However, not all of them seem attributable to *Aragochersislignitesta*. The partial skeleton of an adult individual of Helochelydridae from Ariño is presented here. Its attribution to a form different from *Aragochersis lignitesta* is discussed.

New shell information for the oldest European pleurosternid turtle: the Portuguese Kimmeridgian *Selenemys lusitanica*

Pérez-García, A.[1,2], Camilo, B.[2], Ortega, F.[1,2]

1: Grupo de Biología Evolutiva, Facultad de Ciencias, UNED, Avda. Esparta s/n, 28232 Las Rozas Madrid, Spain. a.perez.garcia@ccia.uned.es, fortega@ccia.uned.es

2: Laboratório de Paleontologia e Paleoecologia da Sociedade de História Natural, Polígono Industrial do Alto do Ameal, Pav.H02 e H06, 2565-641, Torres Vedras, Portugal. bcsilva.paleo@gmail.com

Keywords: Late Jurassic, Testudinata, Paracryptodira, Pleurosternidae, Portugal.

Pleurosternidae is the only lineage of freshwater stem turtles (i.e., Testudinata not attributable to the crown Testudines) recognized in both the Upper Jurassic and the Lower Cretaceous records of Europe. This Laurasian lineage of Paracryptodira was identified by several representatives in this continent, the greatest diversity recorded corresponding to that from the Iberian Peninsula. The Iberian diversity is represented by forms recognized as exclusive to this region, all of them defined after 2010. In fact, the youngest representative of Pleurosternidae and the oldest European member of the group are identified there. The latter corresponds to *Selenemys lusitanica*, from the upper Kimmeridgian of the Lusitanian Basin, in central-western Portugal. The species was defined by a shell preserving the complete plastron and the partial disarticulated carapace, from Santa Rita (Torres Vedras). A partial articulated shell and three isolated plates from the nearby locality of Peralta (Lourinhã) were also attributed to it in the paper where it was defined. Considering the preservation of these remains, the original morphology of the shell could not be adequately defined, and several anatomical characters, some of them being relevant for the systematic discussions about the members of this lineage, could not be recognized. However, no additional material attributed to the species have been subsequently published.

We present here a new shell attributable to *Selenemys lusitanica*. It comes from an upper Kimmeridgian outcrop of the Portuguese locality of Peniche (Lusitanian Basin). Its excellent preservation allows to characterize morphological aspects hitherto unknown for the shell of this taxon, as well as to recognize intraspecific variability for several characters. Therefore, new data allow us to propose here a more detailed characterization for the oldest species of Paracryptodira defined in the European record.

New information provided by the recent finds of helochelydrid turtle remains in the Spanish Cenomanian site of Algora

Pérez-García, A.[1]

1: Grupo de Biología Evolutiva, Facultad de Ciencias, UNED, Avda. Esparta s/n, 28232 Las Rozas, Madrid, Spain. a.perez.garcia@ccia.uned.es

Keywords: Stem turtles, Helochelydridae, Late Cretaceous, Guadalajara, central Spain.

The Spanish palaeontological locality of Algora (Guadalajara) has provided the main concentration of Cenomanian vertebrate macroremains identified in south-western Europe. This faunal ensemble is composed by some vertebrate lineages that were present in the European Lower Cretaceous sites, as well as by others not recognized in the Lower Cretaceous fossil record of the continent. In this way, the information provided through the analysis of the fossil remains found in Algora provides new data to understand, with greater precision, the faunal transition between the European vertebrate faunas of the Lower Cretaceous and those of the uppermost Cretaceous.

One of the lineages of turtles found in Algora corresponds to the group of Laurasian stem turtles Helochelydridae. Although the form represented there was attributed to *Helochelys danubina*, recent studies refuted that attribution, this turtle being identified, in a preliminary way, as aff. *Plastremys lata*. A new excavation in Algora, carried out in 2021, notably increased the number of remains of this lineage known for the fossiliferous locality. In addition, this campaign provided some hitherto unidentified regions of the shell, as well as elements of the girdles and of the appendicular skeleton previously not found. The new fossils that provide more information from a systematic point of view are presented here, so that the systematic position of the Helochelydrid represented in the Cenomanian palaeontological area of Algora is discussed based on the new evidence.

New fossil assemblage with crocodylomorphs and other vertebrates around the Jurassic-Cretaceous transition of the Cameros basin (Soria, Spain)

Puértolas-Pascual, E.[1,2], Canudo, J.I.[1], Aurell, M.[1], Galobart, A.[3,4], Moreno-Azanza, M.[1,2], Castanera, D.[1,3].

1: Grupo Aragosaurus-IUCA, Paleontologia, Facultad de Ciencias, Universidad de Zaragoza, C/Pedro Cerbuna, 12, 50009 Zaragoza, (Zaragoza, Spain). puertolas@unizar.es

2: GeoBioTec, Departamento de Ciências da Terra, FCT, Universidade Nova de Lisboa, 2829-516, Caparica, (Setúbal, Portugal)

3: Institut Català de Paleontologia Miquel Crusafont, C/ Escola Industrial 23, 08201 Sabadell, (Barcelona, Spain). dcastanera@hotmail.es

4: Museu de la Conca Dellà, C/ del Museu 4, 25650, Isona i Conca Dellà.

Keywords: Matute Alloformation, Tithonian-Berriasian, Mesozoic, Ágreda, Pterosauria, Testudines, Osteichthyes.

Introduction

The fossil osteological remains of vertebrates in the geological units that span around the Jurassic/Cretaceous (Tithonian-Berriasian) transition in the easternmost sector of the Cameros basin are very scarce. One of the units that has yielded a few fossil bones is the Matute Fm, with some notable taxa such as the semionotiform actinopterygian *Camerichthys lunae* Bermúdez-Rochas and Poyato-Ariza, 2015, or the freshwater aquatic Chelonia *Pleurosternon moncayensis* Pérez-García, Martín-Jiménez, Aurell, Canudo and Castanera, 2022. This contrasts with the large number of Berriasian tracksites (e.g. Huérteles Fm.) and the diverse ichnofauna present at several parts of the Cameros basin. These are dominated by dinosaurs, but also with presence of pterosaurs, crocodylomorphs and testudine tracks (e.g., Castanera et al., 2018). On the other hand, the osteological record found in the western Cameros basin is also more abundant (e.g., Torcida et al., 2020).

Crocodylomorph remains are scarce in the Tithonian-Berriasian units of the Iberian Basin rift system (e.g., Ortega et al., 1996). In this context, here we present the new paleontological site of Ribota, which contains one of the richest fossil vertebrate assemblages of the whole Cameros basin, and one of the few places in Europe with abundant vertebrate fossils found around the Tithonian-Berriasian transition.

Geographic and geological context

The Ribota site is located close to the locality of Ágreda (Soria province, north-central Spain), in the easternmost sector of the Cameros basin. This basin formed during the extensional tectonics during the Late Jurassic-Early Cretaceous rifting stage (see Aurell et al., 2021 and references therein). The site is located in the lower part of the lacustrine carbonates of the Matute Fm (upper part of the Tera Group). Although the precise age of this unit remains uncertain, its most probable age is late Tithonian-earliest Berriasian (see Pérez-García et al., 2022 and references therein). The Ribota site is included within a carbonate-dominated interval outcropping over a large area of almost 10 hectares, although other nearby areas where this unit outcrops also contain abundant vertebrate remains showing a similar fossil assemblage.

The bonebed has a complex taphonomic history. Preliminary analysis allows its characterization as a time-averaged multitaxic bonebed, formed by attritional accumulation of disarticulated or partially articulated skeletal remains in a context of sediment starvation in a lacustrine environment. The fossildiagenetic history of the site is unusual and interesting. In the field the fossils outcrop as positive reliefs protruding from the lacustrine limestone, being even harder than the rock and showing a very well-preserved external morphology. However, in fracture, the bone tissue is highly recrystallized barely retaining their internal structure, and being almost indistinguishable from the encasing rock. The presence of a very low degree of metamorphism in the area could explain this peculiar mode of fossil preservation. In the same strata there are abundant pyrite crystals (Fig. 1B), some of them centimetric. The presence of large pyrites in the eastern sector of the Cameros basin is well known, and their origin is attributed to deep burial and hydrothermal metamorphism (Azcárate et al., 1995). However, to understand the diagenetic processes that affected these fossils, further mineralogical and geochemical studies are necessary.

Vertebrate assemblage and crocodylomorph remains

Ribota is a mega site of several hectares so rich that bones are practically found in every m^2 of the outcrop. Nevertheless, it can be divided in three main areas with 36 small but very rich, fossiliferous concentrations. With the exception of some articulated partial skeletons of fishes and turtle shells, most of the remains appear scattered and disarticulated. Up to date, over 80 vertebrate fossils have been collected in the area.

In the outcrop, the most abundant remains correspond to isolated and disarticulated fish bones (Fig. 1A), but also some partial skeletons of indeterminate osteichthyans were collected (Fig. 1C). Other vertebrate remains include testudine plates and partial shells (Fig. 1D), and few isolated cranial and appendicular pterosaur bones (Fig. 1E). Interestingly, not a single dinosaur bone has been identified in the area so far.

The most abundant reptiles correspond to crocodylomorphs remains (Fig. 1F-N), that represent more than a half of the collected bones. Isolated amphicoelous vertebrae from the cervical (Fig. 1F), dorsal (Fig. 1H), sacral (Fig. 1G) and caudal (Fig. 1I) regions have been identified. The variety of sizes reveals the presence of small (Fig. 1H) to medium-sized specimens. Some of them were recovered in an area of less than 1 m^2 presenting similar sizes (Fig. 1N), so they could belong to the same individual. In addition, several equidimensional ventral osteoderms (Fig. 1J) with polygonal outlines (hexagonal), have also been recovered. Some dorsal osteoderms (Fig. 1K) twice as wide as they are long, with a smooth articular facet in the anterior margin, an anterolateral peg, and the lateral margin ventrally deflected, have also been identified. Among the cranial material, isolated conical teeth (Fig. 1L) with basiapical ridges are abundant. In addition, disarticulated cranial remains (Fig. 1M) that could correspond to fragments of a mandible, maxilla, or premaxilla have also been recovered. Given the paleogeographic/chronological context, the morphology of the vertebrae and teeth, and the characteristic shape of the osteoderms, most of these remains can be provisionally assigned to Goniopholididae indet. (Puértolas-Pascual and Mateus, 2020). However, until they are prepared, a more precise taxonomic assignment cannot be made.

Conclusions

Here we present the Ribota bonebed, probably the richest osteological multitaxic assemblage in units deposited around the Jurassic-Cretaceous boundary of the eastern Cameros basin. Osteichthyan fishes are the most abundant remains, but it is also worth noting the abundance of gonipholidid crocodylomorphs and the presence of testudines and pterosaurs. This locality adds new data to the scarce European vertebrate fossil assemblage of the Tithonian-Berriasian transition and helps fill the gap in the crocodylomorph fossil record between the Upper Jurassic of Portugal and the Lower Cretaceous of Spain. Further studies on this fossil site will help to have a more reliable snapshot of how the lacustrine ecosystems were during this time interval in this region.

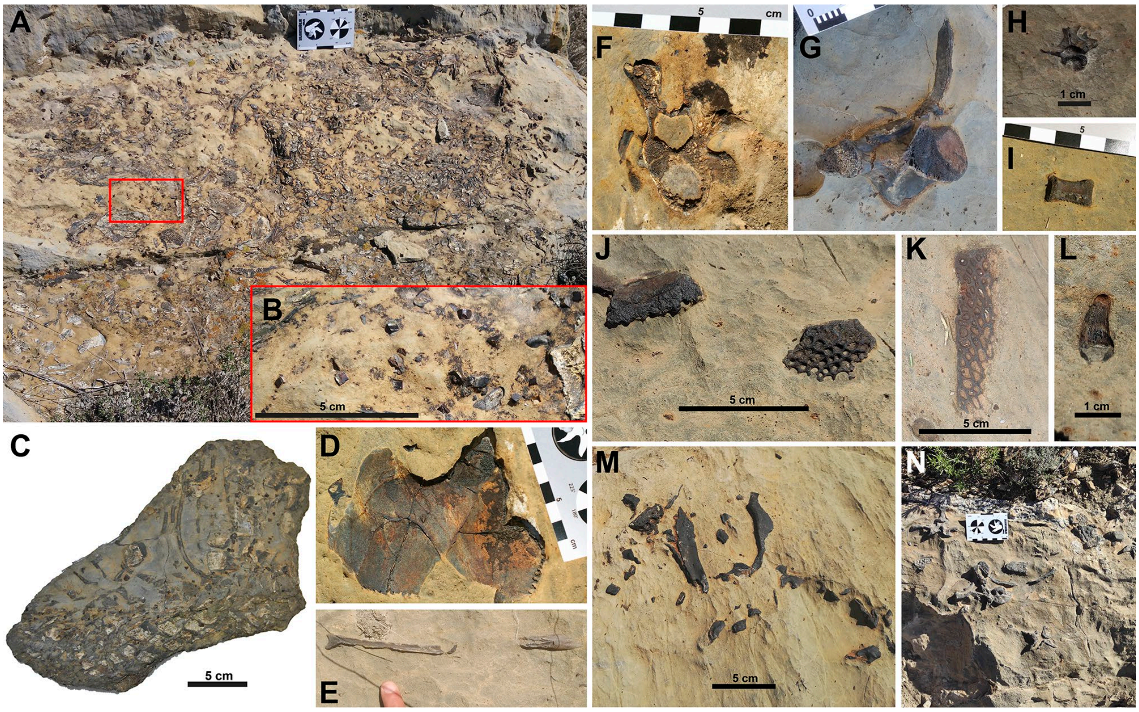

Figure 1. A. disarticulated fish bones; B. pyrite crystals; C. partial fish skeleton; D. partial shell of testudine; E. phalanx pterosaur; F-N. vertebrae (F-I, and N), osteoderms (J, K), tooth (L) and cranial fragments (M) of crocodylomorphs.

References

Alonso-Azcárate, J., Rodas, M., Mas, R., Velasco, F. (1995). Origen de las piritas de la cuenca de Cameros (La Rioja). *Geogaceta*, 18, 180-183.

Aurell, M., Bádenas, B., Castanera, D., Gasca, J. M., Canudo, J. I., Laita, E., Liesa, C. L. (2021). Latest Jurassic–Early Cretaceous synrift evolution of the Torrelapaja Subbasin (Cameros Basin): implications for Northeast Iberia palaeogeography. *Cretaceous Research*, 128, 104997.

Bermúdez-Rochas, D.D., Poyato-Ariza, F.J. (2015). A new semionotiform actinopterygian fish from the Mesozoic of Spain and its phylogenetic implications. *Journal of Systematic Palaeontology*, 13 (4), 265-285.

Castanera, D., Pascual, C., Canudo, J.I., Barco, J.L. (2018). Bringing together research, geoconservation and reaching a broad public in the form of a geotourism project: the Ichnite Route of Soria (Spain). *Geoheritage*, 10 (3), 393-403.

Ortega, F., García, J.J.M., Buscalioni, Á.D., García, J.L.S., Jiménez, S., Valbuena, J. (1996). Sobre la presencia de un cocodrilo fósil (Crocodylomorpha: Neosuchia: "*Goniopholis*" sp.) en la cuenca de Cameros (Cretácico inferior: Vadillos-San Román de Cameros, La Rioja). *Zubía*, (14), 113-120.

Pérez-García, A., Martín-Jiménez, M., Aurell, M., Canudo, J. I., Castanera, D. (2022). A new Iberian pleurosternid (Jurassic-Cretaceous transition, Spain) and first neuroanatomical study of this clade of stem turtles. *Historical Biology*, 34 (2), 298-311.

Puértolas-Pascual, E., Mateus, O. (2020). A three-dimensional skeleton of Goniopholididae from the Late Jurassic of Portugal: implications for the Crocodylomorpha bracing system. *Zoological Journal of the Linnean Society*, 189 (2), 521-548.

Torcida Fernández-Baldor, F., Canudo, J.I., Huerta, P. (2020). New data on sauropod palaeobiodiversity at the Jurassic-Cretaceous transition of Spain (Burgos). *Journal of Iberian Geology*, 46 (4), 351-362.

Palinología del Pliensbachiense superior-Toarciense inferior de la Formación Rodiles en los acantilados de Lastres (Asturias, España)

Rial, S.[1], Santos, A. A. [1,2], Rodríguez-Barreiro, I.[1,2], Piñuela, L.[3], García-Ramos, J. C.[3], Diez, J. B.[1,2]

1: Departamento de Geociencias Marinas, Universidad de Vigo, Campus As Lagoas-Marcosende, Vigo, España. samfernandez@alumnos.uvigo.es

2: Centro de Investigación Mariña, Universidade de Vigo (CIM-UVIGO), Vigo, España

3: MUJA, Museo del Jurásico de Asturias, Rasa de San Telmo, 33328 Colunga, Spain.

Keywords: Jurásico Inferior, Fm. Rodiles, paleopalinología, Evento Anóxico Oceánico, Pliensbachiense Superior, Toarciense Inferior.

Introducción

En el presente trabajo se estudió la palinología de diversos niveles del Pliensbachiense superior-Toarciense inferior de la sección expuesta en los acantilados al N de la playa de Lastres. Este intervalo se caracterizó por grandes cambios de temperatura a nivel global, así como por la presencia del Evento Anóxico Toarciense (T-OAE) (Gómez et al. 2016; Ruhl et al. 2016), que representa una de las mayores perturbaciones ambientales del Fanerozoico. Este evento global implicó un rápido incremento de las temperaturas del mar y anoxia generalizada causando extinciones marinas y una marcada estratificación oceánica (Correia et al. 2017). Dicho evento se caracteriza además por una disminución de los niveles de $\delta^{13}C$ registrados en materia orgánica marina, que fueron también identificados y localizados en diversas secciones de la costa asturiana (e.g., Gómez et al. 2016). A pesar de los grandes cambios producidos en el océano y en los organismos oceánicos durante el Pliensbachiense-Toarciense, poco se conoce todavía sobre los efectos de este evento en las floras terrestres.

Los principales objetivos de este estudio son: (1) Caracterizar las asociaciones palinológicas presentes en el Pliensbachiense superior-Toarciense inferior en la Fm. Rodiles; (2) Observar la respuesta y los cambios de diversidad y abundancia en los palinomorfos marinos y terrestres; (3) caracterizar el paleoambiente de las áreas emergidas que aportaron sedimentos a las series marinas de la Fm. Rodiles en los niveles estudiados; (4) Deducir cambios en las palinofloras terrestres en respuesta al T-OAE.

Contexto geográfico y geológico

Las muestras aquí estudiadas proceden de los acantilados costeros localizados al N de la playa de Lastres, constituidos por alternancias rítmicas de calizas y margas de la Fm. Rodiles (Mb. Santa Mera). La edad de esta Formación es Sinemuriense superior-Bajociense inferior (Valenzuela et al. 1986; Borrego et al. 1996), pero en esta sección estudiada únicamente se ha muestreado desde el Pliensbachiense superior (zonas Margaritatus y Spinatum) hasta el Toarciense inferior (zonas Tenuiscostatum y Serpentinum).

Material y Métodos

En la sección de la playa de Lastres se seleccionaron aquellos niveles con mayor contenido en materia orgánica, con facies adecuadas para realizar análisis palinológicos, y se recogieron 44 muestras palinológicas. Las muestras fueron procesadas mediante el tratamiento palinológico estándar HCl-HF-HCl descrito por Wood (1996) en la que los carbonatos y la sílice presentes en la matriz fueron eliminados mediante uso de HCl al 10% y HF al 40%. La extracción se realizó mediante diferencia de densidades con el uso de una centrifugadora.

Resultados y Discusión

En los 6 niveles productivos en palinomorfos se identificaron un total de 43 taxones. La preservación de las muestras del Mb. Santa Mera en general no fue buena, aunque suficiente para permitir la identificación de los taxones (ver Figura 1). En las muestras estudiadas se observa una predominancia de palinomorfos terrestres (oscilando entre el 80.2-94.6% dependiendo del nivel) frente a los marinos.

Aunque varios de los taxones encontrados presentan un rango estratigráfico amplio, algunos taxones permiten sugerir una edad más concreta, como son el caso de *Callialasporites turbatus*, *Klukisporites lacunus*, *Manumia variverrucata*, *Luehndea spinosa* y *Schistomeringos* cf. *expectatus*, que en conjunto sugieren una edad Pliensbachiense superior-Toarciense inferior coincidiendo con las dataciones previas realizadas con ammonoideos (Comas-Rengifo y Goy, 2010).

Los palinomorfos más abundantes en todos los niveles estudiados fueron los procedentes de gimnospermas (*Spheripollenites*). Esto nos sugiere que durante el Pliensbachiense superior-Toarciense inferior las comunidades vegetales de la zona emergida estaban dominadas por bosques de coníferas costeras con adaptaciones a climas secos. Las muestras de las zonas Margaritatus y Spinatum así como la zona Serpentinum presentan algunos taxones de coníferas oportunistas y pioneros como *Cerebropollenites macroverrucosus* (Abbink et al. 2004); esto también fue observado en otras asociaciones en las que su presencia/abundancia coincidió con la fase de recuperación tras eventos de calentamiento y extinción como fueron los eventos anóxicos del Pliensbachiense y del T-OAE (Slater et al. 2019). Tras el calentamiento del Pliensbachiense inferior se produce una etapa de enfriamiento marino que abarca desde el comienzo de la zona Margaritatushasta el T-OAE (Gómez et al. 2016). Por otro lado, *Araucariacites australis*, una especie asociada a climas fríos y secos (Abbink et al. 2004), no se vuelve abundante hasta el comienzo de la zona Spinatum bastante tiempo después de producirse el inicio de la etapa de enfriamiento y continúa su aparición hasta el comienzo de la zona Serpentinum. Esto sugiere que la respuesta de la vegetación terrestre tiene lugar a largo plazo, y no de forma instantánea. Una interpretación alternativa es que el enfriamiento durante la zona Spinatum es más intenso.

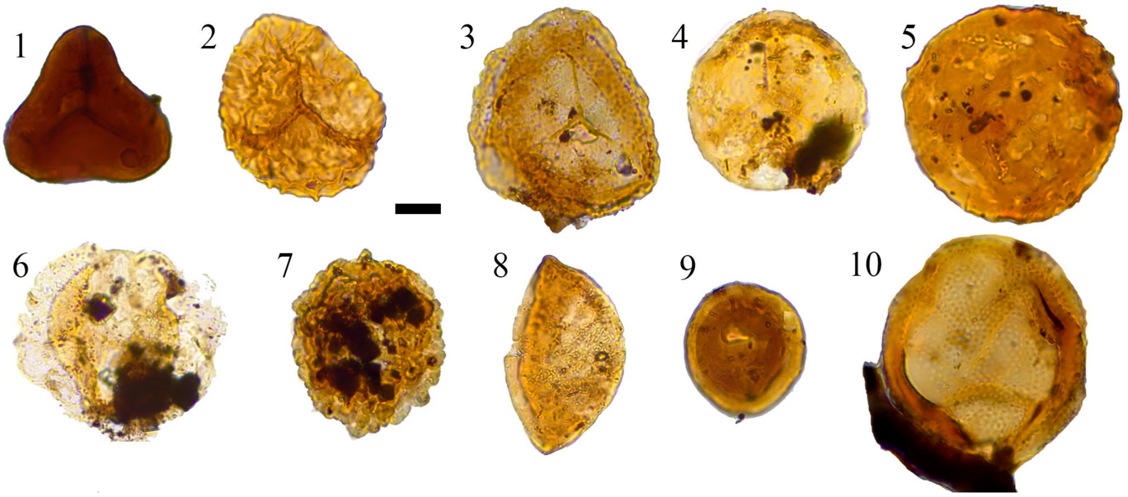

Figura 1: Escala: 10 µm. **1**. *Cibotiumspora jurienensis;***2**. *Camarozonosporites ramosus;***3.***Densoisporites* sp.; **4.***Klukisporites* cf. *variegatus;***5.***Todisporites major;***6.***Alisporites lowoodensis;***7.***Cerebropollenites macroverrucosus;***8.***Cycadopites follicularis;* **9.***Classopollis simplex;* **10.***Tasmanites* sp.

Referencias

Abbink, O.A., Van Konijnenburg-Van Cittert, J.H.A., Visscher, H. (2004): A sporomorph ecogroup model for the Northwest European Jurassic-Lower Cretaceous: concepts and framework. *Netherlands Journal of Geosciences*, (83,1), 17-31.

Borrego, A.G., Hagemann, H.W., Blanco, C.G., Valenzuela, M., De Centi, C.S. (1996): The Pliensbachian (Early Jurassic) "anoxic" event in Asturias, northern Spain: Santa Mera Member, Rodiles Formation. *Organic Geochemistry*, (25,5-7), 295-309.

Comas-Rengifo, M.J., Goy, A. (2010:. Caracterización biocronoestratigráfica del Sinemuriense Superior y el Pliensbachiense entre los afloramientos de la Playa Vega y lastres (Asturias). En: García-Ramos, J.C. (Coord.), Las sucesiones margo-calcáreas marinas del Jurásico Inferior y las series fluviales del Jurásico Superior. Acantilados de la playa de Vega (Ribadesella). Guía de la excursión A del V Congreso del Jurásico de España. Museo del Jurásico de Asturias, Colunga,10-18.

Correia, V.F., Riding, J.B., Fernandes, P., Duarte, L.V., Pereira, Z. (2017): The palynology of the lower and middle Toarcian (Lower Jurassic) in the northern Lusitanian Basin, western Portugal. *Review of Palaeobotany and Palynology* (237), 75-95.

Deconinck, J.-F., Gómez, J. J., Baudin, F., Biscay, H., Bruneau, L., Cocquerez, T., Mathieu, O., Pellenard, P., Santoni, A.-L. (2020): Diagenetic and environmental control of the clay mineralogy, organic matter and stable isotopes (C, O) of Jurassic (Pliensbachian-lowermost Toarcian) sediments of the Rodiles section (Asturian Basin, Northern Spain). *Marine and Petroleum Geology*, (115), 104286.

Deconinck, J.-F., Hesselbo, S.P., Pellenard, P. (2019): Climatic and sea-level control of Jurassic (Pliensbachian) clay mineral sedimentation in the Cardigan Bay Basin, Llanbedr (Mochras Farm) borehole, Wales. *Sedimentology*, (66), 2769-2783.

García-Ramos, J.C., Piñuela, L., Bádenas, B., Aurell, M. (2010): Ciclos elementales de escala milenaria en una ritmita de marga-caliza del Pliensbachiense de Asturias (Formación Rodiles). In Comunicaciones del V Congreso del Jurásico de España. Museo del Jurásico de Asturias (MUJA), Colunga, 8-11 de septiembre de 2010 (J.I. Ruiz-Omeñaca, L. Piñuela y J.C. García-Ramos, Eds.). Museo del Jurásico de Asturias, Colunga, 73 (Vol. 82).

Gómez, J.J., Comas-Rengifo, M.J., Goy, A. (2016). Palaeoclimatic oscillations in the Pliensbachian (Early Jurassic) of the Asturian Basin (Northern Spain), *Climate of the Past*, (12), 1199-1214.

Ruhl, M., Hesselbo, S. P., Hinnov, L., Jenkyns, H. C., Xu, W., Riding, J. B., ... & Leng, M. J. (2016): Astronomical constraints on the duration of the Early Jurassic Pliensbachian Stage and global climatic fluctuations. *Earth and Planetary Science Letters*, (455), 149-165.

Slater, S.M., Twitchett, R.J., Danise, S., Vajda, V. (2019): Substantial vegetation response to Early Jurassic global warming with impacts on oceanic anoxia. *Nature Geoscience*, 12(6), 462-467.

Valenzuela, M., García-Ramos, J.C., Suárez de Centi, C. (1986). The Jurassic sedimentation in Asturias (N Spain). *Trabajos de Geología*, (16,16), 121-132.

Wood, G. D. (1996): Palynological techniques-processing and microscopy. In. Jasonius, J. and McGregor, DC eds., Palynology: Principles and Application. *American Association of Stratigraphic Palynologists Foundatio*n, (1), 29-50.

Middle Jurassic to Late Cretaceous from the Las Loras Geopark (N Iberian Peninsula): An overview of the plant communities based on palynology

Rodríguez-Barreiro, I.[1,2], Santos, A. A.[1,2], Villanueva-Amadoz, U.[3], Diez, J. B.[1,2]

1: Centro de Investigación Mariña, Universidade de Vigo, BASAN, 36310, Vigo, Spain
ivan.rodriguez.barreiro@uvigo.es, asantos@uvigo.es, jbdiez@uvigo.es

2: Departamento de Xeociencias Mariñas e Ordenación do Territorio, Universidade de Vigo, 36310, Vigo, Spain

3: Estación Regional del Noroeste (ERNO), Instituto de Geología, UNAM, 83000, Hermosillo, México
uxue@geologia.unam.mx

Keywords: Mesozoic, Las Loras Geopark, Palynology, Paleoecology, Plant communities

Introduction

The paleobotanical studies comprising a wide age interval (>50 My) in the same area, provide an overview of the paleoecological evolution which presents rewarding information about the faunal/floral turnovers, as well as climate and environmental changes in the past. Unfortunately, there are few studies of this type, either because of the scarcity of continuous sedimentary series or the presence of paleobotanical remains in these deposits.

The Las Loras UNESCO Geopark has an almost complete record of sediments from the Late Triassic to the Paleogene with often exceptional outcrops (López-Olmedo et al., 1991) making it suitable for an extensive palynological study. Although, there are several paleontological works in this area, not many geological formations were correlated with biostratigraphy. Moreover, the paleobotanical studies were restricted to more specific short periods (Diéguez et al., 2009; Santos et al., 2022). Therefore, the scope of this work was to make a complete study of the Mesozoic paleopalynology from a paleoecological perspective but also with a palynostratigraphic component.

Geographical and geological context

The geopark is located at northern Spain, in the provinces of Burgos and Palencia. The Mesozoic deposits in this area belong to the Basque-Cantabrian Basin. Twelve different sites have been sampled, covering from the Bathonian-Callovian (Middle Jurassic) to the

Maastrichtian (Late Cretaceous). These sites correspond to the following geological sections: Porquera de los Infantes (Bathonian-Berriasian), Becerril del Carpio (Bathonian-Kimmeridgian), Villela (Bathonian-Tithonian), Renedo de Zalima (Kimmeridgian-Valanginian), Quintanilla de la Berzosa (Aptian-Albian), Valoria de Aguilar (Aptian-Albian), Olleros (Aptian-Cenomanian), Mundilla (Cenomanian-Turonian), and Castillo de Gama (Santonian-Maastrichtian).

Methodology

More than 80 palynological samples were collected from the Mesozoic deposits of the Las Loras Geopark. The standard palynological treatment of HCl-HF-HCl (Wood et al., 1996) was applied to the samples. A total of 46 samples were productive.

Results

The results were grouped in 12 different palynological assemblages. Porquera de los Infantes A: dominance of Cupressaceae and Araucariaceae pollen, marine influence, early Bathonian; Becerril del Carpio/Villela: dominance of marine palynomorphs, early Callovian; Porquera de los Infantes B/Renedo de Zalima: dominance of pteridophyte spores, no age assignment (late Kimmeridgian-Tithonian?); Quintanilla de la Berzosa/Valoria de Aguilar: dominance of pteridophyte spores, Aptian-Albian; Viejo Mojón (Olleros): dominance of pteridophyte spores, angiosperm pollen become significant, marine influence, middle-late Albian; Cañón de la Horadada: dominance of pteridophyte spores and *Patellasporites* fossil-genus, Normapolles become significant, marine influence, middle Cenomanian; Mundilla A: dominance of marine palynomorphs, middle Cenomanian; Mundilla B: dominance of pteridophyte spores, Taxodiaceae, and Normapolles pollen, marine influence, middle-late Cenomanian; Castillo de Gama: dominance of brackish algae, no age assignment (Maastrichtian?).

Discussion

Most of the palynological assemblages allowed to date these deposits with previously little or no biostratigraphic data. These datings (in some cases unexpected ages) provided a more concise stratigraphy in the studied area and allowed a more precise stratigraphic correlation.

The Middle Jurassic microflora (Porquera de los Infantes A, Becerril del Carpio and Villela) have a special relevance as the palynological assemblages with Bathonian-Callovian age are scarce in SW Europe. These aggregates showed a dominance of marine elements resulting from the prevailing marine conditions of the paleoenvironments along the Middle Jurassic in the Iberian Peninsula. The few continental elements showed a representation of coniferous coastal forests (Cupressaceae and Araucariaceae pollen).

On the other hand, the Late Jurassic assemblages (Porquera de los Infantes B and Renedo de Zalima) shifted to a strictly continental composition, where the pteridophyte spores were the dominants (Lycopodiaceae, Cyatheaeceae, and Dicksoniaceae). These samples are important for the contribution to the palynology of the Jurassic-Cretaceous boundary as they were collected from the lacustrine limestones of the Aguilar Fm. with a late Tithonian-Berriasian age, according to charophytes (Hernández et al., 1999). In the Iberian Peninsula, the microfloras close to the Jurassic-Cretaceous boundary are scarce (Trincão, 1990; Santos et al., 2018; Rodríguez-Barreiro et al., 2022).

In the Early Cretaceous microflora (Quintanilla de la Berzosa, Valoria de Aguilar, and Viejo Mojón) the pteridophytes were still dominant (in this case, Schizaeaceae and Cyatheaeceae spores). However, a diversification of angiosperm pollen during the middle-late Albian was observed in the Viejo Mojón assemblage (e.g., *Tricolpites*, *Asteropollis*, *Clavatipollenites*, *Rousea*, *Striatopollis*, *Stellatopollenites*…).

Eventually, the Late Cretaceous microflora (Cañón de la Horadada, Mundilla A, Mundilla B and Castillo de Gama) showed several major changes. First, during the middle Cenomanian, the earlier occurrences of Normapolles have been observed, as well as a shift to occasional marine dominance (Mundilla A). On the other hand, during the middle-late Cenomanian angiosperm dominance happens through the Normapolles group (Mundilla B). These levels could be related to the Plenus Cold Event phenomenon recorded during the early stages of the Cenomanian-Turonian Boundary Event (OAE2) where a peak in Normapolles have already been found (Heimhofer et al., 2018). In the case of the uppermost Cretaceous (Castillo de Gama), the assemblage was dominated by brackish algae, with the presence of marine and continental palynomorphs as well.

Conclusions

This palynological study involves a framework for reconstructing terrestrial paleoenvironments and paleoecology spanning about a hundred million years. Three major paleoecological changes were observed in this area: (1) a shift from a dominance of marine to terrestrial palynomorphs during the Callovian to the late Kimmeridgian interval, (2) diversification of angiosperm pollen during the middle-late Albian, (3) the first Normapolles occurrences in the middle Cenomanian (earliest Late Cretaceous), and (4) a dominance of brackish algae at the end of the latest Late Cretaceous (late Campanian-Maastrichtian?).

References

Diéguez, C., Hernández, J.M., Pujalte, V. (2009): A fern-bennettitalean floral assemblage in Tithonian-Berriasian travertine deposits (Aguilar Formation, Burgos-Palencia, N Spain) and its palaeoclimatic and vegetational implications. *Journal of Iberian Geology*, (35, 2), 127-140.

Heimhofer, U., Wucherpfennig, N., Adatte, T., Schouten, S., Schneebeli-Hermann, E., Gardin, S., Kujau, A. (2018): Vegetation response to exceptional global warmth during Oceanic Anoxic Event 2. *Nature Communications*, (9,1), 1-8.

Hernández, J.M., Pujalte, V., Robles, S., Martin-Closas, C. (1999): División estratigráfica genética del Grupo Campóo (Malm-Cretácico inferior, SW Cuenca Vascocantábrica). *Revista de la Sociedad Geológica de España*, (12), 377-396.

López-Olmedo, F., Enrile, A., Cabra, P. (1991): Memoria de la Hoja nº 133 (Prádanos de Ojeda). Mapa Geológico de España E. 1:50.000 (MAGNA), Segunda Serie, Primera edición. IGME, 162 pp.

Rodríguez-Barreiro, I., Santos, A.A., Arribas, M.E., Mas, R., Arribas, J., Villanueva-Amadoz, U., Torcida Fernández-Baldor, F. Diez, J.B. (2022): The Jurassic–Cretaceous transition in the West Cameros Basin (Tera Group, Burgos, Spain): Sedimentological and palynostratigraphical insights. *Cretaceous Research*, 105300.

Santos, A. A., Villanueva-Amadoz, U., Royo-Torres, R., Sender, L. M., Cobos, A., Alcala, L., Diez, J.B. (2018): Palaeobotanical records associated with the first dinosaur defined in Spain: Palynostratigraphy, taxonomy and palaeoenvironmental remarks. *Cretaceous Research*, (90), 318-334.

Santos, A.A., Nel, A., Rodríguez-Barreiro, I., Sender, L.M., Wappler, T., Diez, J.B. (2022): Insect and Plant Diversity in Hot-Spring Ecosystems during the Jurassic-Cretaceous Boundary from Spain (Aguilar Fm., Palencia). *Biology*, 11 (2), p. 273, 10.3390/biology11020273

Trincão, P.R. (1990): Esporos e granos de pólenes do Cretácico inferior (Berriasiano Aptiano) de Portugal: Palaeontología e Biostratigrafia. PhD, Universidade de Aveiro, 312 p.

Wood, G.D., Gabriel, A.M., Lawson, J.C. (1996): Palynological techniques-processing and microscopy. In: Jansonius, J., McGregor, D.C., (eds.), Palynology: Principles and Applications, vol. 1. American Association of Stratigraphic Palynologists, Dallas, TX, 29-50.

A tibia of *Iguanodon bernissartensis* with patological morphology from the Lower Cretaceous of Arcillas de Morella Formation (Castellón, Spain)

Salas-Herrera, J.[1], Escaso, F.[1], Gasulla, J.M.[1], Ortega, F.[1]

1: Grupo de Biología Evolutiva, Facultad de Ciencias, Universidad Nacional de Educación a Distancia (UNED), Avda. Esparta s/n, 28232 Las Rozas de Madrid. jsalas198@alumno.uned.es, fescaso@ccia.uned.es, jm.gasulla@gmail.com, fortega@ccia.uned.es

Keywords: Arcillas de Morella Formation, Lower Cretaceous, Styracosterna, paleopathology, tibia.

The vertebrate fossil record of the Barremian Arcillas de Morella Formation is one of the most abundant and diverse in the Iberian Peninsula, being remarkable and the most representative of this formation the Mas de la Parreta quarry (CMP), located at the southwest of the locality of Morella (Castellón province, Spain). Here the best represented, and by far the most abundant group of dinosaurs throughout the Iberian Lower Cretaceous,are styracosternan ornithopods. To date three styracosternan species have been identified: *Iguanodon bernissartensis, Mantellisaurus atherfieldensis* and *Morelladon beltrani* (Gasulla *et al.* 2015). Among the material identified as belonging to *Iguanodon bernissartensis*, CMP-11 is one of the sites inside the CMP in which fossil bones of this species have been discovered (Gasulla 2015). Among cranial and postcranial bones recovered from CMP-11 is interesting a right tibia with an anomalous posteromedial bone overgrowth located at mid-height of the tibial shaft.

Here a comparative anatomical study of this tibia was carried out to discriminate possible pathologies from myological characteristics, being that the anomalous overgrowth area does not correspond to the origin or insertion areas of the muscles described for the hindlimbs in styracosternans or hadrosaurids ornithopods (Norman, 1986; Dilkes, 1999; Dilkes *et al.* 2012). A differential diagnosis has been developed based on a macroscopic analysis. The presence of new bone growth in a tibial diaphysis may be considered as an involucrum (Ortner, 2003; Rotschild & Martin, 2006) and, tentatively, as a result of a pyogenic osteomyelitis, an infectious condition already observed in dinosaurs (Hunt *et al.* 2019; Aureliano *et al.* 2021).

References

Aureliano, T., Nascimento, C. S., Fernandes, M. A., Ricardi-Branco, F., Ghilardi, A. M. (2021): Blood parasites and acute osteomyelitis in a non-avian dinosaur (Sauropoda, Titanosauria) from the Upper Cretaceous Adamantina Formation, Bauru Basin, Southeast Brazil. *Cretaceous Research*, *118*, 104672. doi.org/10.1016/j.cretres.2020.104672.

Dilkes, D. W. (1999). Appendicular myology of the hadrosaurian dinosaur Maiasaura peeblesorum from the Late Cretaceous (Campanian) of Montana. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 90(2), 87-125.

Dilkes, D. W., Hutchinson, J. R., Holliday, C. M., Witmer, L. M., Brett-Surman, M. K., Holtz, T. R., Farlow, J. O. (2012): Reconstructing the musculature of dinosaurs. In: *The Complete Dinosaur.* Indiana University Press, Bloomington, IN, 151-190.

Gasulla, J.M. (2015): *Los dinosaurios de la Cantera del Mas de la Parreta, Morella (Formación Morella, Barremiense superior, Cretácico Inferior): Sistemática, análisis filogenético e implicaciones paleobiológicas*. Ph.D. Thesis, Universidad Autónoma de Madrid, Madrid, 306 p.

Gasulla, J.M., Escaso, F., Narváez, I., Ortega, F., Sanz, J.L. (2015): A New Sail-Backed Styracosternan (Dinosauria: Ornithopoda) from the Early Cretaceous of Morella, Spain. *PLoS ONE*, (10,12), e0144167.

Hunt, T. C., Peterson, J. E., Frederickson, J. A., Cohen, J. E., Berry, J. L. (2019): First documented pathologies in *Tenontosaurus tilletti* with comments on infection in non-avian dinosaurs. *Scientific Reports,* 9(1), 1-8.

Norman, D. B. (1986): On the anatomy of Iguanodon atherfieldensis (Ornithischia: Ornithopoda). *Bulletin-Institut royal des sciences naturelles de Belgique. Sciences de la terre*, *56*, 281-372.

Ortner, D. J. (2003): *Identification of pathological conditions in human skeletal remains*. Academic press, 645 p.

Rothschild, B. M., Martin, L. D. (2006): *Skeletal impact of disease.* New Mexico Museum of Natural History and Science (Vol. 33), 226 p.

Ecological constraints of the titanosaur nesting areas from the Upper Cretaceous of the Villalba de la Sierra Fm (Cuenca and Guadalajara, Central Spain)

Sanguino, F.[1], de Celis, A.[1], Gascó-Lluna, F.[1,2], Pérez-García, A.[1], Ortega, F.[1].

1: Grupo de Biología Evolutiva, Facultad de Ciencias, UNED, Avda. Esparta s/n, 28232. Las Rozas. Madrid. fernand1988sg@gmail.com; ane.detecla@gmail.com; francisco.gasco.com; a.perez.garcia@ccia.uned.es; fortega@ccia.uned.es

2: Facultad de Humanidades y Ciencias Sociales, Universidad Internacional Isabel I de Castilla, Burgos.

Keywords: Campanian, Maastrichtian, Megaloolithidae, Fusioolithidae, reproductive biology, Sauropoda.

The design of the amniote egg is a great example of an adaptative response to the environment, since the morphology of the egg and the functional properties of its eggshells regulate the interactions of the embryo with its surroundings. Depending on the productor taxa, these eggs are laid in a broad range of ecological conditions which may or may not be controlled by reproductive behavior, including nesting patterns and/or parental incubation strategies.

Recent works on extant birds (D'Alba *et al.* 2016; Duursma *et al.* 2018) and non-avian reptiles (D'Alba *et al.* 2021) have found that egg size and shape, and eggshell thickness and porosity have a complex relationship with several abiotic (mainly precipitation and substrate temperature) and biotic (mainly adult body size and nest type) selective pressures. Among the abiotic factors studied, these authors found that, in extant non-avian reptiles, eggshell thickness has a positive relationship with precipitation but not with ground temperature; which is instead negatively related to porosity (D'Alba *et al.* 2021). In addition, observations in extant avian species find that rounder eggs are more common than elongated ones in hot and dry environments, possibly due to higher heat capacity (Duursma *et al.* 2018).

Regarding biotic factors, the authors found that adult body size was also directly related with eggshell thickness and egg size and shape. Species with larger adults usually produce thicker eggshells and larger, rounder eggs, while elongation seems to be an adaptation for enabling larger eggs in smaller species (D'Alba *et al.* 2021). On the other hand, porosity is significantly associated with nest type: with elevations of temperature, eggs have higher porosity when laid in mounds or piles of decaying vegetation and lower porosity when laid in burrows, as differences in covering materials produce hot and humid or hot and dry microclimatic conditions, respectively (D'Alba *et al.* 2021). These relationships observed on extant species can be extrapolated to estimate the developmental conditions on extinct species and infer aspects of their reproductive biology.

Among dinosaurs, eggs from two oofamilies are currently believed to have been produced by titanosaurian sauropods: Megaloolithidae and Fusioolithidae. These oofamilies are known from the Upper Cretaceous record of South America, India and Europe. Global palaeoclimatic reconstructions of the Santonian and Maastrichtian (Chumakov *et al.* 1995) place occurrence of this eggs in arid climatic belts based on evidence from climate-sensitive sediments and fossils. The majority of the uppermost Cretaceous European terrestrial successions are composed of sandstones and conglomerates that are interbedded with floodplain deposits formed on seasonally variable semiarid climate (Csiki-Sava *et al.* 2015). The abundance of evaporites in several Iberian formations (Escavy *et al.* 2012), however, should be taken as evidence for a more arid environment (as discussed by Chumakov *et al.* 1995 for other locations). Within this broad arid climatic belt, titanosaurs seem to have selected specific spots as recurrent nesting areas. The differences on the ootaxa assemblages represented on these nesting areas could be related to age differences, biogeographical patterns, or may be reflecting differences in local and regional environmental conditions and in reproductive and nesting behavior among their productor taxa.

The Poyos locality (Campanian-Maastrichtian, Villalba de la Sierra Formation) from Sacedón (Guadalajara, Spain) represents one of these recurrent dinosaur nesting areas that has provided clutches with complete, large (>20 cm) subespherical eggs and abundant eggshells across several stratigraphic levels. Most eggshells from this site are very thin (~1 mm) and present extremely low porosity, while *Megaloolithus siruguei* eggshells recovered at Portilla site (Cuenca, Spain) from the same Formation (Moratalla 2008), are twice to thrice as thick (~2-3 mm) and present a considerably higher porosity. Although part of these differences may be related to constructional and mechanical resistance constraints; eggshells from Poyos still present a considerably lower porosity even when compared to fusioolithids and megaloolithids of similar egg size and eggshell thickness (i.e. *Fusioolithus baghensis*). These differences have been interpreted as the eggs from Poyos being adapted for developing in even dryer and hotter conditions than other titanosaur eggs (Sanguino *et al.* 2022).

On one hand, a common titanosaur nesting pattern have been interpreted as a relatively high number of large eggs laid in a comma-shaped groove that may be covered by sediments (Vila *et al.* 2010). The partial clutches recovered from Poyos are compatible with this pattern, and the taphonomical evidence suggest that the eggs might also have been buried (Sanguino *et al.* 2021). Thus, Poyos eggs might have been incubated in microclimatic conditions akin to those recorded on burrows from modern species, which is in agreement with the adequate incubation conditions inferred through the microstructure (Sanguino *et al.* 2022). Nevertheless, while no complete eggs or clutches have been found to date at Portilla, *M. siruguei* complete clutches have been reported from the Pinyes locality (Lleida) at Pyrenees, and are consistent with the same nesting pattern as Auca Mahuevo (Vila *et al.* 2010). Therefore, if the nesting behavior of the productor taxa were the same for both ootaxa, the differences on environmental conditions to which they were adapted might be related with other factors.

On the other hand, sedimentological and fossil evidence from the Villalba de la Sierra Fm. suggest that the Lo Hueco site, and consequently the Portilla site, would be close to the shoreline (Ortega *et al.* 2015) than the Poyos site, which would be located further inland and would be less exposed to moisture coming from the sea. Therefore, Poyos and other inland outcrops of the Villalba de la Sierra Formation would likely have overall dryer environmental conditions.

Lastly, although both sites are currently considered Campanian-Maastrichtian, their precise age has yet to be determined. A dinosaur faunal turnover has been discussed to have occurred during the Maastrichtian (Fondevilla *et al.* 2019)with evidence of a climate shift (Dinarès-Turell *et al.* 2013), and the relationship between the replacement of titanosaur taxa and ootaxa has already been discussed in similarly aged European formations (Vila *et al.* 2022). Depending on the relative stratigraphic position of Poyos and Portilla on the Villalba de la Sierra Formation, these sites could represent different stages of this climate shift and faunal turnover.

Acknowledgements

This research is supported by a FPI fellowship to FS related to the project PID2019-111488RB-I00 from the Ministerio de Ciencia e Innovación del Gobierno de España, and projects SBPLY/19/180801/000044 and SBPLY/21/180801/000045 from the Gobierno de la Junta de Comunidades de Castilla-La Mancha.

References

Chumakov, N.M., Zharkov, M.A., Herman, A.B., Doludenko, M.P., Kalandadze, N.N., Lebedev, E.L., Ponomarenko, A.G. & Rautian, A.S. 1995. Climatic belts of the mid-Cretaceous time. *Stratigraphy and Geological Correlation*, 3(3): 241-260.

Csiki-Sava, Z., Buffetaut, E., Ősi, A., Pereda-Suberbiola, X. & Brusatte, S.L. 2015. Island life in the Cretaceous - faunal composition, biogeography, evolution, and extinction of land-living vertebrates on the Late Cretaceous European archipelago. *ZooKeys*(469): 1-161.

D'Alba, L., Goldenberg, J., Nallapaneni, A., Parkinson, D., Zhu, C., Vanthournout, B. & Shawkey, M.D. 2021. Evolution of eggshell structure in relation to nesting ecology in non-avian reptiles. *Journal of Morphology*, n/a(n/a).

D'Alba, L., Maia, R., Hauber, M.E. & Shawkey, M.D. 2016. The evolution of eggshell cuticle in relation to nesting ecology. *Proceedings. Biological Sciences*, 283(1836): 20160687.

Dinarès-Turell, J., Pujalte, V., Stoykova, K. & Elorza, J.J.B.G.y.M. 2013. Detailed correlation and astronomical forcing within the Upper Maastrichtian succession in the Basque Basin, 124(2): 253-282.

Duursma, D.E., Gallagher, R.V., Price, J.J. & Griffith, S.C. 2018. Variation in avian egg shape and nest structure is explained by climatic conditions. *Scientific Reports*, 8(1): 4141.

Escavy, J.I., Herrero, M.J. & Arribas, M.E. 2012. Gypsum resources of Spain: Temporal and spatial distribution. *Ore Geology Reviews*, 49: 72-84.

Fondevilla, V., Riera, V., Vila, B., Sellés, A.G., Dinarès-Turell, J., Vicens, E., Gaete, R., Oms, O. & Galobart, À. 2019. Chronostratigraphic synthesis of the latest Cretaceous dinosaur turnover in south-western Europe. *Earth-Science Reviews*, 191: 168-189.

Moratalla, J.J. 2008. Portilla: a dinosaur nesting site from the Upper Cretaceous of the Cuenca province (Spain)*Society of Vertebrate Paleontology 68th annual meeting*, Cleveland.

Ortega, F., Bardet, N., Barroso-Barcenilla, F., Callapez, P.M., Cambra-Moo, Ó., Daviero-Gómez, V., Díez-Díaz, V., Domingo, L., Elvira, A., Escaso, F., García-Oliva, M., Gómez, B., Houssaye, A., Knoll, F., Marcos-Fernández, F., Martín, M., Mocho, P., Narváez, I., Pérez-García, A., Peyrot, D., Segura, M., Serrano, H., Torices, A., Vidal, D. & Sanz, J.L. 2015. The biota of the Upper Cretaceous site of Lo Hueco (Cuenca, Spain). *Journal of Iberian Geology*, 41(1): 83-99.

Sanguino, F., de Celis, A., Gascó-Lluna, F., Pérez-García, A. & Ortega, F. 2021. Evidence of hatching on dinosaur eggs from the Campanian-Maastrichtian of the Villalba de la Sierra Formation (Central Spain)*65th Annual Meeting of the Palaeontological Association*, Manchester, UK.

Sanguino, F., de Celis, A., Gascó-Lluna, F., Pérez-García, A. & Ortega, F. 2022. Eggshell structure provides a first insight into the nesting ecology of the dinosaur egg clutches from Poyos (Upper Cretaceous, Guadalajara, Spain). Pp. 76-77 in F. Sanguino, S. Ozkaya de Juanas, S. Romero, Á. Simarro and E. García-Zamora (eds) *20 años de encuentros. Libro de resúmenes del XX Encuentro de Jóvenes Investigadores en Paleontología en Cañaveral de León*, Cañaveral de León, Huelva.

Vila, B., Jackson, F.D., Fortuny, J., Sellés, A.G. & Galobart, À. 2010. 3-D Modelling of Megaloolithid Clutches: Insights about Nest Construction and Dinosaur Behaviour. *PLOS ONE*, 5(5): e10362.

Vila, B., Sellés, A., Moreno-Azanza, M., Razzolini, N.L., Gil-Delgado, A., Canudo, J.I. & Galobart, À. 2022. A titanosaurian sauropod with Gondwanan affinities in the latest Cretaceous of Europe. *Nature Ecology & Evolution*, 6(3): 288-296.

Palinología de la sucesión del Jurásico Superior en “La Costa de los Dinosaurios” (Asturias, España): Nuevos datos palinoestratigráficos y paleoambientales de la Formación Lastres

Santos, A.[1,2], Sender, L. M.[3], Piñuela, L.[4], García-Ramos, J. C.[4], Diez, J. B.[1,2]

1: Departamento de Geociencias Marinas, Universidad de Vigo, Campus As Lagoas-Marcosende, Vigo, España. artaisantos@gmail.com

2: Centro de Investigación Mariña, Universidade de Vigo (CIM-UVIGO), Vigo, España

3: Fundación Conjunto Paleontológico de Teruel-Dinópolis/Museo Aragonés de Paleontología. Avenida Sagunto s/n, 44002 Teruel, España.

4: MUJA, Museo del Jurásico de Asturias, Rasa de San Telmo, 33328 Colunga, Spain.

Keywords: Jurásico Superior, Formación Lastres, SEGs, Comunidades vegetales, palinología, palinoestratigrafía.

Introduction

“La Costa de los Dinosaurios” de Asturias es bien conocida por la cantidad y variedad de fósiles de estos reptiles y de otros vertebrados (Piñuela 2015) e invertebrados. Sin embargo, este conocimiento de la paleofauna de la Formación Lastres contrasta con el escaso conocimiento de las comunidades vegetales del entorno. Por esta razón era necesario realizar un estudio palinológico que permitiese conocer mejor la vegetación que modelaba el paisaje de la costa asturiana durante el Jurásico Superior.

Además de facilitar la reconstrucción del entorno vegetal en el que vivían los dinosaurios, la palinología también nos permite aportar nuevos datos estratigráficos para mejorar el conocimiento de la edad de la Formación Lastres, datada como Kimmeridgiense inferior en base a ammonoideos (Olóriz et al. 1988) y como Oxfordiense tardío-Titoniense temprano en base a ostrácodos (Schudack and Schudack, 2002). Por lo tanto, los principales objetivos de este trabajo son: (1) Caracterizar la asociación palinológica de las series de la Formación Lastres; (2) proporcionar nuevos datos bioestratigráficos para mejorar la resolución cronoestratigráfica de la formación; y (3) Reconstruir el paleoambiente y entorno vegetal a partir de las afinidades botánicas de los palinomorfos.

Material y Métodos

Se han muestreado 4 secciones diferentes de la Formación Lastres que contienen a menudo tanto restos directos como icnitas de dinosaurios y otros vertebrados. Las secciones estudiadas se localizan en los acantilados de Oles (Villaviciosa) y de Luces-Lastres (Colunga) habiéndose recogido un total de 16 muestras palinológicas.

Las muestras fueron tratadas utilizando técnicas estándar en palinología, incluyendo alternancia de tratamientos físicos y químicos (HCl-HF-HCl). Todas ellas fueron montadas y fijadas en láminas para ser estudiadas bajo microscopio óptico, y montadas en rosetas y cubiertas por oro posteriormente para complementar su determinación en el microscopio electrónico de barrido (SEM).

Resultados y Discusión

Las 16 muestras estudiadas fueron positivas en palinomorfos, mostrando una palinoflora relativamente rica y bien preservada. Se identificaron un total de 62 morfoespecies y 49 morfogéneros incluyendo polen, esporas, algas, hongos, dinoflagelados, foraminíferos y escolecodontos. De estos grupos, las esporas fueron el palinomorfo dominante en términos de abundancia y diversidad aunque el taxón más abundante fue *Spherinopollenites* (sobre el 20%), que es un morfogénero asociado a las coníferas.

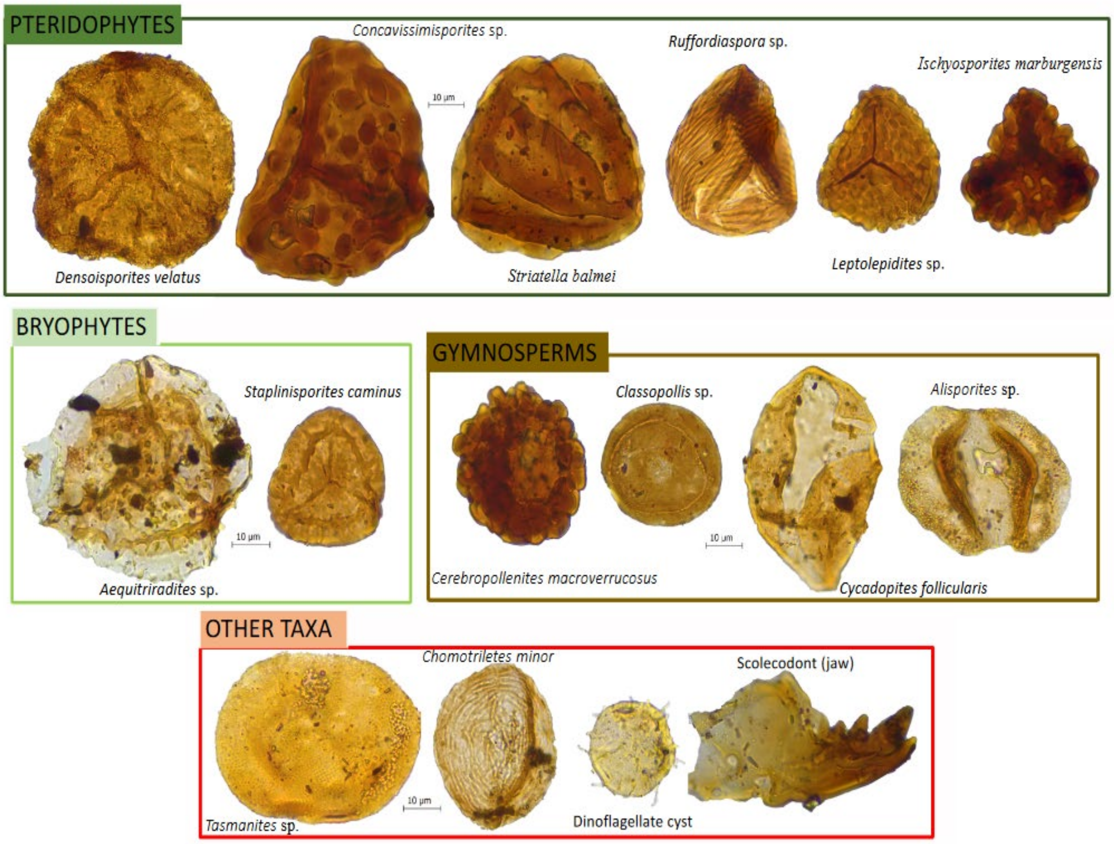

Figura 1*: Algunos de los palinomorfos más representativos de la Formación Lastres.*

Aunque la mayoría de los taxones encontrados en la Fm. Lastres presentan un rango estratigráfico que abarca todo el Jurásico, algunas especies muestran un rango más limitado. La presencia de *Cicatricosisporites* spp., *Aequitriradites spinulosus*, *Impardecispora apiverrucata* y *Pilosisporites trichopapillosus* sugiere una edad Kimmeridgiense-Titoniense.

Ambientalmente, la presencia de palinomorfos marinos, costeros y terrestres sugiere un ambiente de sedimentación de transición, con clara influencia marina (presencia de foraminíferos y dinoflagelados entre los palinomorfos), aunque también se han encontrado palinomorfos típicos de agua dulce. Las características de esta asociación son compatibles con un ambiente de sedimentación deltaica de dominio fluvial asociada a un lagoon (García-Ramos et al. 2011, 2021). Las afinidades botánicas y ambientales de los palinomorfos terrestres sugieren la presencia de diferentes comunidades vegetales en la zona, incluyendo comunidades de plantas en áreas húmedas como cauces fluviales o riberas de los mismos, así como otras relacionadas con pequeñas charcas de agua dulce, que estarían dominadas por briofitas y helechos. Por otro lado también se identifican comunidades vegetales costeras, probablemente de ambientes más secos y áridos, con predominio de gimnospermas y algunos grupos de helechos más resistentes, donde estas masas vegetales podrían representar una fuente de alimentación y protección para algunos de los dinosaurios herbívoros coetáneos.

Referencias

García-Ramos, J.C., Piñuela, L. y Rodríguez-Tovar, F.J. (2011): Post-workshop field trip guide of the XI International Ichnofabric Workshop, Museo del Jurásico de Asturias, Colunga, 89p.

García-Ramos, J.C., Piñuela Suárez, L., & González Fernández, B. (2021): La Vida en la Era Mesozoica. En: Gutiérrez Claverol, M. & Villa, E (eds), *El Patrimonio Geológico de Asturias*, 295-328.

Olóriz, F., Valenzuela, M., García-Ramos, J.C., & Suárez de Centi, C. (1988): The first record of the genus *Eurasenia* (Ammonitina) from the Upper Jurassic of Asturias (northern Spain). *Geobios*, *21*(6), 741-748.

Piñuela, L. (2015): *Huellas de dinosaurios y de otros reptiles del Jurásico Superior de Asturias*. Tesis Doctoral, Universidad de Oviedo, 326p.

Schudack, M. E., & Schudack, U. (2002): New biostratigraphical data for the Upper Jurassic of Asturias (northern Spain) based on Ostracoda. *Revista Española de Micropaleontología, 34(1)*, 1-18.

New insights on the theropod paleodiversity of the Upper Jurassic of the Cameros Basin (N. Spain)

Simarro, A.[1], Arias-Riesgo, C[1],Torcida Fernández-Baldor, F.[1,2]

[1]*Museo de Dinosaurios de Salas de los Infantes, Plaza Jesús Aparicio 9, 09600 Salas de los Infantes, Burgos, Spain. alvarosimarro94@gmail.com; arias.caterine@gmail.com.*

[2]*Colectivo Arqueológico-Paleontológico Salense (CAS), Plaza Jesús Aparicio 6, 09600 Salas de los Infantes, Burgos, Spain. fideltorcida@hotmail.com*

Keywords: theropod teeth, Upper Jurassic, Cameros Basin, diversity, paleobiogeography.

Isolated theropod teeth are an important evidence to know the diversity of this clade as well as its biogeographic and stratigraphic distribution (Gascó *et al.,* 2012, Young *et al*., 2018). However, very precise identification of isolated teeth at lower taxonomic levels is complex, especially for those morphotypes related to poorly represented groups. Also, few had been reported in the Upper Jurassic of the Cameros Basin thus far.

Here, a set of 25 isolated theropod teeth collected in Valdepalazuelos-Tenadas del Carrascal site from the Tithonian of the Cameros Basin are described and discussed, extending the previous work by Simarro *et al*. (2021). The Valdepalazuelos-Tenadas del Carrascal site is located near Torrelara, Burgos, in the Sierra de la Demanda (Rupelo Fm.; Tithonian-Berriasian). This formation is interpreted as shallow lacustrine / palustrine deposits with low-gradient margins and periodic changes in the water level (Torcida Fernández-Baldor *et al*. 2020).

These teeth were grouped into five distinct morphotypes based first on qualitative morphology and comparative anatomy following the established guidelines by Hendricks *et al*. (2019). Multivariate statistical analyses of quantitative measurements, such as Principal Component Analysis (PCA) and Discriminant Linear Analysis (DLA), as well as cladistic analyses, were performed in order to assign each morphotype to a certain taxon. The multivariate statistical analyzes performed provided results consistent with the systematic developed with classical parameters.

The current analyses assign some morphotypes to a piatnitzkysaurid possibly related to *Marshosaurus* Megalosauridae, basal Tyrannosauroidea (this could be the first record of this group in Spain) and Dromaeosauridae (Fig. 1). The results of our study confirm a high diversity of theropods in the Late Jurassic of the Sierra de la Demanda (Cameros Basin).

This analysis indicates a great similarity of the theropod faunas of the Gijón-Villaviciosa Basin, in Asturias (Spain) (Alonso, 2019), other European chronocorrelative localities such as those from the Lusitanian Basin (Portugal) (Zenke, 1998; Malafaia *et al.,* 2017b), France (Vullo *et al.,* 2014) and Germany (Gerke y Wings, 2016), and the North American Morrison Formation (Bakker, 1996), during the Upper Jurassic. This supports the Upper Jurassic dating for the Valdepalazuelos site. Furthermore, it implies the existence of terrestrial connections between these localities that would allow an exchange fauna.

References

Alonso, A. (2019): *Nuevas contribuciones a la paleodiversidad de dinosaurios terópodos del Jurásico y Cretácico de España a partir de dientes aislados.*Tesis doctoral. Universidad de Zaragoza, 335 pp.

Bakker, R. T. (1996): Dinosaur Feet in the Three Dimensions: Anatomy for Climbing, Digging, and Leaping. *The Paleontological Society Special Publications*, 8, 20-20.

Gascó, F., Cobos, A., Royo-Torres, R., Mampel, L. and Alcalá, L. (2012): Theropod teeth diversity from the Villar del Arzobispo Formation (Tithonian-Berriasian) at Riodeva (Teruel, Spain). *Palaeobiodiversity and Palaeoenvironments,* 92 (2): 273-285.

Gerke, O. and Wings, O. (2016): Multivariate and cladistic analyses of isolated teeth reveal sympatry of theropod dinosaurs in the Late Jurassic of Northern Germany. *PLoS ONE* ,11 (7): 1-52.

Hendrickx, C., Mateus, O., Araújo, R. and Choiniere, J. (2019): The distribution of dental features in non-avian theropod dinosaurs: Taxonomic potential, degree of homoplasy, and major evolutionary trends. *Palaeontologia Electronica*, 22.3.74 1–110.

Malafaia, E., Escaso, F., Mocho, P., Serrano-Martínez, A., Torices, A., Cachão, M. and Ortega, F. (2017b): Analysis of diversity, stratigraphic and geographical distribution of isolated theropod teeth from the Upper Jurassic of the Lusitanian Basin, Portugal. *Journal of Iberian Geology* ,43 (2): 257-291.

Simarro A., Riesgo-Arias C., Martínez-Pérez C., Fernández Torcida-Baldor F. (2021): Theropod paleodiversity of the Upper Jurassic of the Cameros Basin (N. Spain). *Abstract book of the annual conference of the European Association of Vertebrate Palaeontologists*, online 5th- 9th July 2021. *Paleovertebrata,* 44, 152.

Torcida Fernández-Baldor, F., Canudo, J. I., and Huerta, P. (2020): New data on sauropod palaeobiodiversity at the Jurassic-Cretaceous transition of Spain (Burgos). *Journal of Iberian Geology*, 46: 351–362.

Vullo, R., Abit, D., Ballèvre, M., Billon-Bruyat, J.-P., Bourgeais, R., Buffetaut, É., Daviero-Gomez, V., Garcia, G., Gomez, B., Mazin, J.-M., Morel, S., Néraudeau, D., Pouech, J., Rage, J.-C., Schnyder, J and Tong, H. (2014): Palaeontology of the Purbeck-type (Tithonian, Late Jurassic) bonebeds of Chassiron (Oléron Island, western France). *Comptes Rendus Palevol*, 13(5), 421–441.

Young, C. M. E., Hendrickx, C., Challands, T. J., Foffa, D., Ross, D. A., Butler, I. B. and Brusatte, S. L. (2018): New theropod dinosaur teeth from the middle jurassic of the isle of Skye, Scotland. Scottish Journal of Geology 55: 7–19.

Zinke, J. (1998): Small theropod teeth from the Upper Jurassic coal mine of Guimarota (Portugal). *Palaiontologische Zeitschrifl* ,72: 179-189.

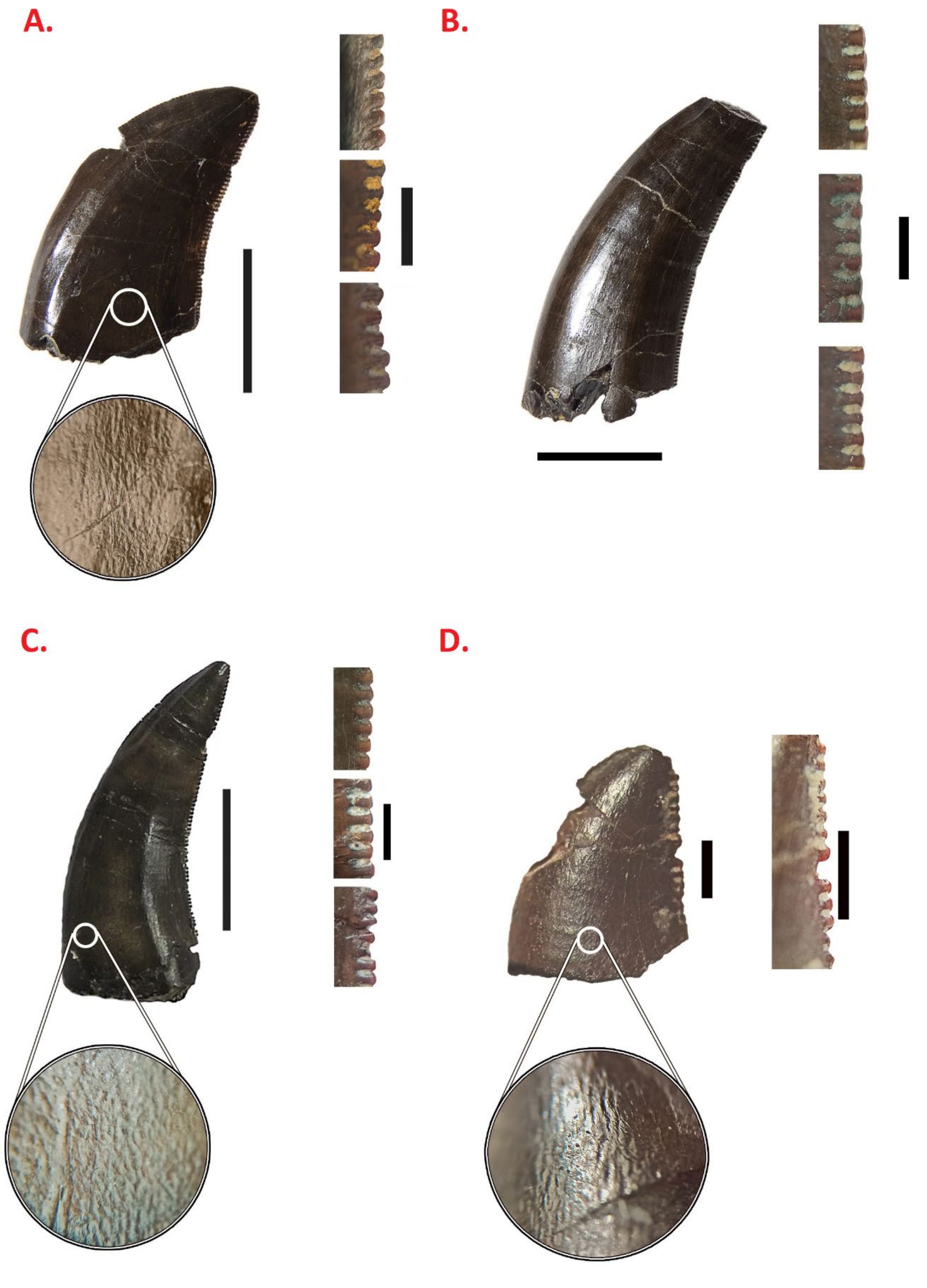

Figure 1.- Lingual views of the selected teeth representing the assigned taxa, with distal apical, mesial and basal denticules detail and texture. A) Piatnitkysaurid tooth. B) Megalosauridae tooth. C) Basal Tyrannosauridae tooh amd D) Dromaeosauridae tooth. Scales: 10 mm next to the crowns except D), and 1 mm for all denticules and D) crown.

El braquiosáurido de Los Ganchos (Jurásico Superior) de Alpuente (Valencia, España). Recuperación, estudio y divulgación

Suñer, M.[1], Royo-Torres, R.[2], Marin-Monfort, M. D.[3], Sánchez-Fenollosa, S.[1], Gamonal, A.[1], Galobart, A. [4,5], Santisteban, C. de [6]

1:, Museo Paleontológico de Alpuente. Av. San Blas, 17, 46178, Alpuente, Valencia, España.

2: Grupo Beagle-IUCA,, Departamento Didácticas Específicas, Facultad Ciencias Sociales y Humanas, Universidad de Zaragoza, C/ Atarazana,4, 44003 Teruel, Spain.

3:Departamento de Paleobiología, Museo Nacional de Ciencias Naturales-CSIC, C/ José Gutiérrez Abascal, 2, 28006 Madrid, España.

4: Institut Català de Paleontologia Miquel Crusafont, Universitat Autònoma de Barcelona, C/ Escola Industrial 23, 08201 Sabadell, Barcelona, España.

5: Museu de la Conca Dellà, C/ del Museu 4, 25650 Isona i Conca Dellà, Lleida, España

6: Departamento de Botánica y Geología. Universitat de València. Av. Dr. Moliner, 50, 46100 Burjassot, Valencia, España.

Palabras clave: Formación Villar del Arzobispo, comarca de Los Serranos, preparación fósil, Sauropoda, Titanosauriformes, Divulgación Científica.

Introducción

El yacimiento de “Los Ganchos”, situado en las proximidades de la aldea de Baldovar (municipio de Alpuente, Valencia, España), se localiza en la cuenca Íbero-Levantina o Sur-Ibérica dentro de la unidad Calizas, areniscas y arcillas de Villar del Arzobispo, de edad Kimmeridgiense-Tithoniense (Campos et al., 2019). Se compone de varios niveles fosilíferos, correspondientes al menos a dos secuencias deposicionales de carácter transgresivo – regresivo, como las descritas por Santisteban y Santos-Cubedo (2008) con materiales depositados en la zona de transición marino-continental. Esta localidad se descubrió en el año 2000, momento en el que se realizó una campaña de salvamento para recuperar los fósiles expuestos en superficie, llevándose a cabo posteriormente hasta cuatro actuaciones más. Las dos primeras intervenciones (2000 y 2001), centradas en el nivel inferior (constituido por areniscas blancas), dieron como resultado la recuperación del esqueleto parcial de un saurópodo, así como un diente de crocodiliformey restos de coníferas y pteridofitas indeterminadas. En las siguientes intervenciones (2002, 2003 y 2004), se excavó un nivel superior de areniscas grises del cual se extrajeron fósiles asignados de manera preliminar a Stegosauria indet. Recientemente, varios niveles lutíticos, por encima de los anteriores, han permitido un estudio paleobotánico más pormenorizado, constatando una gran abundancia y diversidad de pteridofitas, briofitas y hongos, y un paisaje dominado por coníferas (López-Fernández et al., 2021, y en este mismo volumen). Por último, mencionar que en un nivel superior de brecha poligénica se halló una pequeña vértebra de un posible ornitópodo.

Material estudiado

Este trabajo se centra en los fósiles asignados a un dinosaurio saurópodo extraídos del nivel más inferior del yacimiento. Los restos recuperados corresponden a varias costillas dorsales, elementos de la cintura escapular y extremidad anterior: placa esternal, coracoides, fragmentos de escápula, húmero, fragmentos proximal y distal de ulna, un carpal, 5 metacarpales, una falange ungueal y huesos de la cintura pélvica, con dos fragmentos de ilion y un isquion.

Preparación fósil

Una vez excavado el yacimiento y transportados los restos al laboratorio comenzaron los trabajos de preparación, realizados también en distintas fases en las instalaciones del Aula de Recuperación Paleontológica de Alpuente. En ellos se han seguido los criterios de reversibilidad y perdurabilidad, tratando a su vez de que la actuación fuera lo menos invasiva posible.Destacar del proceso de preparación la complejidad para trabajar algunas de las piezas, y mencionar el empleo de una técnica que se ha denominado “de volteo”. Ha sido empleada en piezas planas del yacimiento de Los Ganchos (concretamente, en elementos de la cintura escapular y pélvica), por ser extremadamente frágiles, estar muy fragmentadas (con fracturas ortogonales o en mosaico, derivadas de causas diagenéticas) y presentar una ligera separación y acumulación de sedimento entre los fragmentos.

El procedimiento comienza con una primera limpieza superficial del fósil, eliminando parcialmente el sedimento de manera mecánica o utilizando algún disolvente (acetona o alcohol etílico, según convenga). Se procede a consolidar en profundidad por goteo, y a retirar poco a poco el sedimento de entre las grietas. Conforme se va eliminado el sedimento, se va de nuevo consolidando, aplicando seguidamente resina adhesiva (con o sin carga de sílice micronizado) y, una vez pasado el tiempo de curado de esta, se incorpora la resina reintegrante. A continuación, se realiza una cama rígida provisional (confeccionada con escayola o con espuma de poliuretano), se voltea y se repite el proceso de eliminación de sedimento hasta alcanzar la resina aplicada por el otro lado. El empleo de esta técnica permite que cada fragmento se mantenga en su sitio y la pieza no quede deformada, evitando así posibles alteraciones derivadas de factores tréficos.

Estudio sistemático

Suñer et al. (2009) dan a conocer el yacimiento de Los Ganchos, constatando la presencia de un titanosauriforme indeterminado en la Formación Villar del Arzobispo de la

Cordillera Ibérica. Tras una revisión de este material y a partir de los fósiles preparados posteriormente, Suñer et al. (2018), en un trabajo sobre la diversidad de saurópodos en esta región, indican que el material de Los Ganchos presenta algunos caracteres diagnósticos de Titanosauriformes (presencia de cavidades neumáticas en el extremo proximal de la costilla dorsal estudiada, la costilla dorsal en forma de tablón, el cóndilo distal del metacarpal I sin dividir y con la superficie articular distal reducida), así como caracteres de braquiosaúridos (metacarpales largos y con una morfología esbelta) y una falange ungueal en el primer dedo reducida (menor del 30% la longitud del metacarpal I, tal como ocurre en *Giraffatitan brancai*; Mannion et al., 2017). Por la presencia de los caracteres señalados, el material aquí presentado se asigna a Brachiosauridae indet. El registro de Titanosauriformes del Jurásico Superior de la Península Ibérica, y más concretamente de braquiosáuridos, está representado de manera clara por *Lusotitan atalaiensis,* deLourinhã, en Portugal, y recientemente Pueyo et al. (2019) restablecen G*alvesaurus herreroi*de Galve (Teruel) como taxón hermano del anterior. Otro material que ha sido asignado a Titanosauriformes, aunque fragmentario, serían: varios dientes de la comarca de Los Serranos (Sanz, 1985, Casanovas-Cladellas et al., 1993, Pueyo et al., 2019 y referencias), un fémur de la localidad de Tera, en Soria (Canudo et al., 2010), así como un fragmento proximal de ulna y una costilla dorsal de distintas localidades de Alpuente (Suñer et al., 2018).

Un dinosaurio con vocación de enseñar y ser enseñado

El saurópodo de Los Ganchos se encuentra actualmente en las instalaciones del Aula de Recuperación Paleontológica de Alpuente, donde permanece parcialmente expuesto. Desde la apertura de sus puertas en 2001, el Aula de Recuperación Paleontológica, situada en una de las antiguas escuelas, ha sido un espacio emblemático dentro del Proyecto Paleontológico de Alpuente. Allí pueden observarse losfósiles de dinosaurios en preparación y algunas de las herramientas y técnicas que se utilizan durante los trabajos de laboratorio e investigación paleontológica. Cuenta con unos paneles explicativos, un área de almacén y un espacio destinado a actividades didácticas. Los huesos fósiles del saurópodo de Los Ganchos, de grandes dimensiones y tan característicos, han sido parte del disfrute de turistas que se han acercado hasta Alpuente. Es de resaltar que, además del aprovechamiento desde un punto de vista turístico, el municipio cuenta con un programa didáctico (Suñer et al., en prensa) y por este espacio han pasado también multitud de estudiantes de distintas etapas educativas. En este sentido, se realizan actividades con alumnado de Educación Infantil y Primaria, institutos y también con universitarios formándose en el área de Paleontología, para los cuales los restos fósiles de este saurópodo ha servido de ejemplo y de muestra para conocer mejor algunas de las técnicas de trabajo en el campo o en el laboratorio, así como para asentar conceptos de anatomía o aprender sobre algunos procesos tafonómicos.

*Agradecimientos***.** A la familia Martínez Monzón, a Chelo Villar, Héctor Herrero y familia, José Vicente Debón y demás vecinos y compañeros geólogos o paleontólogos, su colaboración en los trabajos de campo y preparación. Estos han sido realizados con el apoyo de la Universitat de València, la Conselleria de Cultura, Educación y Deporte, la Diputación de Valencia, el Ayuntamiento de Alpuente, el Institut Català de Paleontologia y la Fundación Conjunto Paleontológico de Teruel-Dinópolis en el marco de los proyectos BTE2001-0185-C02-02, CGL2005-07878-C02-01/02/BTE, CGL2008-06533-C03-01/03/BTE, PGC2018-094034-B-C22 del Ministerio de Ciencia y Tecnología.

Referencias

Canudo, J.I., Barco, J.L., Castanera, D., Torcida Fernández-Baldor, F. (2010): New record of a sauropod in the Jurassic–Cretaceous transition of the Iberian Peninsula (Spain): palaeobiogeographical implications. *Paläontologische Zeitschrift*, 84(3), 427-435.

Campos-Soto, S., Benito, M.I., Cobos, A., Caus, E., Quijada, E., Suarez-Gonzalez, P., Mas, R., Royo-Torres, R., Alcalá, L. (2019): Revisiting the age and palaeoenvironments of the Upper Jurassic–Lower Cretaceous? dinosaur-bearing sedimentary record of Eastern Spain: Implications for Iberian palaeogeography. *Journal of Iberian Geolog*y (45), 471–510.

Casanovas-Cladellas, M.L., Santafé-Llopis, J.V., Santisteban-Bove, C. (1993): First dinosaur teeth from the Lower Cretaceous of Benicatazara (Aras de Alpuente, Valencia). *Revue de Paléobiologie*, (7), 37–44.

López-Fernández, P., Santos A.A., Diez, J.B., Suñer, M. (2021): Palynology from different dinosaur-bearing beds in Alpuente area (Villar del Arzobispo Fm, Valencia, Spain). In: *3rd Palaeontological Virtual Congress*, *"Palaeontology in the Virtual Era"* (Vlachos et al., Eds.), Book of Abstracts, p. 80.

Mannion, P., Allain, R., Moine, O. (2017). The earliest known titanosauriform sauropod dinosaur and the evolution of Brachiosauridae. *PeerJ*, (5), e3217.

Pérez-Pueyo, M., Moreno-Azanza, M, Barco, J.L., Canudo, J.I. (2019): New contributions to the phylogenetic position of the sauropod *Galvesaurus herreroi* from the late Kimmeridgian-early Tithonian (Jurassic) of Teruel (Spain). *Boletín Geológico y Minero,* (130, 3), 375–392.

Santisteban, C. de y Santos-Cubedo, A. (2008). El entorno geológico de los yacimientos con dinosaurios del Jurásico Superior y Cretácico Inferior del Levante-II.In: Poza, B. Galobart, A., Suñer, M., Nieto, E. (coords.) *Dinosaurios del Levante Peninsular*. EDC Natura, Fundación Omacha, 22–37.

Sanz, J.L. 1985. Nouveaux gisements de dinosaures dans le Crétacé espagnol. In: *Les Dinosaures de la Chine a la France*, Museum d'histoire naturelle de Toulouse, 81–88 .

Suñer, M., de Santisteban, C. and Galobart, À. (2009). Direct evidence of Titanosauriformes found in an UpperJurassic site of Alpuente (Los Serranos, Valencia, Spain). In: *Abstracts 10th International Meeting of Mesozoic Terrestrial Ecosystems and Biota*, Teruel (Buscalioni, A.D., Fregenal, M.F., Eds.). UA Ediciones, Madrid, p. 139.

Suñer, M., Royo-Torres, R. and Gamonal,A. (2018). Sauropod diversity from the Villar del Arzobispo Formation (Kimmeridgian-Early Berrasian) of Los Serranos regios (Valencia Province, Spain). In: *1st Palaeontological Virtual Congress, "Palaeontology in the Virtual Era"*(Crespo, V.D. et al., Eds.), Book of Abstracts. Universitat de València, Museo de Alpuente & Museu Valencià d'Historia Natural, p. 156.

Suñer, M., Sepúlveda, A., Poza, B. (en prensa). Actividades y recursos didácticos sobre dinosaurios: el proyecto paleontológico de Alpuente (Valencia). *Enseñanza de las Ciencias de la Tierra*, Monográfico "Dinosaurios".

New teeth of a basal Macronaria (Sauropoda) from the Jurassic-Cretaceous transition of Spain

Torcida Fernández-Baldor, F.[1], Huerta, P.[1,2], Puértolas-Pascual, E.[3], Canudo, J. I.[3]

1:Museo de Dinosaurios de Salas de los Infantes and Colectivo Arqueológico-Paleontológico Salense (CAS), Plaza Jesús Aparicio 9, 09600 Salas de los Infantes, Burgos, Spain. fideltorcida@hotmail.com

2: Departamento de Geología, Escuela Politécnica Superior de Ávila, Universidad de Salamanca, Salamanca, Spain. phuerta@usal.es

3:Aragosaurus-IUCA, Paleontología, Facultad de Ciencias, Universidad de Zaragoza, 50009 Zaragoza, Spain. jicanudo@unizar.es; puertolas@unizar.es

Keywords: Dinosauria, Sauropoda, Cameros Basin, Rupelo Fm., Tithonian, Burgos

Introduction

The Valdepalazuelos-Tenadas del Carrascal (Burgos, Spain) is a rich vertebrate fossil site, especially in sauropod dinosaur remains. More than a hundred disarticulated fossils have been recovered during the 2018-2021 excavation campaigns, which are pending preparation and study. So far, only one isolated sauropod humerus, provisionally assigned to a brachiosaurid titanosauriform close to *Duriatitan*, has been published (Torcida Fernández-Baldor et al., 2020). The aim of this paper is to describe the sauropod teeth and cranial material founded in the Valdezpalazuelos site and to relate it to other remains of sauropods found at this site.

Geographical and Geological setting

The Valdepalazuelos site is located close to the village of Torrelara, in Burgos (North of Spain). Geologically, it is in the western part of the Cameros Basin, and is stratigraphically located in the lower part of the Rupelo Formation. Recently, the upper part of the Rupelo Fm.has been assigned to the Berriasian (Maset al., 2019), but the Valdepalazuelos site, which is located at thebase of Rupelo Fm. in Torrelara, is considered by the sameauthors as Tithonian (Boleras Fm.) (Sacristán-Horcajadaet al., 2015).

The site of Valdepalazuelos is constituted by a 2 m-thick grey marl bed that contains numerous vertebrate bones. Calcite nodules are widespread in the bed and some contain bone fragments in their cores. The bones are covered by a millimetric grey micrite crust, and charcoal and leaf fragments are common. The site is interpreted as a ponded area located within the alluvial-calcrete fringe transition. The sediment recorded anoxic conditions, as is evidenced by the charcoal and carbonized leaf fragments (Torcida Fernández-Baldor et al., 2020).

Systematic Paleontology

The studied teeth are deposited in the Museo de Salas de los Infantes (MDS) labeled as: MDS-VPCR, 349, MDS-VPCR, 416 and MDS-VPCR, 560 are almost complete teeth; MDS-VPCR, 606 is a dental crown apicobasally sectioned with pronounced wear due to use; MDS-VPCR, 476 and MDS-VPCR, 648 are teeth fragments; and MDS-VPCR, 851 is a dentary fragment.

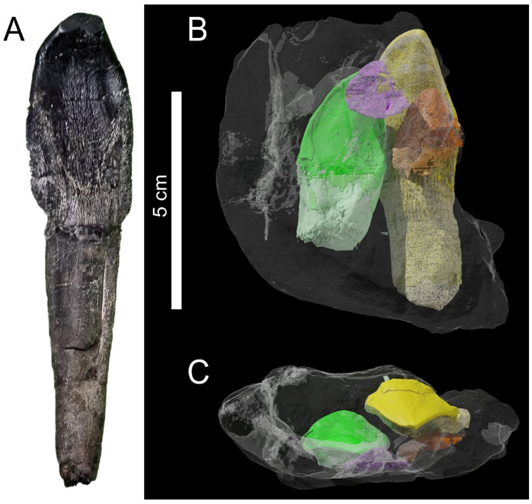

Figure 1. A. Tooth MDS-VPCR,560 in lingual view. B-C. CT scan 3D reconstruction of the right dentary fragment MDS-VPCR, 851 in lingual (A) and dorsal (B) views; two well-formed teeth (green and yellow) and another two in formation (purple and orange) can be seen.

The teeth are spatulate, with wrinkled enamel and a D-shaped section. The mesial and distal edges are parallel up to two-thirds of the crown, gently curving toward the apex at the mesial edge, and somewhat concave at the distal. The convergence of the edges of the crown in the apical zone forms an apex that has a slight deviation towards the distal margin. The labial face has a very marked convexity in the mesiodistal direction, with a well-developed bulb apicobasally. This bulb is bordered on its flanks by two wide and shallow grooves, more pronounced at its base, that run through the entire crown from the base to the apex. The bulb develops towards the apex of the crown. The contact between the crown and the root develops an apically curved contour. The tooth enamel is incised by V-shaped wear facets. The teeth have an SI (Slenderness Index) value that ranges between 1.9 and 2, with the exception of 2.8 in MDS-VPCR, 349, which is the smallest tooth.

MDS-VPCR, 851 is a fragment of the anterior symphyseal area of a right dentary. Two replacement teeth in each of the two preserved alveoli have been identified. The newest and less developed replacement tooth begins to be formed and is located within the lingual wall of the alveolus. Considering the lost functional tooth (whose root seems to be partially preserved in one of the alveoli), it gives a total of three teeth per dental alveolus. Of these teeth, the most developed shows a great morphological similarity with MDS-VPCR, 416 and MDS-VPCR, 560.

Discussion and conclusions

The size and morphology of the teeth from Valdepalazuelos are consistent with their assignment to the same taxon, and even to the same individual. The morphological differences between teeth can be attributed to small heterodont variations of the jaw dentition. The heart-shaped teeth of Turiasauria (Royo-Torres et al., 2006) and the pencil-shaped teeth of Diplodocoidea (Mocho et al., 2017) are very different from the spatulate teeth of Valdepalazuelos. The spatulate morphology is present in euhelopids, camarasaurids and mamenchisaurids. However, euhelopids show lingual bosses (Canudo et al., 2002) that are not present in the studied teeth, and mamenchisaurids have not been recorded in Europe. In the Upper Jurassic of the Lusitanian basin (Portugal) there are several isolated spatulate teeth that have been related with basal macronarians such as camarasaurids (Mocho et al., 2017).

The dental replacement pattern of MDS-VPCR, 851 and the morphology of the studied teeth bear strong similarities to those of *Camarasaurus* from the Late Jurassic of North America. These are the presence of two replacement teeth (up to three in *Camarasaurus*); spoon-shaped teeth, with lack of denticles on the mesial and distal edges of the crown, relatively poorly developed lingual ridge (Wiersma and Sander, 2016), lingual facets bordered by pronounced ridges, and SI between 1.57 and 2.47 (Chure et al., 2010). In addition, the robustness of MDS-VPCR, 851 is similar to the robust dentary of *Camarasaurus* s.l. (McIntosh et al., 1996; Wiersma and Sander, 2016).

Abundant and disarticulated sauropod postcranial material has been recovered at Valdepalazuelos site. In a first morphological and size approximation, these fossils are consistent with a single sauropod taxon. However, the presence of several repeated anatomical elements indicates that more than one individual is represented. An isolated humerus has been tentatively assigned to a basal Titanosauriformes that is morphologically close to *Duriatitan* (Torcida Fernández-Baldor et al., 2020). However, the studied teeth seem to be from a more primitive taxon, such as a basal Macronaria. Since the phylogenetic history of the most primitive Macronaria is poorly known, beyond the well-known *Camarasaurus*, if the humerus and teeth belong to the same taxon still cannot be ruled out. Therefore, the Macronaria fossils from the Valdepalazuelos-Tenadas del Carrascal site are a good opportunity to help clarify the phylogeny of these sauropods.

References

Canudo J.I., Ruiz-Omeñaca J.I., Barco J.L., Royo-Torres R. (2002): ¿Saurópodos asiáticos en el Barremiense Inferior (Cretácico Inferior) de España? *Ameghiniana*, (39, 4), 443-452.

Chure, D., Britt, B.B., Whitlock, J.A., Wilson, J.A. (2010): First complete sauropod dinosaur skull from the Cretaceous of the Americas and the evolution of sauropod dentition. *Naturwissenschaften*, (97, 4), 379-391.

Mas, R., Arribas, M.E., Gonzalez–Acebron, L., Quijada, I.M., Campos–Soto, S., Suarez–Gonzalez, P., Sacristan–Horcajada, S., Arribas, J., Benito, M.I., Perez–Garrido, C., Alonso, A. (2019): Coastal wetlands as markers of transgression in proximal extensional systems (Berriasian, W Cameros Basin, Spain). *Journal of Iberian Geology*, (45), 1-27.

McIntosh, J.S., Miles, C.A., Cloward, K.C., Parker, J.R. (1996): A nearly complete skeleton of *Camarasaurus*. *Bulletin of Gunma Museum of Natural History*, (1), 1-187.

Mocho, P., Royo-Torres, R., Malafaia, E., Escaso, F., Ortega, F. (2017): Sauropod tooth morphotypes from the Upper Jurassic of the Lusitanian Basin (Portugal). *Papers in Palaeontology*, (3, 2), 259-295.

Royo-Torres, R., Cobos, A., Alcalá, L. (2006): A giant European dinosaur and a new sauropod clade. *Science*, (314, 22), 1925-1927.

Sacristán-Horcajada, S., Mas, R., Arribas, M.E. (2015): Early Syn-Rift Evolution in the West Cameros Basin (Upper Jurassic, NW Iberian Range), Spain. *Journal of Sedimentary Research*, (85, 7), 794-819.

Torcida Fernández-Baldor, F., Canudo, J.I., Huerta, P. (2020): New data on sauropod palaeobiodiversity at the Jurassic-Cretaceous transition of Spain (Burgos). *Journal of Iberian Geology*, (46), 351-362.

Wiersma, K., Sander, P.M. (2016): The dentition of a well-preserved specimen of *Camarasaurus* sp.: implications for function, tooth replacement, soft part reconstruction, and food intake. *Paläontologische Zeitschrift*, (91), 145-161.

A new possible Diplodocoidea from the Berriasian of Spain

Torcida Fernández-Baldor, F.[1, 2], Barriuso Caraballo, A.[3], Canudo, J. I.[4], Huerta, P.[2, 5]
Gasca, J. M.[5]

1: Museo de Dinosaurios de Salas de los Infantes; 09600 Salas de los Infantes (Burgos), Spain. fideltorcida@hotmail.com

2: Colectivo Arqueológico y Paleontológico de Salas; 09600 Salas de los Infantes (Burgos), Spain

3: Universidad de Salamanca, Salamanca, Spain abarrc07@estudiantes.unileon.es

4: Aragosaurus-IUCA, Paleontología, Facultad de Ciencias, Universidad de Zaragoza, 50009 Zaragoza, Spain. jicanudo@unizar.esjicanudo@unizar.es

5: Departamento de Geología, Universidad de Salamanca, 37008, Salamanca, Spain. phuerta@usal.es; gasca@usal.es

Keywords: Sauropoda, Cameros Basin, Nuestra Señora de los Brezales Fm, Burgos, Early Cretaceous

Introduction

The uppermost Jurassic-lowermost Cretaceous sauropod record from the Iberian Peninsula shows an unusual biodiversity and abundance of sauropods. Between the Kimmeridgian and the Berriasian, several taxa have been recognized in the Iberian Peninsula belonging to different clades of sauropods (Royo-Torres et al., 2009; Mocho et al., 2017; Torcida Fernández-Baldor et al., 2020). Most of the reported taxa are neosauropods, whereas non-neosauropods are grouped in Turiasaria. Whitin the neosauropods, macronarians are the most common, including brachiosaurids and other basal macronarians. In contrast, the members of Macronaria Diplodocoidea are scarce and poorly know. The best remain is a cervical-dorsal vertebrae firstly described with the name *Dinheirosaurus* from the Kimmeridgian of Portugal (Bonaparte & Mateus, 1999), and recently related with *Supersaurus* (Tschopp et al., 2015). In Spain, around the Jurassic-Cretaceous transition fragmentary remains attributed to derived Diplodocimorpha have been described in Teruel, in some cases related to Diplodocidae (Royo-Torres & Cobos, 2004), included an enigmatic pencil-like teeth (Cuenca-Bescós et al., 1997).

Tenada Tizuela is a vertebrate fossil site where isolated remains of Stegosauria indet. has been described (Pereda Suberbiola et al., 2003). Moreover, isolated remains of Sauropoda have been found. The aim of this work is to describe a metatarsal V of an indeterminate sauropod of the Tenada Tizuela site and discuss its systematic position.

Geographical and Geological setting

The Tenada Tizuela site is located at the southwest of the village of Aldea del Pinar (Burgos province, Spain). The fossiliferous level is poorly exposed, and the outcrop is covered by a cereal field and the vertebrate remains appear scattered on the terrain surface.

Geologically, it is located in the western part of the Cameros Basin, within the Nuestra Señora de los Brezales Formation. Some stratigraphically close grey limestone and marlstone beds of the same unit have been sampled for its geological and palaeontological characterization. The screen-washed samples of marlstones show detrital content, quartz and limestone grains well rounded and poor fossil content. Despite the poor bioclast content some vertebrate, invertebrate (mollusk shell fragments) and charophyte remains have been found. Vertebrate remains consist of indetermined bone fragments and scarce eggshell fragments (Megaloolithidae), and crocodylomorph remains (osteoderms and teeth of cf. *Bernissartia* sp.).

The limestone bed has wackestone texture and a fossil content consisting of charophytes, bivalves and ostracods. Charophyte remains are gyrogonites identified as *Porochara kimmeridgensis kimmeridgensis.* Ostracods are scarce, but have been assigned to *Theriosynoecum fittoni.*According the scarce available biostratigraphic data and the regional stratigraphy of the Western Cameros basin, the Tenada Tizuela site most probable age is early Berriasian considering the occurrence of the charophyte *P. kimmeridgensis kimmeridgensis* and the ostracod *T. fittoni.*

Systematic Palaeontology

The studied material is deposited in the Museo de Salas de los Infantes (MD) and labelled as MDS-TZA, 6. MDS-TZA, 6 is an almost complete right metatarsal V. Its proximodistal length is 261 mm. It is a robust metatarsal, with an IR (Robustness index) value of 1.24 *(sensu* Royo-Torres 2005). The general shape of MDS-TZA, 6 in lateral view is T-shaped, compressed lateromedially, with the proximal end very expanded and the distal end little. The expansion of the distal end (210 mm) is almost double that of the distal end (107 mm). The proximal and distal ends show asymmetry, with the dorsoplantar axis inclined, so that bone is oriented proximally towards the plantar side and distally towards the dorsal side. In lateral view, the proximal border is curved, with the exception of the medial corner, which is distinctly straight. The shaft is relatively long and straight. It has a small lateral ridge at the distal end, selvage *sensu* Cooper (1984).

Discussion and conclusions

MDS-TZA, 6 shows a general funnel shape typical of sauropods. The asymmetry of the proximal end of metatarsus V is the primitive stage present in non-neosauropods eusauropods, with the exception of Turiasauria, which would possibly represents a convergence. The proximally symmetric metatarsus V would be a character of Macronaria (see references in Royo-Torres, 2005). In diplodocoid neosauropods such as *Barosaurus* or Dicraeosauridae it is asymmetric, and the primitive condition could be maintained. The presence of selvage is a character present in primitive eusauropods, but it has also been cited in some diplodocoids such as *Barosaurus*. However, in macronarians such as *Camarasaurus* and *Tastavinsaurus* it is absent. Royo-Torres (2005) points out that it would be an autapomorphy of Macronaria, therefore MDS-TZA, 6, following this author, could not be included in this clade.

The greatest morphological similarity of MDS-TZA,6 is with some diplodocoids, such as *Barosaurus* from the Tithonian of USA and dicraeosaurids such as *Dicraeosaurus sattleri* from the Kimmeridgian-Tithonian of Tanzania and *Dicraeosaurus hansemanni* from the Oxfordian-Kimmeridgian of Tanzania (Janensch, 1961; McIntosh, 2005). They share similar robustness values, asymmetry at the proximal end, proximal end with a widening that is double the distal end, small distal widening of the diaphysis and presence of selvage. Dicraeosaurids have not been cited in the Iberian Peninsula, and the presence of diplodocids is documented with little diagnostic material. The Diplodocoidea is a poorly known group in the Iberian Peninsula with the exception of the rebbachisaurid *Demandasaurus* from the Barremian-Aptian of Burgos (Torcida Fernández-Baldor et al., 2011). The morphology of MDS-TZA,6 is consistent with a diplodocoid, thus demonstrating the presence of representatives of this clade in the Berriasian of the Iberian Peninsula. Future excavation work at the site that increases the available material will allow us to better determine the position of the sauropod of Tenada Tizuela within Diplodocoidea.

References

Bonaparte, J.F., Mateus, O. (1999): A new diplodocid, *Dinheirosaurus lourinhanensis* gen. et sp. nov., from the Late Jurassic beds of Portugal. *Revista del Museo Argentino de Ciencias Naturales*, (5, 2), 13-29.

Cooper, M.R. (1984): A Reassessment of *Vulcanodon karibaensis* Raath (Dinosauria: Saurischia) and the origin of the Sauropoda. *Palaeontologia Africana*, (25), 203-231.

Cuenca Bescós, G., Canudo, J.I., Ruiz-Omeñaca, J.I. (1997): Dinosaurios del tránsito Jurásico-Cretácico en Aragón. In: *V Jornadas Aragonesas de Paleontología "Vida y ambientes del Jurásico"* (Gámez Vintaned, J.A., Liñán, E., Eds.), 193-221.

Janensch, W. (1961): DieGliedmaszen und Gliendmaszengürtel der Saoropoden del Tendaguruschichten. *Palaeontographica*, Suppl. (7, 2), 178-233.

McIntosh, J. S. (2005): The genus *Barosaurus* Marsh (Sauropoda, Diplodocidae). In: Tidwell, V., Carpenter, K., (eds). *Thunder-lizards: The Sauropod Dinosaurs*. Indiana University Press, Bloomington, 38-77.

Mocho, P., Royo-Torres, R., Malafaia, E., Escaso, F., Ortega, F. (2017): Sauropod tooth morphotypes from the Upper Jurassic of the Lusitanian Basin (Portugal). *Papers in Palaeontology*, (3, 2), 259-295.

Pereda-Suberbiola, X., Galton, P., Torcida, F., Huerta, P., Izquierdo, L.A., Montero, D., Pérez, G., Urién, V. (2003): First stegosaurian dinosaur remains from the Early Cretaceous of Burgos (Spain), with a review of Cretaceous stegosaurs. *Revista Española de Paleontología,* (18, 2), 143-150.

Royo-Torres, R. (2009): El saurópodo de Peñarroya de Tastavins. *Monografías turolenses*, (6), 1-544.

Royo-Torres, R., Cobos, R. (2004): Estudio sistemático de un ilion de Sauropoda del yacimiento Pino de Jarque 2 en Riodeva (Teruel). *Geo-Temas*, (6, 5), 59-62.

Royo-Torres, R., Cobos, A., Luque, L., Aberasturi, A., Espílez, E., Fierro, I., González, A., Mampel, L., Alcalá, L. (2009): High european sauropod dinosaur diversity during Jurassic-Cretaceous transition in Riodeva (Teruel, Spain). *Palaeontology*, (5, 2), 1009-1027.

Torcida Fernández-Baldor, F., Canudo, J.I., Huerta, P., Montero, D., Pereda-Suberbiola, X. Salgado, L. (2011): *Demandasaurus darwini*, a new rebbachisaurid sauropod from the Early Cretaceous of the Iberian Peninsula. *Acta Paleontologica Polonica*, (56, 3), 535-552

Torcida Fernández-Baldor, F., Canudo, J.I., Huerta, P. (2020): New data on sauropod palaeobiodiversity at the Jurassic-Cretaceous transition of Spain (Burgos). *Journal of Iberian Geology*, (46), 351-362.

Tschopp, E., Mateus, O., Benson, R. B. J. (2015): A specimen-level phylogenetic analysis and taxonomic revision of Diplodocidae (Dinosauria, Sauropoda). *PeerJ*, (3)**,** e857.

Titanosaurian (Dinosauria: Sauropoda) dental material from the Els Nerets locality (Upper Cretaceous, Southern Pyrenees)

Vázquez, B. J.[1], Vila, B*.[1,2], Castanera, D.[1]

*1: Institut Català de Paleontologia Miquel Crusafont, Universitat Autònoma de Barcelona, Carrer Escola Industrial 23, 08201 Sabadell (Barcelona), Catalonia, Spain. * bernat95@hotmail.es*

2: Museu de la Conca Dellà, Carrer del Museu, 4, Isona (Lleida), Catalonia, Spain.

Keywords: Cretaceous, Tremp Fm., Sauropoda, Titanosaurs, Dentition

The historical lower Maastrichtian (70-71Ma) locality of Els Nerets (Spain, Southern Pyrenees) has recently yielded the largest sample of titanosaurian teeth from the Ibero-armorican domain. For the first time, twenty pieces are described in detail, leading to the establishment of four different dental morphotypes, roughly corresponding with the anterior-to-distal sections of the toothrow.

The teeth have been compared to the known Ibero-armorican titanosaurs (*Ampelosaurus atacis*, Le Loeuff, 1995; *Atsinganosaurus velauciensis*, Díez Díaz et al., 2018; *Lirainosaurus astibiae*, Sanz et al. 1999; *Lohuecotitan pandafilandi,* Díez Díaz et al., 2016; and the Massecaps titanosaur, Díez Díaz et al., 2013). Despite numerous morphological similarities with some of them (especially Morphotype A from Lo Hueco and the Massecaps titanosaur), the teeth from Els Nerets are seen to be morphologically distinct enough to belong to a new species. The teeth are larger than most of the other Ibero-armorican taxa and, at the same time, one of the slendermost teeth from Ibero-armorica. They are the most labiolingually compressed among those of the Ibero-armorican titanosaurs, the cusps tilt with a lower angle than the other species, and the enamel ornamentation is different to that of most of other French and Spanish taxa. To further highlight these differences, the specimens' dimensions have been plotted in a bivariate (CI vs SI) dispersion analysis (DA) based on the work of Holwerda et al. (2018). The specimens with complete crowns also present a specific pattern of enamel wrinkling at the base of the crown regardless of their arrangement in the dental series. Since a similar general pattern is present in other biogeographically close taxa, further detailed comparisons between the enamel wrinkling of known Ibero-Armorican taxa are required.Tooth wear has also been characterized for the Els Nerets sample. Thus, the teeth show Type B wear (Wiersma and Sander, 2017; Saegusa and Tomida, 2011) and, more specifically, almost all the studied teeth present Type 3 abrasion.

References

Díez Díaz, V., Tortosa, T., Le Loeuff, J. (2013): Sauropod diversity in the Late Cretaceous of southwestern Europe: The lessons of odontology. Ann. Paleontol. 99, 2, 119–129. https://doi.org/10.1016/j.annpal.2012.12.002

Díez Díaz, V., Mocho, P., Páramo, A., Escaso, F., Marcos-Fernández, F., Sanz, J.L., Ortega, F. (2016): A new titanosaur (Dinosauria, Sauropoda) from the Upper Cretaceous of Lo Hueco (Cuenca, Spain). Cretac. Res. 68, 49–60. https://doi.org/10.1016/j.cretres.2016.08.001

Díez Díaz, V., Garcia, G., Pereda-Suberbiola, X., Jentgen-Ceschino, B., Stein, K., Godefroit, P., Valentin, X. (2018): The titanosaurian dinosaur *Atsinganosaurus velauciensis* (Sauropoda) from the Upper Cretaceous of southern France: New material, phylogenetic affinities, and palaeobiogeographical implications. Cretac. Res. 91, 429–456. https://doi.org/10.1016/j.cretres.2018.06.015

Holwerda, F.M., Díaz, V.D., Blanco, A., Montie, R., Reumer, J.W.F. (2018): Late Cretaceous sauropod tooth morphotypes may provide supporting evidence for faunal connections between North Africa and Southern Europe. PeerJ 2018. https://doi.org/10.7717/peerj.5925

Le Loeuff, J. (1995): Ampelosaurus atacis (nov.gen., nov. sp.), un nouveau Titanosauridae (Dinosauria, Sauropoda) du Crétacé supérieur de la Haute Vallée de l'Aude (France). C.R.A ad. Sci. Paris 321, 693–699.

Saegusa, H., Tomida, Y. 2011): Titanosauriform teeth from the Cretaceous of Japan. An. Acad. Bras. Cienc. 83, 1, 247–265. https://doi.org/10.1590/S0001-37652011000100014

Sanz, J.L.; Powell J.E., Le Loeuff, J., Martínez, R. and Pereda Suberbiola, X., (1999): Sauropod remains from the Upper Cretaceous of Laño (Northcentral Spain). Titanosaur phylogenetic relationships. Estudios del Museo de Ciencias Naturales de Álava 14 (Número Especial 1): 235–255.

Wiersma, K., Sander, P.M. (2017): The dentition of a well-preserved specimen of *Camarasaurus* sp.: implications for function, tooth replacement, soft part reconstruction, and food intake. Palaontologische Zeitschrift 91, 1, 145–161. https://doi.org/10.1007/s12542-016-0332-6

The dominion of large-bodied titanosaurs at the run-up to the end-Cretaceous extinction in SW Europe

Vila, B.[1,2], Sellés, A.[1,2], Vidigal, M.[3]

1: Institut Català de Paleontologia Miquel Crusafont, Universitat Autònoma de Barcelona, Carrer Escola Industrial 23, 08201 Sabadell (Barcelona), Catalonia, Spain. bernat.vila@icp.cat (ORCID ID: 0000-0002-5935-1732); albert.selles@icp.cat (ORCID ID: 0000-0002-4637-6084)

2: Museu de la Conca Dellà, Carrer del Museu, 4, Isona (Lleida), Catalonia, Spain.

3: martavidigalp@gmail.com

Keywords: Late Cretaceous, Titanosauria, body mass, insularity, migration

At the very end of the Cretaceous, Europe consisted of an extensive archipelago in which the main landmass was the Ibero-Armorican Island. There, the evolution of dinosaur communities features a replacement of fauna that started in the early Maastrichtian and ended in the early late Maastrichtian (a span of 2.5–2.8 million of years), generally characterized by a shift from a sauropod-dominated to a hadrosauroid-dominated faunal assemblages (Le Loeuff et al., 1994; Vila et al., 2016; Fondevilla et al., 2019). For the pre-turnover (late Campanian–early Maastrichtian) titanosaurian assemblage, the most prominent feature was undoubtedly their small size relative to their contemporary relatives out of the European archipelago. Body mass estimates for the small-to-moderate-sized species of *Lirainosaurus*, *Garrigatitan*, *Atsinganosaurus*, *Ampelosaurus*, and *Lohuecotitan* range from 1,000-5,000 Kg. On contrast, post-turnover titanosaurians tend to be three to four times larger than preceding species, as evidenced by the recently described *Abditosaurus,* which has an estimated body mass of 14,000 Kg. Further, it is regarded as a member of an immigrant lineage, unequivocally distinct from some of the island dwarfs of the European archipelago (Vila et al., 2022).

The present work reports the remains of two new large-bodied titanosaurian taxa from the Southern Pyrenees. The first taxon is from Les Gavarres locality (early Maastrichtian, Tremp basin) and consists of appendicular (forelimb) and cervical material, which body mass is estimated at 21,000 Kg. This makes the 'Les Gavarres taxon' the largest titanosaurian ever reported in the Upper Cretaceous of Europe. The second taxon was collected at the Peguera-1 locality (early Maastrichtian, Vallcebre syncline) and consists of appendicular, girdle, and axial elements. Its estimated body mass range is 13,000-

19,000 Kg. A morphological comparison was made with the known Ibero-Armorican species, indicating that the two new taxa might represent new titanosaurian species, pending definitive description. In addition, other large-bodied titanosaurians are known from the region, such as the 'Serraduy taxon' (Canudo, 2011), with an estimated body mass of 17,000 Kg. The three large-bodied titanosaurs, together with *Abditosaurus*, provide new evidence to support the hypothesis of the arrival of large-bodied immigrant titanosaurs to the European archipelago during the early Maastrichtian (70.6 Ma), probably as a result of a global and regional sea-level drop that reactivated ancient dispersal routes between Europe and other continents (Vila et al., 2002). The irruption of such large-bodied titanosaurs in the European insular ecosystems could have caused dramatic changes in dinosaur community dynamics, especially with respect to the 'island rule' effect and ecological stress (Sellés et al., 2017).

References

Canudo, J. I. (2001): Descripción de un fragmento proximal de fémur de Titanosauridae (Dinosauria, Sauropoda) del Maastrichtiense superior de Serraduy (Huesca). In: *XVII Jornadas de la Sociedad Española de Paleontología* (Meléndez, G. et al., Eds.). Sociedad Española de Paleontología y Área y Museo de Paleontología de la Universidad de Zaragoza, 255–262.

Fondevilla, V., Riera, V., Vila, B., Sellés, A.G., Dinarès-Turell, J., Vicens, E., Gaete, R., Oms, O., Galobart, À. (2019): Chronostratigraphic synthesis of the latest Cretaceous dinosaur turnover in south-western Europe. *Earth Science Review*, (191), 168–189.

Le Loeuff, J., Buffetaut, E., Martin, M. (1994): The last stages of dinosaur faunal history in Europe: a succession of Maastrichtian dinosaur assemblages from the Corbières (southern France). *Geological Magazine,* (131), 625–630.

Sellés, A.G., Vila, B., Galobart, À. (2017). Evidence of reproductive stress in titanosaurian sauropods triggered by an increase in ecological competition. *Scientific Reports*, (7), 13827.

Vila, B., Sellés, A.G., Brusatte, S.L. (2016): Diversity and faunal changes in the latest Cretaceous dinosaur communities of southwestern Europe. *Cretaceous Research*, (57), 552–564.

Vila, B., Sellés, A., Moreno-Azanza, M., Razzolini, N.L., Gil-Delgado, A., Canudo, J.I., Galobart, À. (2022): A titanosaurian sauropod with Gondwanan affinities in the latest Cretaceous of Europe. *Nature Ecology & Evolution*, (6), 288–296.