Preliminary results on the stratigraphy and taphonomy of multiple bonebeds in the Triassic of Algarve

Hugo Campos[1,2*], Octávio Mateus[1,2], Miguel Moreno-Azanza[1,2]

[1] Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, 2829-516, Caparica, Portugal; email: hugomcfields@gmail.com;

[2] GEAL-Museu da Lourinhã, Rua João Luís de Moura, 2530-157, Lourinhã, Portugal

Keywords: *Penina, Late Triassic, temnospondyl, cyamodontoid.*

The Triassic is a period in time where many successful tetrapod groups originated and diversified, such as dinosaurs, pterosaurs, ichthyosaurs, mammals, lepidosaurs, turtles, crocodilians and lissamphibians, and whose end was marked by a major extinction event. Understanding Late Triassic ecosystems and its evolution over time is of great interest, not only because it can give us good insight into many tetrapod groups' origins and diversification, but also because it can help us to better understand the Triassic-Jurassic extinction event and the impact it had on Earth's ecosystems. There are few places in the world where there is a high-resolution stratigraphic framework containing well-preserved Late Triassic vertebrate fossils and geological climate proxies. This result in poor understanding about the scale of the impact the end-Triassic extinction event had on the ecosystems, as well as the initial radiation of many vertebrate groups. In this regard, the Triassic-Jurassic sediments in Algarve Basin have great potential to reveal more about the paleoenvironmental and faunal changes that occurred during the Late Triassic to Early Jurassic interval, presenting an extensive and widely exposed stratigraphic sequence (the 'Grés de Silves' Group), and bearing well-preserved vertebrate fossils (Brusatte *et al.,* 2015). Still, the Algarve has mostly been neglected by vertebrate paleontologists, with few discoveries being made prior to the finding of one very rich temnospondyl-containing bonebed in 2009 in Penina (Brusatte *et al.*, 2015).

In 2016, a new expedition to the site where this bonebed was discovered was made, in order to better understand the stratigraphical framework in which the temnospondyl bonebed was inserted. Four new stratigraphic sections where studied: three in Penina (near Rocha da Pena) and one in Messines (near IC1 highway), resulting in four new local stratigraphical logs. This study led to the discovery of five new Late Triassic bonebeds (three in Penina and two in Messines). In contrast to the bonebed where *M. algarvensis* was discovered, no bone larger than 5 centimeters was found in any of these new bonebeds, leading us to classify them as microvertebrate bonebeds (according to the classification adopted by Eberth *et al*., 2007). These newly found bonebeds and the one where *M. algarvensis* was found (identified as IC1722-2, IC172-2, Pen-T2, Pen-T4, Pen-S4 and Pen-S6) will give us a deeper insight at the paleoenvironmental and faunal successions during the Late Triassic of Algarve.

The first stratigraphic section studied is in Messines, near the IC1 highway. The section, reaching 11 meters from base to top, is composed of metric layers of red claystone interbedded with decimetric layers of mainly gray pelite, one of limestone with peloids and one of red sandstone. The two lowermost beds of pelite are lenticular layers in the middle of a thicker claystone bed, and each one was found to be a bonebed (the lower bed named IC1722-2 and the upper one IC1722-3). No reference layers were identified that allow correlation of the studied section with the sections in Penina and the general stratigraphic section of the Grés de Silves Formation, as studied by Palain (1976). Future fieldwork and detailed geological mapping is needed to stablish if these outcrops are over or below the AB1 unit, as named by Palain (1976).

In the IC1722-2 bonebed, various cyamodontoid placodont's osteoderms (carapace elements) were identified in the middle of the bed, marking the first record of placodonts in Portugal, together with other unidentified and fragmented bones of small dimensions. A block of this bed was collected to be prepared in laboratory and to help to study this bonebed. Most of these osteoderms are very fragmented and placed close to each other and other bones in the matrix in a very chaotic matter, but small radial marks in the osteoderms can be easily observed. With so many carapace elements fragmented, it is difficult to estimate the difference in size of the majority of the osteoderms, but there appears to exist some heterogeneity in sizes based on the fewer more com-

plete elements. Despite this, due to the large number of osteoderms that cyamodontoids had in their carapaces, it could still be the case that the osteoderms found belong to a single individual. More samples would have to be collected and studied to reach a clearer conclusion.

In the IC1722-3 bonebed, a large number of small bone fragments, still unidentified, were found on top of the layer, as well as some mud cracks. Due to time limitations, not much of this bonebed was analyzed. Future research would require more samples to be collected and studied from this layer too.

In Penina, three stratigraphic sections were studied, belonging to the AB2 unit named after Palain, 1976 (Brusatte *et al*., 2015). One could be seen on the way to the *M. algarvensis* digging site, on the south slope of Rocha da Pena, while the other two were just south of the road from Penina to Salir. Of the latter, the western one is a section 9 meters thick composed of mainly decimetric-to-metric layers of red claystone, interbedded with decimetric layers of red pelite and greenish gray sandstone layer near the base, and two layers of calcarenite at the top, both containing peloids. In the greenish gray sandstone (bed named Pen-S4) a bonebed was discovered, and another one in the lowest calcarenite layer (bed named Pen-S6).

The bonebed PenS-4 has just a few rare bone fragments, still unidentified, and seen apart on few places on top of the bed. The bonebed PenS-6 contains a variety of small bones, with some heterogeneity in size, at the top of the bed, most of them fragmented and very difficult to identify. Still, at least one complete and relatively well-preserved cyamodontoid's osteoderm was identified, with some other fragments appearing to be parts of osteoderms.

The eastern section, measuring 24 meters in thickness, is mainly composed of metric layers of red claystone interbedded with decimetric layers of sandstone and pelite near the base, and with calcarenite, harder sandstone (in one cross-bedding could be observed) and limestone near the top. In some beds, various small desert roses were found. No bonebed was discovered in this sequence, however, one bone was found over the upper part of the red pelites with seven intercalations, appearing to have slipped from an upper layer.

The stratigraphic section observed on the way to the digging site reached

at least 13 meters in thickness, and is composed of, from base to top: a metric layer of red claystone, with gypsum nodules near the middle; the *M. algarvensis* bonebed, a decimetric layer of fossil-rich red claystone with some sand fraction; another metric layer of red claystone, near the top of which one phytosaur jaw was discovered (Mateus *et al*., 2014); a decimetric layer of gray mottled pelite with bone flakes, constituting another new bonebed (named Pen-T4); and at the top a layer of red claystone that could not be fully measured but was at least 4 meters thick, and contained two lenticular decimetric layers: one of greenish gray pelites, a meter from the base, and one of claystone in the middle, with secondary laminar gypsum.

Pen-T2 is the bonebed where *M. algarvensis* was found, and is a monodominant bonebed (though future excavations could prove otherwise) that contains a large number of skull bones as well as some post-cranial material of *M. algarvensis* densely packed within a narrow stratigraphic horizon (Brusatte *et al*., 2015).

The Pen-T4 bonebed is mainly composed of undetermined small bone fragments of heterogeneous sizes, but some very small fish scales were also found, and at least one almost complete cyamodontoid's osteoderm, although it didn't present the radial marks that could be observed in the other discovered osteoderms.

The presence of these six bonebeds is an important discovery because it presents a more or less continuous Late Triassic succession, and further research into these beds may help to rebuild the Late Triassic paleoenvironments and how they evolved.

ACKNOWLEDGEMENTS

The 2016 expedition to Penina was financed by Câmara Municipal de Loulé (the local municipality) and the specimens collected are currently stored and being prepared in Faculdade de Ciências e Tecnologias of Universidade Nova de Lisboa and in Museu da Lourinhã as part of the first author's master thesis, supported by a grant provided by Fundação António Aleixo. Also special thanks to Steve Brusatte, Jean-Sébastien Steyer and Richard Butler for their collaboration in the studies of the area of Penina.

REFERENCES

Brusatte, S. L.; Butler, R. J.; Mateus, O.; Steyer, J. S. 2015. A new species of Metoposaurus from the Late Triassic of Portugal and comments on the systematics and biogeography of metoposaurid temnospondyls. *Journal of Vertebrate Paleontology*, 35(3): e912988.

Eberth, D. A.; Shannon, M.; Noland, B. G. 2007. A Bonebeds Database: Classification, Biases, and Patterns of Occurrence. In: Rogers, R. R., Eberth, D. A., & Fiorillo, A. R. (Eds.). *Bonebeds: genesis, analysis, and paleobiological significance*. University of Chicago Press, 103-131.

Mateus, O.; Butler, R. J.; Brusatte, S. L.; Whiteside, J. H.; Steyer, J. S. 2014. The first phytosaur (Diapsida, Archosauriformes) from the Late Triassic of the Iberian Peninsula. *Journal of Vertebrate Paleontology*, 34(4): 970-975.

Palain, C. 1976. Une serie detrique terrigene «Les Gres de SiIves»: Trias et Lias inferieur du Portugal. *Memória/Serviços geológicos de Portugal. Direcção-geral de minas e serviços geológicos (Nova Série)*, (25).