Synchrotron radiation-based micro-computed tomography applied to the characterization of dinosaur fossils from the Lourinhã Formation

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Abstract

The Lourinhã Formation, central west Portugal, is very rich in dinosaur fossils of the Late Jurassic. In what concerns dinosaurs, the Museum of Lourinhã contains the most varied and best-preserved paleontological collection in the country. However, the potential of this material has not yet been fully explored because traditional non-destructive methods only allow analysis of exposed surfaces. Several embryonic vertebrae and fossilized eggshell fragments have been studied by Synchrotron Radiation-based Micro-Computed Tomography (SRμCT) at the BW2 and HARWI II beamlines, respectively. These beamlines are operated by the Helmholtz-Zentrum Geesthacht at the storage ring DORIS III at the Deutsches Elektronen–Synchrotron DESY in Hamburg, Germany. We have obtained high-resolution three-dimensional tomographic datasets using a non-destructive procedure.

Introduction

One of the most relevant specimens of the Museum of Lourinhã is the nest found in Paimogo, in 1993, by Isabel Mateus, with embryos attributed to *Lourinhanosaurus antunesi* [1]. In this nest more than 100 eggs or eggshell concentrations were detected. The embryonic remains were found as isolated skeletal elements within eggs or in close association with them. The material found in this site is late Jurassic in age, which fills an important temporal and phylogenetic gap of the fossil record regarding theropod embryos. Furthermore, it belongs to the Theropoda clade widely regarded as ancestors of birds. The theropod *Lourinhanosaurus antunesi* was previously known from a sub-adult individual from Peralta, about 5 km from the nesting site. Therefore, it is a rare opportunity to correlate morphological details in two stages of development. The study of the fossilized eggshells can provide precious information about the organisms that laid the eggs and the depositional environment in which eggshell has been preserved. For example, the study of the porosity of the shell can provide valuable information about the level of humidity of the area where the egg was laid.

Results and discussion

A photograph showing a dinosaur embryonic vertebra (ML565_Paim55) found in the Paimogo nest is presented in Figure 1(a). The specimen was imaged by microtomography in absorption mode with photon energy of 24 keV at BW2. Microtomographic slices through the vertebra are shown in Figure 1 (b)-(c). The effective pixel size corresponds to 3.5 μm.

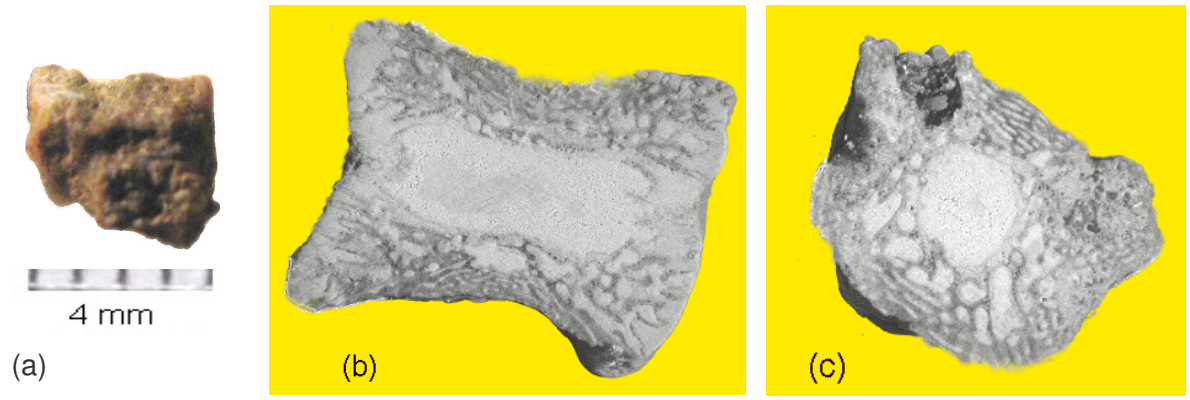

Figure 1. Embryonic vertebra of *Lourinhanosaurus antunesi* found in the nest recovered from Paimogo site: (a) photograph of the vertebra; (b) longitudinal section of the vertebra; (c) general view of a centrum cross-section of the vertebra.

One of the most astonishing aspects of the theropod embryos of the Upper Jurassic of the Lourinhã Formation is the accuracy of their anatomical details and their early differentiation. The first SRμCT data recorded for dinosaur eggshells collected in the Lourinhã Formation allowed a non-destructive visualization of the pore morphology and connectivity of the pore in the eggshells. More details about the experimental procedure as well as results obtained at the HARWI II beamline can be found in Ref. [2].

Conclusions

The exquisite anatomical and histological preservation of the embryonic bones, comprising the first dinosaur embryonic remains reported in Europe, will allow observations of unprecedented precision and detail for theropods. This material allows us to extend in time and to considerably supplement in great detail our knowledge of early ontogeny of carnivorous dinosaurs. SRμCT is an extremely useful technique for non-destructive imaging of the morphology of dinosaur eggshells, revealing otherwise inaccessible details such as the network of pores in the eggshells.

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