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IDENTIFICATION OF A NEW SNAKE FOSSIL FROM THE CANARY ISLANDS USING MICRO-CT TECHNIQUES

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Resumen

En el Mioceno de las Islas Canarias se ha citado la presencia de una vértebra de boido, que por su pequeño tamaño pudo haber llegado a las islas desde el cercano continente africano en el tracto digestivo de un ave. Sin embargo, en un tubo volcánico de Fuerteventura se han encontrado restos de vértebras y costillas articuladas, cubiertas por una capa de calcita y de edad incierta, que pertenecen a una serpiente de la familia 'Colubridae'. Para su estudio, dadas la fragilidad de los restos y la dificultad para eliminar la calcita, se utilizó un escáner micro CT para obtener modelos digitales tridimensionales.

Palabras clave: serpiente fósil, escáner micro CT, Islas Canarias

Abstract

There are no native snakes on the Canary Islands today. The recovery of a boid vertebra from Miocene deposits on Fuerteventura suggested snakes could have been present in the past, but this single small vertebra could have reached the islands from the nearby African continent in the gut of a bird. Now, however, the articulated remains of a snake have been found in a volcanic cave on Fuerteventura. The specimen is covered by a calcitic matrix and is of uncertain age. Given the fragility of the remains and the difficulty of removing the calcite matrix, we used micro-CT scans to make three-dimensional digital models for study. These reveal that the bones belong to a 'colubrid' snake.

Keywords: fossil snake, micro-CT scan, Canary Islands

Introduction

The remains of vertebrate fossils from volcanic islands provide important evidence from which to reconstruct the evolutionary history of this type of environment, so they are always exceptional (Steadman, 2006). If the remains are fragile, however, the mechanical or chemical removal of any surrounding matrix can be difficult and risky. This has led to the application of new diagnostic techniques that allow a non-invasive study of fossil remains (Sutton, 2008).

The fossil record of vertebrates on the Canaries extends from the Miocene to the Holocene and includes birds, tortoises, lizards and mammals (Castillo et al., 1996), most of which were endemic. In the case of the turtles and giant birds of Lanzarote, extinction appears to have been related to volcanism (Hutterer et al., 1997). In contrast, the Holocene extinctions (mainly of small mammals and birds as well as several species of lizards) may have been due to a combination of interspecific competition and the arrival of humans on the islands (Castillo et al., 2001). Today the Canary Islands contain no native snakes and, until recently, there was no evidence of their past presence on the islands. However, in 1998 a boid (Serpentes, Boidae) snake vertebra was recovered from the Miocene of Lanzarote (Barahona et al., 1998). This raised the possibility that snakes were once part of the Canary Islands fauna but given the small size of the single vertebra, it could also have been carried from the African mainland in the gut of a predatory bird.

More recently, an articulated snake fossil was recovered from a cave in Fuerteventura, but it is a fragile specimen embedded in calcitic matrix. Several technologies can generate tomograms without visible light penetration or physical exposure of the surfaces. The most widely used of these is X-ray computed tomography (CT) which produces tomograms representing X-ray attenuation maps. Micro-CT scanners produce scans of high resolution suitable for imaging small living and fossil specimens. Use of this technique revealed details of the new fossil articulated snake remains showing it to be distinct from the Lanzarote material.

Fossil locality

The fossil site is a volcanic cave formed by Miocene volcanic activity (Coello et al., 1992), near Caleta de Fuste locality, east of Fuerteventura. The deposits are of a highly altered basaltic material covered superficially by major calcareous crusts. The calcium carbonate that makes up these crusts dissolves during times of high rainfall seeping through cracks in the floor. This forms thin sheets of calcite that covering everything within the cave.

The volcanic tube was opened during some urban excavation work, allowing a superficial explo-

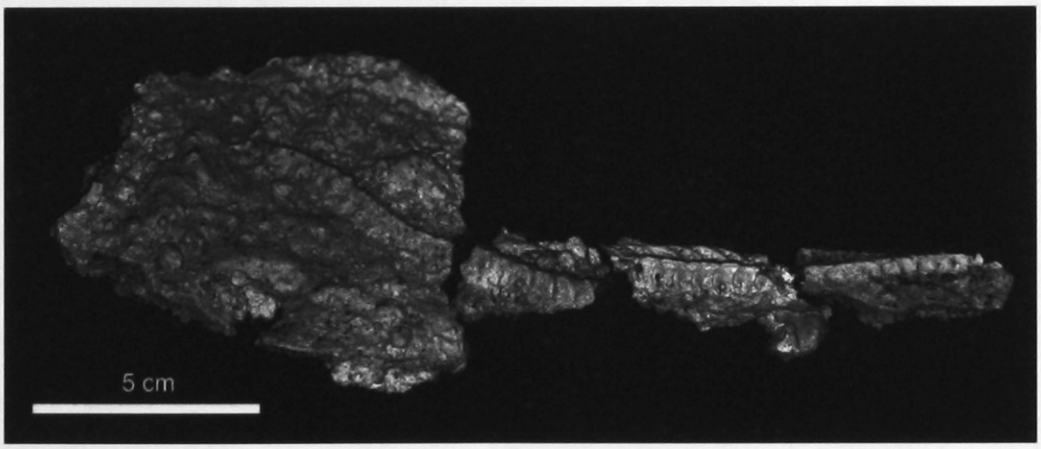

FIG. 1. View of the fossil snake remains covered by calcitic matrix.

ration of the site. The remains were found on the floor of the tube, covered in calcitic matrix. The specimen consists of partial vertebral column with approximatlely 40 articulated vertebrae and ribs (FIG. 1). Fossils of several other species of vertebrates (*Malpaisomys insularis*, *Mus musculus*, *Crocidura canariensis* and *Puffinus* cf. *holeae*) were found in association, although these were not articulated and the calcite cover was less extensive.

Methodology

The calcitic matrix covering the specimen is difficult to prepare without causing major damage. We therefore used a Micro-CT scanner to image small pieces of the skeleton and to prepare detailed 3-D computer models to reveal details of vertebral structure.

The specimen was scanned at the Natural History Museum, London, using the Nikon Metrology HMX ST 225 a micro-CT (Metris X-Tek, Tring, UK). The instrument uses a cone beam projection system with a four megapixel Perkin Elmer XRD 1621 AN3 HS detector panel, a molybdenum target, an accelerating voltage of 190 kV and a current of 140 uA; no filter was used. The scan parameters allowed a model with voxel dimensions of 0.024 mm (24 microns) in xyz dimensions (z = slice thickness). A total of 3142 radial X-ray projection images were acquired over a 360° of specimen rotation at 0.1146° intervals. The micro-CT data was reconstructed in Amira 4.1 (Konrad-Zuse-Zentrum, Berlin, Germany). Using the same software program a three dimensional (3-D) model was segmented using contrast thresholding. From this surface models were made and smoothed by two iterations.

Results

The relatively elongate vertebrae have well-developed prezygapophysial processes on the vertebrae showing that this is a colubroid (advanced) snake rather a boid. The presence of haemal keels and the absence of hypapophyses on the trunk vertebrae suggest that this is not a viperid or elapid snake. It thus belongs with the 'Colubridae' – the name once used for non-viperid, non-elapid higher snakes. Modern phylogenetic analysis has shown 'colubrids' to be paraphyletic, with several distinct lineages, most notably the natricines, colubrines, lampropeltines, boodontines, calamarines, and dipsadines. The absence of hypapophyses on the vertebrae rules out natricines, but there are a large number of candidate taxa amongst West African colubrine and lamprophiid snakes (as possible source populations), and more precise identification will require detailed comparison with modern snake vertebrae from western Africa.

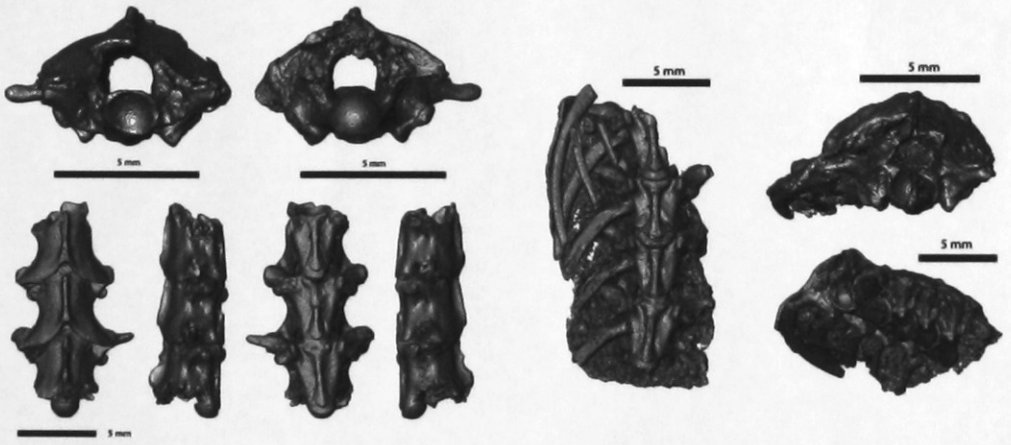

FIG. 2. Micro CT images of remains of the Fuerteventura fossil snake.

Discussion

The application of Micro-CT scanning to vertebrate remains has revolutionised the study of morphology in both living and extinct taxa. For fossil specimens, provided the matrix and fossil differ sufficiently in their density to be separated by threshholding, Micro-CT provides a method by which 3-D images of matrix embedded fossils can be obtained without damaging the specimen. This is crucial for small delicate specimens (Sutton, 2008) but also in the investigation of delicate regions of larger specimens, for example the ear of the early tetrapod *Ichthyostega* (Clack et al., 2003) and the braincase of the early bird *Archaeopteryx* (Domínguez Alonso et al., 2004). The detailed 3-D models developed from these scans can also be used in further computer based methodologies (e.g. Finite Element Analysis) to explore the relationship between structure and function in extinct animals (e.g. Rayfield et al., 2001). In the study presented here, it has provided us with detailed 3-D images for study and comparison to identify the taxon represented.

Currently there are no snakes in the Canary Islands, and the new snake remains provide further evidence that the past fauna of the Canary Islands was more diverse than it is today. The lava mouse (*Malpaisomys insularis*) and Hole´s shearwater (*Puffinus* cf. *holeae*), found near the snake fossil, went extinct during the Quaternary (Castillo et al., 2001; Rando & Alcover, 2008). However, there are also remains of house mice (*Mus musculus*), a species for which there is some controversy as to the timing of its colonization of the islands (Alcover et al., 2009), although it was probably quite recent. This suggests that despite the Miocene age of the volcanic cavity itself, the fossils it contains could be quite recent, but more rigorous dating is needed to provide an accurate age.

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