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Using Virtual Palaeontology to Investigate Trace Fossil–Body Fossil Associations in Molluscs from the Mesozoic of Madagascar

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Three-dimensional (3-D) computer reconstruction of fossils, or virtual palaeontology, is a powerful approach for elucidating the history of life. Fossils are visualized with the aid of cutting-edge imaging and computer technologies (Sutton et al. 2012), yielding novel insights into their anatomy, function, and evolution. Owing to its capability to rapidly and non-destructively image centimetre-scale samples at high resolutions, X-ray microtomography (μCT) has proven to be a particularly effective tool for virtual palaeontology (Abel et al. 2012; Rahman et al. 2012). The technique has been used to study a range of different groups, including arthropods (e.g. Garwood et al., 2011), echinoderms (e.g. Zamora et al., 2012), and molluscs (e.g. Vinther et al., 2012). In addition, μCT was used to visualize the 3-D relationship between trace and body fossils in specimens from the Kaili Biota of Guizhou, China (Lin et al., 2010).

To further explore the association between trace and body fossils in three dimensions, three well-preserved molluscs from the Mesozoic of Madagascar (a gastropod, an ammonite, and a nautiloid) were studied with the aid of μCT. Fossils were scanned on a Nikon (formerly Metris X-Tek) XT H 225 cabinet scanner at the Natural History Museum, London, using a current/voltage of 210 kV/190 μA and 3142 projections for the gastropod, a current/voltage of 210 kV/175 μA and 3142 projections for the ammonite, and a current/voltage of 215 kV/200 μA and 6284 projections for the nautiloid. Two out of the three specimens yielded promising results, with two different types of trace fossils (burrows) recognizable in the μCT scans and the digital reconstructions (Figs 1, 2).

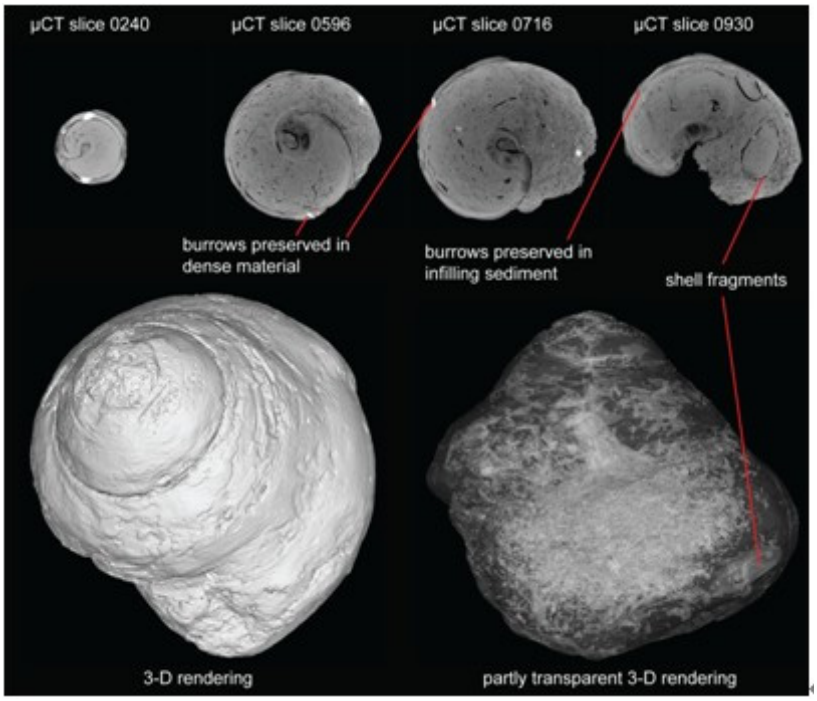

Fig. 1. μCT slices and 3-D computer reconstruction of an undetermined gastropod (NIGP158310) from the Mesozoic of Madagascar.

The first type of trace fossil is associated with the gastropod (Fig. 1). The body fossil is infilled with brownish sediment and numerous shell fragments (preserved as voids), which are concentrated in the outer chamber. Small tubular burrows (probably borings) occur in the outer shell, but do not penetrate far into the infilling sediment; these structures are preserved in the same material as the infilling sediment or as a denser material,

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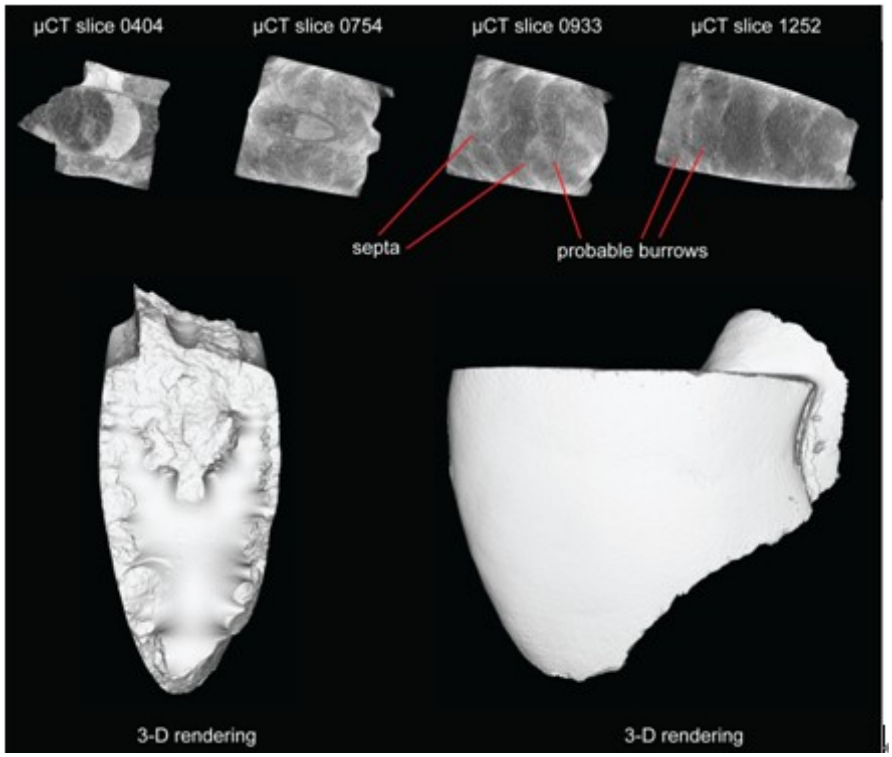

Fig. 2. µCT slices and 3-D computer reconstruction of an undetermined ammonite fragment (NIGP158311) from the Mesozoic of Madagascar.

which appears as bright pixels in the µCT scan. The taphonomic history of this specimen is unclear; the absence of trace fossils in the infilling sediment could indicate that the burrows were formed prior to the shell being filled with sediment, or that the burrowing organisms preferentially bored through the outer shell, or that any burrows formed in the inner shell were not preserved.

The second type of trace fossil occurs within the ammonite fragment (Fig. 2). The body fossil is represented by bright (?aragonite) and mottled dark (infilling sediment) pixels in the µCT scan. The distinctive ammonitic suture pattern is clearly visible on the fossil exterior – although this is not apparent in the computer reconstruction, which does not include information about the surface appearance of the fossil – indicating the generally excellent preservation of the specimen. Small tubular burrows occur extensively within the fossil, but never cross between septa, sometimes following chamber walls for a considerable distance; burrows are represented by fairly bright pixels (dense material) and septa are represented by light-grey pixels. This demonstrates that the burrows were formed after the shell had been infilled with sediment, and suggests that the chamber walls of the ammonite acted as barriers to the movement of the burrowing organisms.

Our computer reconstructions (Figs. 1, 2) provide 3-D information on the interior of Mesozoic Madagascan molluscs for the first time. Of particular note, they allow us to identify trace fossil burrows closely associated with body fossils in a gastropod and an ammonite. Although these burrows are similar in size and shape, they might have had quite different histories. In the gastropod, we were able to determine how the shell fragments were compacted inside the shell, but the exact taphonomic history of this fossil is otherwise unclear. In contrast, the history of the ammonite can be more fully deciphered – burrows were formed in the fossil following sediment infill. This work, together with the study of Lin et al. (2010), demonstrate the great potential of virtual palaeontology for investigating trace fossil–body fossil associations in different invertebrate groups. Studied fossils (NIGP158310-158312) are deposited at the Nanjing Institute of Geology and Palaeontology.

Key words: palaeontology, X-ray microtomography, ichnology, taphonomy, molluscs

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