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Reid, R. E. H. (Robin)

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A SHORT HISTORY OF DINOSAURIAN OSTEOCYTES.

by

R.E.H. (Robin) Reid

School of Geosciences, The Queen's University of Belfast, Belfast BT7 INN, Northern Ireland.

ABSRACT

A recent supposed discovery of dinosaurian osteocytes by Fukuda and Obata (1993) ignored earlier records from more than 20 dinosaurs, dating back 150 years. Some of the bodies they identified as osteocytes are also more likely to represent chondrocytes.

KEYWORDS: Bone histology, osteocytes.

INTRODUCTION

In a recent paper, Fukuda and Obata (1993) claimed the discovery of dinosaurian osteocytes, in the form of mineral casts of their lacunae and canaliculi seen in hadrosaurid bones, and stated that, despite recent histological studies, ". . . there is no information on osteocytes in dinosaur bone tissues" (p. 99, para. 1). At that date, however, earlier studies outlined here contained records from more than 20 dinosaurs, dating back 150 years (Quelett 1849), and even electron microscope photographs had been in print since 1966 (Pawlicki, Korbel & Kubiak 1966). This note reviews a range of relevant references, for readers not familiar with them, and also shows that some bodies identified as osteocytes by Fukuda and Obata in the articular surface of a dinosaur limb bone, are more likely to represent chondrocytes.

Historical outline

First, under the old name "bone cells", the presence of osteocyte lacunae was recorded from bones of the ornithopod *Iguanodon* by Quekett (1849) and of the sauropod *Pelorosaurus* by Mantell (1850). These are the oldest ornithischian and saurischian records respectively. Strictly, Quekett (p. 57) only stated that bones of *Iguanodon* do not differ from those of modern lizards in minute structure; but his numerous figures of lacunae and canaliculi from modern forms (plates 5-8) and from a pterosaur (plate 8, Figure 2) leave no doubt of what he meant. Subsequently Hasse (1878) recorded osteocyte lacunae in a vertebra ascribed to the prosauropod *Thecodontosaurus*, contrasting spindle-shaped examples from periosteal bone with stellate forms seen in a nothosaur (p. 499), and giving a figure which shows their presence in endochondral bone (Figure 24b). Their presence is seen readily in some of Seitz's (1907) photographic figures e.g. Figure 57, *Megalosaurus*; Figures 59-61, *Iguanodon*; Figure 76, "*Trachodon*" (*Anatosaurus*); and his text, in which he called them "bone corpuscles" (Knochenkörperchen), contains records of their presence and arrangement in bones of *Plateosaurus* (p. 265), *Megalosaurus* (p. 288) *Brontosaurus* (pp. 302, 303), *Diplodocus* (pp. 304, 306), *Camarasaurus* (p. 311, as "*Morosaurus*" pp. 322, 324), *Haplocanthosaurus* (pp.313, 314), *Allosaurus* (pp. 315, 316), *Stegosaurus* (p. 321) *Iguanodon* (pp. 326-328), *Dryptosaurus* (p. 344), *Triceratops* (p. 346), and *Anatosaurus* (pp. 348-350), as "*Trachodon*". Osteocyte *Stegosaurus* lacunae recorded as from *Zanclodon* (p. 262), which is now considered indeterminate, are probably from a prosauropod (c.f. Benton 1986, pp. 295-297). A preserved canalicular network was noted in *Brontosaurus* (p. 302), though not illustrated, and lacunae affected by fungal enlargement, mineral infilling, loss of canaliculae or complete obliteration were reported from various genera. Records from prosauropods, sauropods, theropods, ornithopods, a stegosaur and a ceratopsian have thus been in print for most of this century; and Seitz's (1970) study contains more such records than any other single paper.

In later work, Moodie (1928) reported the presence of lacunae and canaliculae in Haversian bone from "ossified tendons" of *Anatosaurus* (as "*Trachodon*") and *Ankylosaurus* (p.2), and that of lucunae is obvious in some of his "*Trachodon*" figures (Figures 2b, 6a & 6b). Bacterial enlargement of lacunae was also reported (p.2 and Figure 6a). Nopcsa and Heidsieck (1933) found lacunae and canaliculae in periosteal and Haversian bone from a half-grown *Hypacrosaurus*, and in fibro-lamellar tissue from a juvenile *Procheneosaurus* (as "*Tetragonosaurus*"), reporting round and polygonal lacunae as having diameters between 3-7μ, and spindle-shaped examples short diameters between 2-4μ (pp. 222, 224, 225). In the juvenile, the presence of lacunae is obvious in their figure (Figure 2); and they reported canaliculae connecting them as forming a network with meshes "about 4μ" wide (p. 225). Gross (1934, pp. 755-759) reported the presence and arrangement of lacunae in bone from *Plateosaurus*, *Brachiosaurus* and *Iguanodon*, calling them "bone cells" (Knochenzellen) or simply "cells" (Zellen), and gave figures showing obvious examples in *Brachiosaurus* tissues

(Figures 19 and 20), also noting contrasting arrangements in different parts of secondary osteons (Figure 20). De Lapparent (1947), Figure 6 and Plate 6, figures 1-4, 6) figured bone showing lacunae and canaliculae in *Rhabdodon*, with a drawn figure showing the canalicular network (figure 6c); and Pawlicki, Korbel & Kubiak (1966, Figures 1 and 3) used transmission EM photographs to illustrate these features as seen in an unnamed Gobi dinosaur. Later, Pawlicki (1977) reported concentration of mucopolysaccharide traces around lucunae and canaliculae in *Tarbosaurus*; used optical, transmission EM and SEM photographs (1978, Figures 1-6) to illustrate their form in this genus, also noting two types of fusiform lacunae with differently arranged canaliculae; and discussed (1984) the metabolic significance of dinosaurian lacunae and canaliculae. Reid (1984a, Figure 1) figured mineral filled lacunae and canaliculae from *Iguanodon*, mentioned Mantell's *Pelorosaurus* record (p. 629), and pointed out lacunae shown in Seitz's *Anatosaurus* figure (Reid 1985, p. 141), besides figuring bone with obvious lacunae from *Cetiosaurus*, *Valdosaurus*, *Aristosuchus* (1984a, Figures 2, 3 and 15; 1985, Figures 3, 4 and 8) and *Hypsilophodon* (1984b, Figure 1j). Besides lacunae, canaliculi can be seen in the 1985 *Aristosuchus* Figure; and Chinsamy (1990, p. 78) reported strongly branched examples from *Syntarsus*.

DISCUSSION

As noted at the start of this study, Fukuda and Oblata's (1993) paper involves two distinct problems. First, it is clear that they were wrong to suppose that nothing was known of dinosaurian osteocytes; and why they should have thought so is puzzling, when so much had been known for so long. Genera cited above, from which preserved lacunae were then known, total two (three?) prosauropods, seven sauropods, six theropods, five ornithopods, including three hadrosaurs, a stegosaur, an ankylosaur and a ceratopsian. The persistence of lacunae in dinosaurian bones had been known for 144 years (Quekett 1848); many details of their form, arrangement and preservation in over a dozen dinosaurs for 86 years (Seitz 1907); and their dimentions in two hadrosaurs, including a juvenile, for 60 years (Nopcsa & Heidsieck 1933). A transmission EM photograph had been in print for 27 years (Pawlicki, Korbel & Kubiak 1966), and scanning EM photographs for 15 years (Pawlicki 1978). Some of the relevant publications are probably not widely known (e.g. Hasse 1878); but *Nature*, in which the first EM photograph appeared, is not an obscure journal, and Seitz's classic "Vergleichende Studien" (1907) is required basic reading for anyone working on fossil bone. Perhaps, however, the answer is that osteocytes have not been involved in the controversy over dinosaurian physiology, except indirectly as secondary markers of different types of bone at fibrillar level (e.g. de Ricqlès 1975, p. 59 and Figure 1), and have hence received little or no attention in papers concerned with that topic (e.g. de Ricqles 1980; Reid 1987). Persons not familiar with studies of bone histology could thus get a false impression that nothing was known about them. Hopefully, this note will make how much we know more widely known.

Second, Fukuda and Obata's sample from a juvenile *Maiasaura* was stated to be compact bone from the upper articular surface of a limb bone (pp. 99-101), and was found to contain casts of lacunae which did not emit canaliculi (p. 101 and Figure 6). This they ascribed to "retardation of bone calcification in the juvenile" and taphonomic damage (pp. 101 and 102). But the articular faces of dinosaurian limb bones are not formed from compact bone, whose presence there would block growth in length, but from calcified cartilage, representing the deep parts of the growth plates under which new endochondral bone was formed (e.g. Reid 1984a, pp. 645 and 646 and Figures 24-27, *Iguanodon*; Reid 1996, Figures 38 and 39, *Allosaurus*; Figures 41 and 81, *Camptosaurus*); and a characteristic of cartilage is that the lacunae occupied by its chondrocytes do not emit canaliculi. Hence it seems likely that the tissue called compact bone was really calcified cartilage; and this would fit the style of calcification which their Figure 6 shows. The preservation of calcified cartilage in dinosaurian bones is again no new discovery, having first been figured by Hasse (1878, Figure 24a) from *Thecodontosaurus*.

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