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THE HISTOLOGICAL NATURE OF OSSIFIED TENDONS FOUND IN DINOSAURS

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Ossified tendons, under the term "tendon bones," have been known to palæontologists for a long time, and their occurrence in the dinosaurs, especially, has been a matter of common knowledge. It would be of no especial value for me to review the literature relating to the occurrence of these objects among fossil reptiles, so I shall merely cite two papers by Barnum Brown[1], [2], who has written the most recent and most complete accounts of these structures.

I was attracted by the possibility of explaining the nature of some of the vertebral lesions in *Smilodon*[3], on the basis of the comparative histology of the structures involved. If those curious lesions in the sabre-tooth are really myositis, then there should be some evidence of a modification in the histology of the lesions toward a ligamentous or tendinous structure. Such proved not to be the case, and I now believe those vertebral lesions of *Smilodon* to be parosteal, due to injury of the vertebræ.

Mr. Brown sent me specimens of ossified tendons from two genera of dinosaurs, *Trachodon* and *Ankylosaurus*. He also secured funds to pay for making the photomicrographs, shown on the accompanying figures. The tendons sent for study were of the size of lead-pencils, and where weathered showed the osseous appearance so well known to experienced fossil-hunters. Their fibers run longitudinally without interruption.

Although there have been a number of studies on the histological nature of fossil bone, no attempt has been made previously to describe the histology of petrified tendons, so the results given herewith are all

[1]Brown, Barnum. 1916. *Corythosaurus casuarius*: Skeleton, Musculature and Epidermis. Second Paper.
Bull. Amer. Mus. Nat. Hist., XXXV, Art. XXXVIII, pp. 709–716, Pls. XIII–XXII. On page 711, under the caption "Tendons and musculature," is given the pertinent discussion.

[2]———— 1917. A complete Skeleton of the Horned Dinosaur *Monoclonius*, and Description of a second Skeleton showing Skin Impressions.
Ibid, XXXVII, Art. X, pp. 281–306, Pls. XI–XIX. "Ossified tendons," page 290. Plates XII and XVI show the arrangement of the tendons especially well.

[3]Moodie, Roy L. 1927. Studies in Paleopathology, XIX. Vertebral Lesions in the Sabre-tooth, Pleistocene of California, resembling the so-called *Myositis ossificans progressiva*, compared with certain Ossifications in the Dinosaurs. Annals of Medical History. IX, No. 1, pp. 91–102, Figs. 1–11.

new. I have reviewed elsewhere[1] the literature of fossil histology, and further reference to that subject need not be made here.

Cross and longitudinal sections of the ossified tendons of *Trachodon* and *Ankylosaurus* reveal the histological characters. One who is accustomed to examining the microscopical structures of ancient fossil bone is at once impressed with the absence of vascular spaces, which are extremely abundant in skeletal bone. The arrangement of Haversian systems is strikingly regular, and there is no evidence of stellate cells, or bundles of tissue, so characteristic of recent tendons. Osteoid tissue, so abundant in the skeletal parts of fossil reptiles, is strikingly absent from the fossil tendons. There is an interesting similarity in the histology of the ossified tendons and pathological fossil bone in the tendency in both to the production of fairly perfect Haversian systems. The systems seen in the tendons are quite perfectly formed and include all the principal elements, i. e., lacunæ, lamellæ, canals, fibrillar ground substance, and absorption areas. I cannot be sure of an intercommunication between the canaliculi of adjoining lacunæ. The lacunæ, in fact, on closer examination (Fig. 2, B), are not definitely arranged in concentric layers, between the quite apparent lamellæ. The lacunæ show a number of definite canaliculi, springing both from the two poles and from the sides of the spindles. However, they agree in general with the structure, form, and size of other dinosaurian lacunæ.

Bacterial invasion, through vascular channels, of the lacunæ and canaliculi is known to have taken place with similar results from the Devonian ostracoderms down to the Pleistocene mammals and to this common occurrence the ossified tendons of the two Cretaceous dinosaurs offer no exception. Fig. 6, A, shows several lacunæ invaded and enlarged by the bacteria of decay, whose activities were stopped and their effects preserved by fossilization.

SUMMARY

The histology of the ossified tendons of two genera of dinosaurs is structurally unlike that of the skeletal bone of fossil reptiles, in the presence of fairly well-developed Haversian systems. In this respect the tendons approach the structure of mammalian long bones. There is an absence of osteoid tissue in the tendons. The concentric lamellæ are few, rarely more than six. The lacunæ are shaped like those seen in skeletal bones of dinosaurs, and the canaliculi are few, short, and unbranched.

[1]Moodie, Roy L. 1926. Studies in Paleopathology, XIII. The Elements of the Haversian System in normal and Pathological Structures among fossil Vertebrates. Biologia Generalis, II, pp. 63–95, 12 Plates, 10 figs.

Figures 1 to 6

Fig. 1

A. Cross section of an area in an ossified tendon, from near the sacrum, of a dinosaur, *Trachodon annectens*. Lance Formation, near Hell Creek, Montana. $\times 50$.

The sharp, dark lines are cracks filled with calcite. There is considerable interstitial material between the Haversian systems, and absorption areas are evident.

B. High-power photomicrograph of same area, $\times 100$. It will be noted from the varying sizes of the Haversian canals that the Haversian systems are not continuous for any great distance, but tend to pinch out. There are only a few systems which are oblique, the majority running in the direction of the length of the tendon. Vascular spaces, so abundant in the skeletal bone of ancient reptiles, are wanting here.

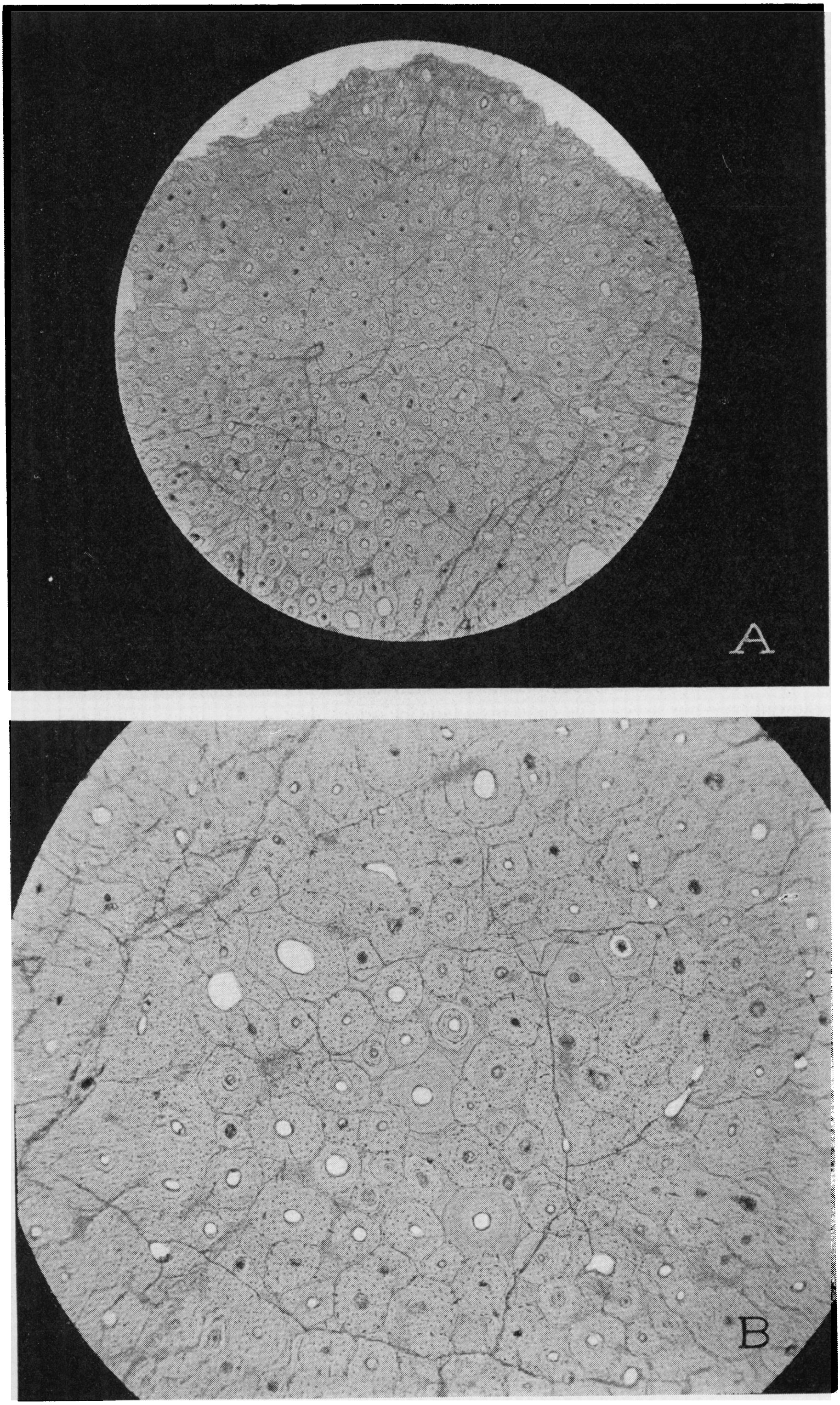

Fig. 1

Fig. 2

A. Another area of the same slide, $\times 100$, showing less distinct boundaries to the small Haversian systems.

B. Same section, $\times 300$. Enlarged view of some of the Haversian systems, showing varying sizes. The concentric lamellæ are evident in the upper right-hand corner of the figure, and adjoining this system is an absorption area which does not differ essentially from an area in modern human bone. The interstitial ground substance has lacunæ of unmodified type. The dark line running obliquely across the bottom of the figure is a post-fossilization crack.

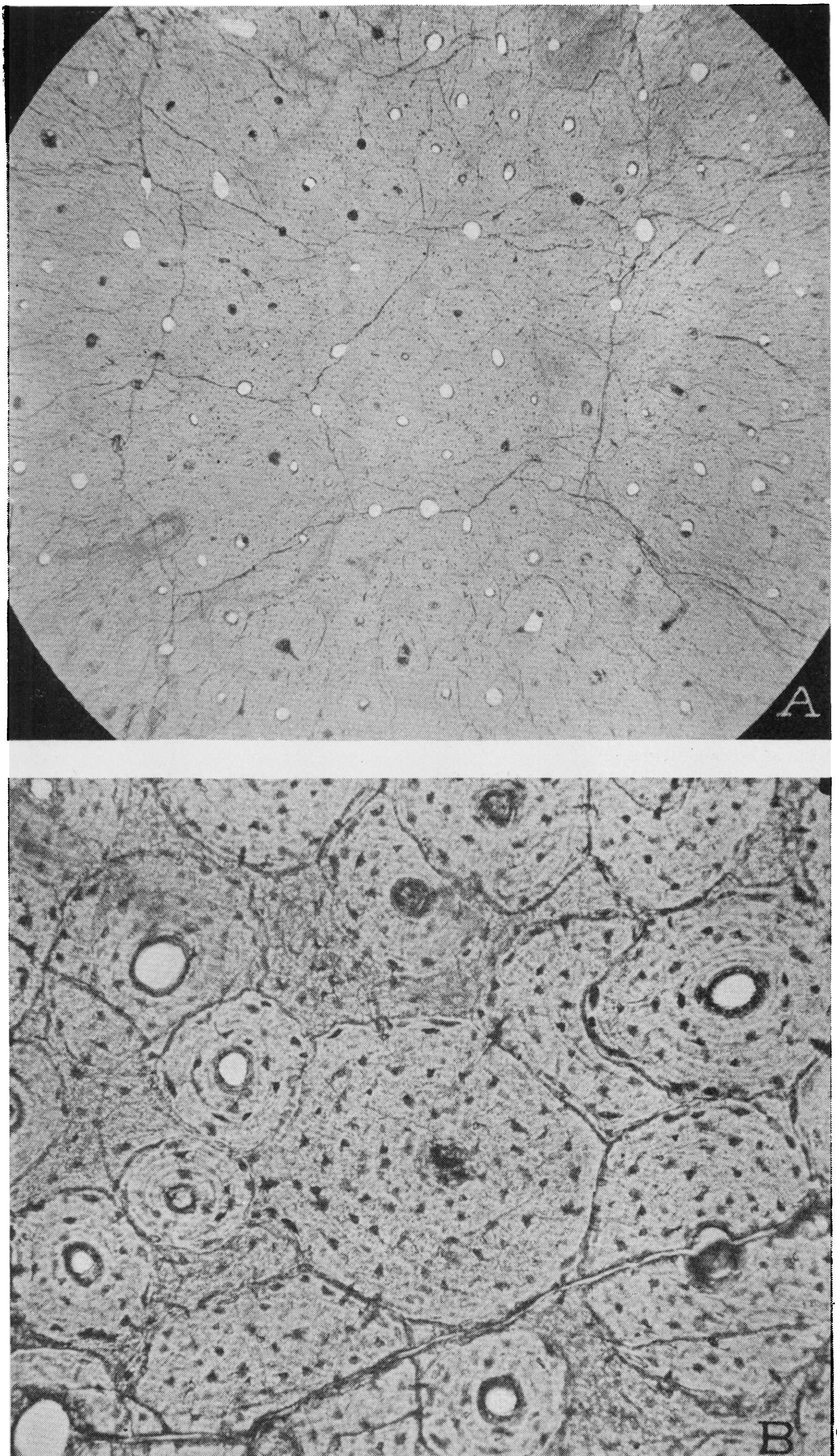

Fig. 2

Fig. 3

A. Cross section of ossified tendon from the tail of *Ankylosaurus*, Lower Edmonton Beds, Red Deer River, Canada. ×50. This is quite different in appearance from the similar section in *Trachodon* (Fig. 1, A). The concentric lamellæ are distinct. The Haversian canals are quite large, some of them oblique. The ground substance is almost homogeneous.

B. Same area, enlarged ×150. When compared with Fig. 2, A—this tendon in *Ankylosaurus* is seen to be widely different. The lacunæ are indistinct and indifferently arranged. The opacity of the field indicates a different chemical composition from that found in *Trachodon*, due doubtless to a different matrix.

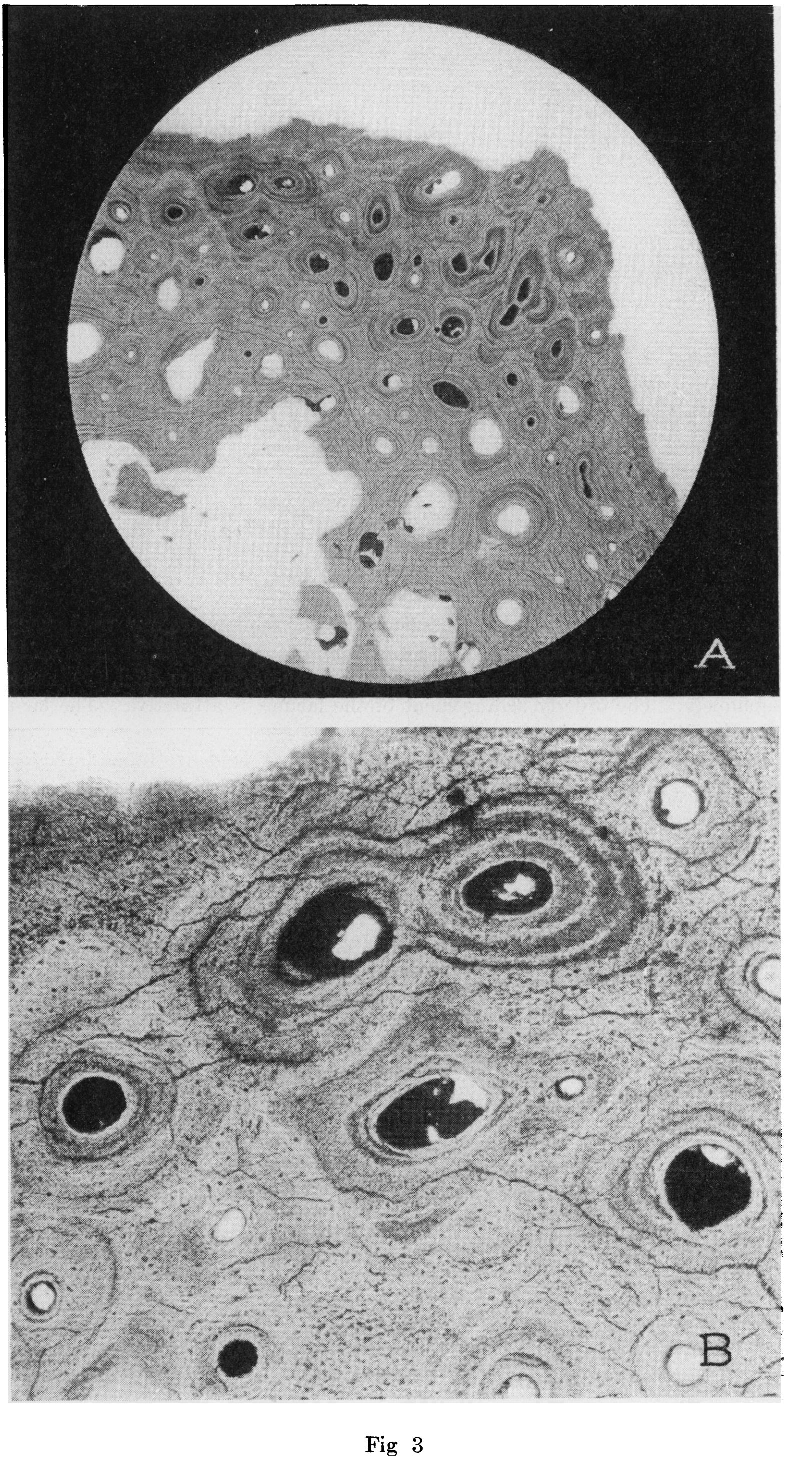

Fig 3

Fig. 4

A. Longitudinal section of an ossified dinosaur tendon, from near the sacrum of *Trachodon annectens*, from the Lance Formation, near Hell Creek, Montana. ×70.

Two Haversian canals are shown, one extending across the field. Others are cut obliquely. The orderly arrangement of the lacunæ is attractive. The lacunæ are small and numerous.

B. Same section, enlarged ×150. Upper part of field has numerous cracks. Some of the lacunæ in the lower part of the field are quite large, as if invaded by bacteria.

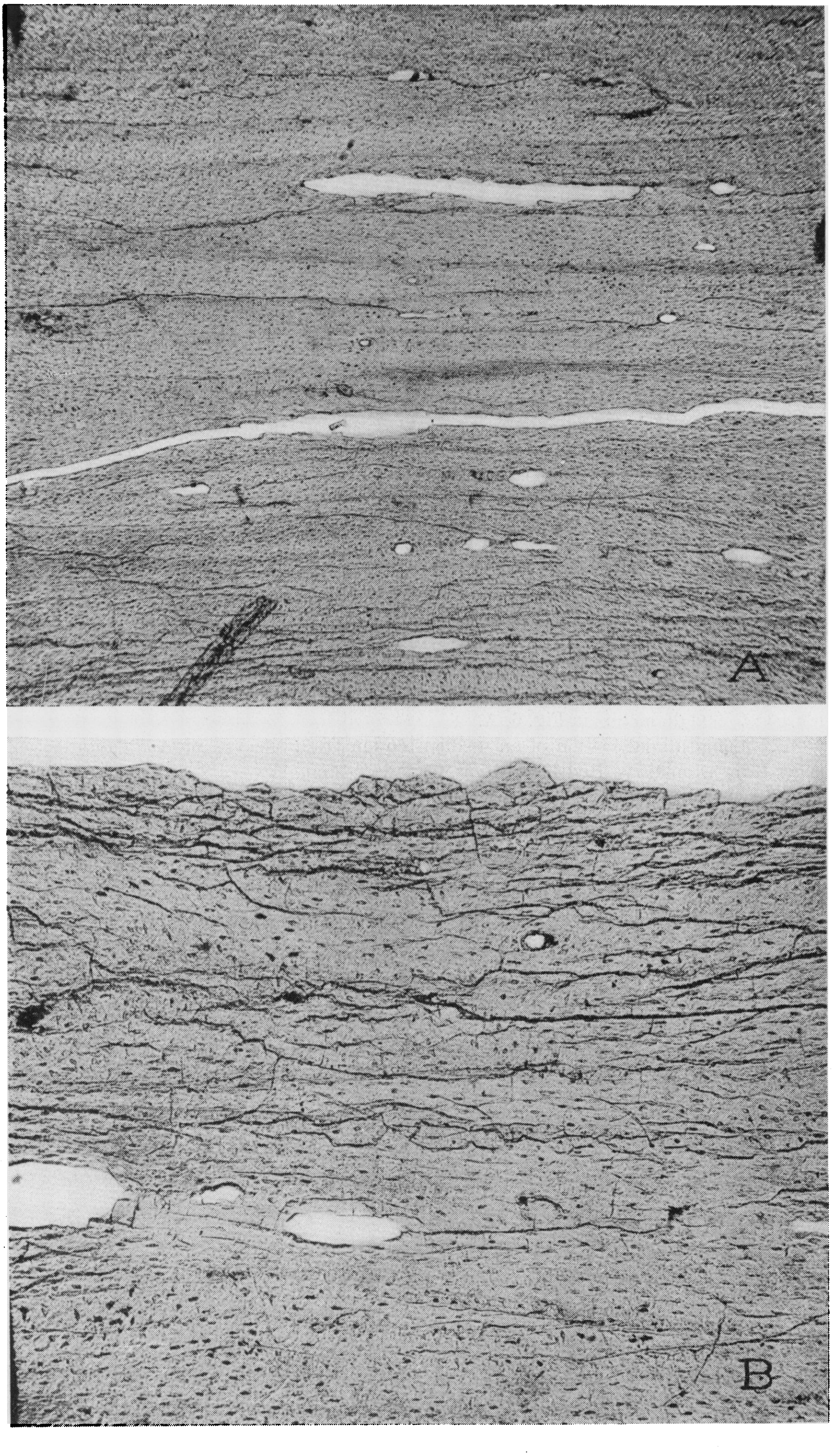

Fig. 4

Fig. 5

A. Longitudinal section of an ossified tendon from near the sacrum of *Trachodon annectens*. Lance Formation, near Hell Creek, Montana. ×300.

This shows the early effect of the invasion of lacunæ by bacteria of decay, before fossilization. The canaliculi are hypertrophied. Normal lacunæ in dinosaur bone possess only brief canaliculi. The three lacunæ shown in the middle above are figured enlarged to 600 diameters in Fig. 6, A.

B. Longitudinal section of an ossified tendon from the tail of *Ankylosaurus*. Lower Edmonton Beds, Red Deer River, Canada. ×50.

The Haversian canals have the appearance of vascular spaces. The lamellæ and lacunæ are indistinct. The entire area presents a dull opacity wanting in the sections of *Trachodon*.

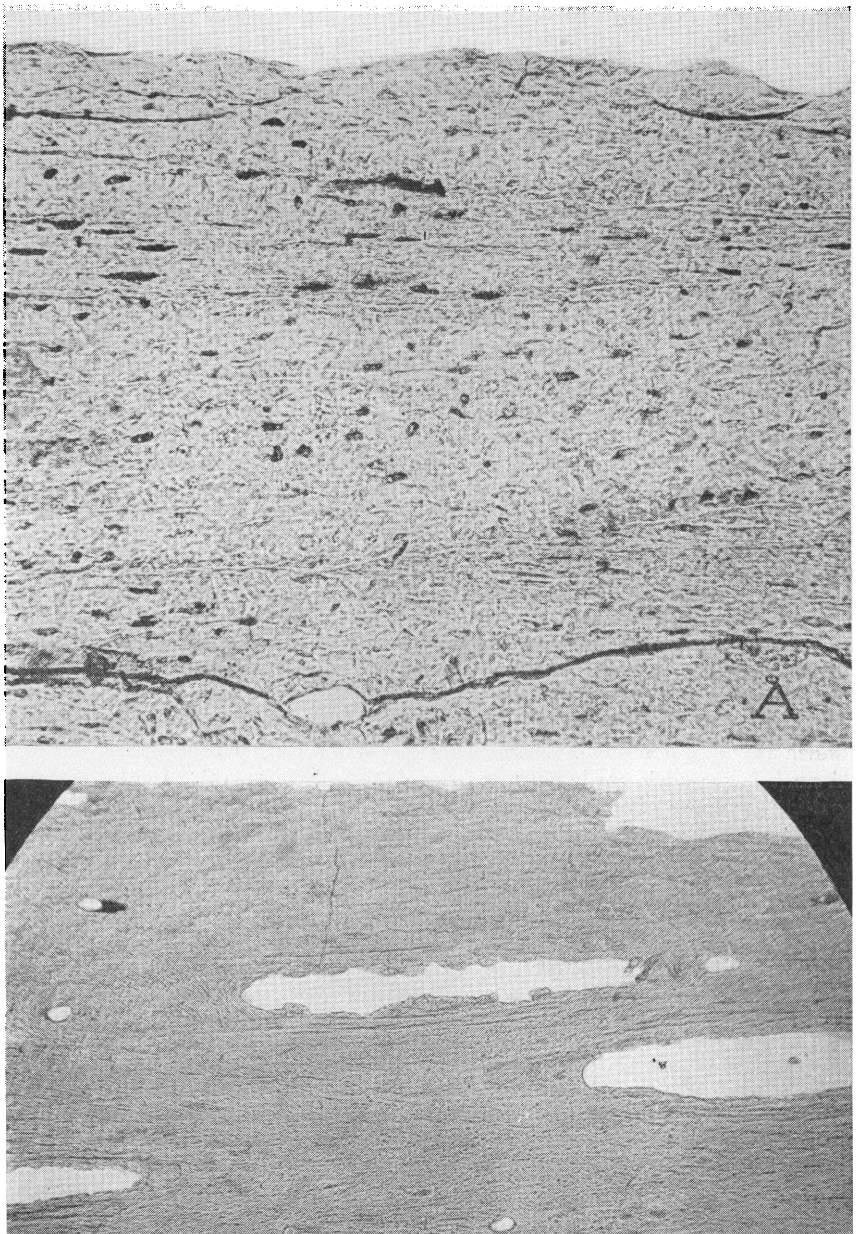

Fig. 5

Fig. 6

A. Lacunæ, some of them invaded by bacteria, seen in longitudinal section of ossified tendon of dinosaur, *Trachodon annectens*. Lance Formation, near Hell Creek, Montana. ×600.

In the lower part of the field is a structure, running obliquely from right to left, which has the appearance of a perforating fiber of Sharpey. The fibrillæ are distinct. A similar structure is seen in the upper part of the field shown in B. Another is shown cutting the upper left corner of A.

B. Another area of same section. ×600. Numerous lacunæ are shown cut at different angles. The normal, uninvaded, lacunæ present short canaliculi. The ground substance has a fibrillar structure.

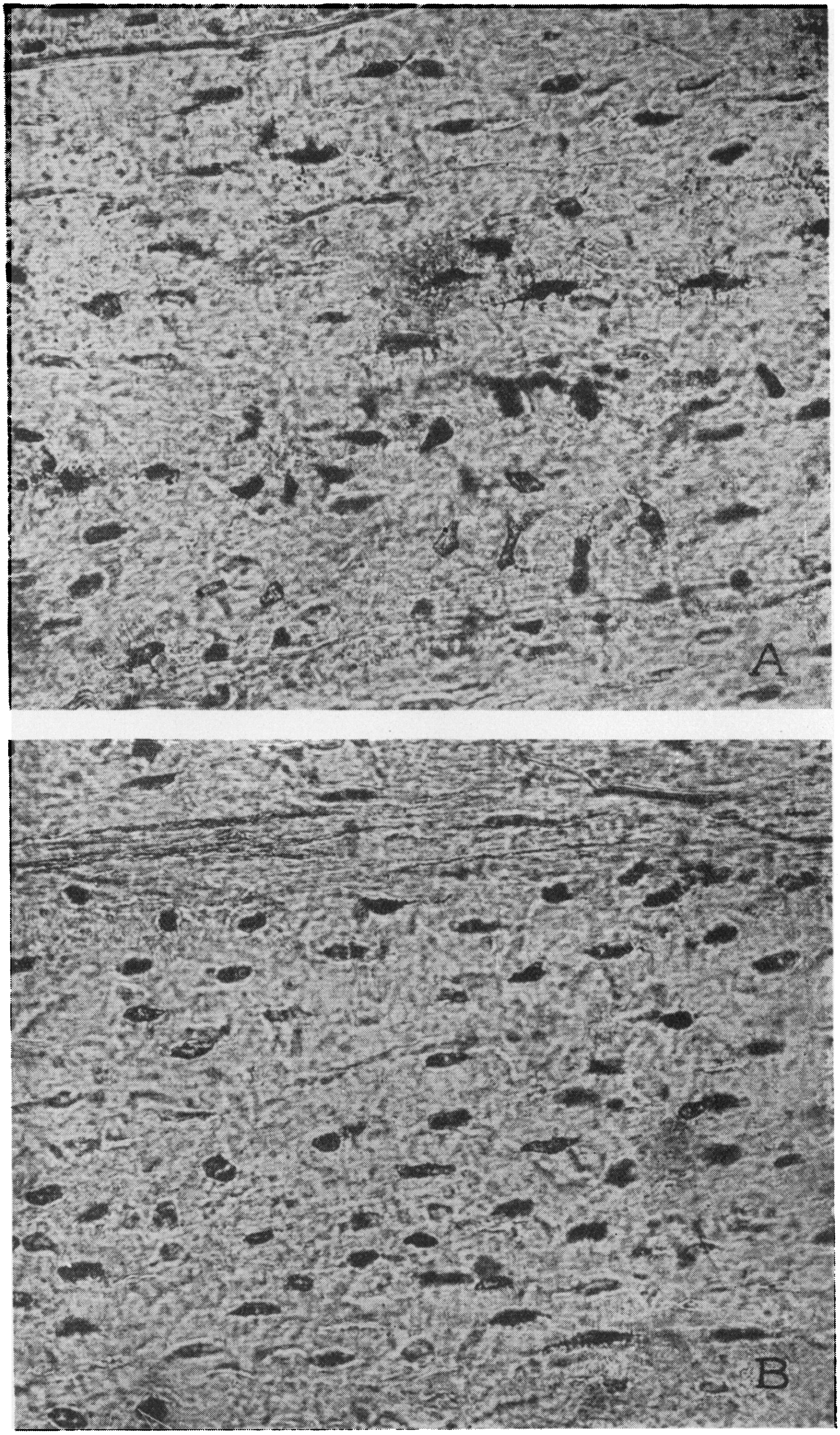

Fig 6