

Comment on the absence of ossified sternal elements in basal paravian dinosaurs

In a recent paper, Zheng et al. (1) studied the presence and absence of sternal elements within the pectoral girdle of three paravian theropods (*Anchiornis*, *Jeholornis*, and *Sapeornis*) from the Jehol Biota of China, which are each known from a number of specimens. Based on the consistent absence of any traces of sternal elements in *Anchiornis* and *Sapeornis*, but the frequent perseveration of soft tissues (e.g., feathers) in the sediments of the Jehol Biota, the authors conclude that sternal elements were completely absent in these taxa, even as chondral elements. Because of the lack of ossified sternal elements, Zheng et al. conclude the same for *Archaeopteryx*, and finally propose the complete absence of sternal elements as plesiomorphic condition for Avialae and that the sternal elements of basal birds are not homologous to those of Oviraptorosauria or Dromaeosauridae.

However, these conclusions are problematic for several reasons. First, in contrast to sauropodomorphs and ornithischians, most theropod dinosaurs lack ossified sternal elements (2). Thus, following the argument put forth by Zheng et al., the absence of these bones would not represent the plesiomorphic condition for Avialae, but for theropods in general. Second, the frequent preservation of feathers and skin remains in the sediments of the Jehol Biota is not a strong argument for the absence of chondral sternal elements

in *Anchiornis* and *Sapeornis*, because the fossilization of these integumental structures is usually based on the preservation of melanosomes (3). Because cartilage does not contain melanin-rich pigment cells, its chances for fossilization would be generally smaller under the same taphonomic conditions. Third, although ossified sternal elements are frequently lacking in the fossils of *Archaeopteryx*, the third to eighth thoracic ribs are somewhat expanded at their distal ends, probably representing articular facets for six pairs of cartilagenous sternal ribs (4). Furthermore, the remains of the pectoral girdle in the Berlin specimen contain a triangular crystalline calcite structure between the right humerus and the left coracoid, which lies ventral to the glenoid fossa of the right scapula. Based on its anatomical position, and the fact that in the Solnhofen limestones chondral elements are often replaced by crystalline calcite after their decay, it is probable that this calcite structure represents the remains of a cartilagenous sternal element (5). Thus, the supposed number of sternal ribs would further indicate that the chondral sternal elements of *Archaeopteryx* were quite large, allowing the attachment of relatively extensive pectoral muscles.

Based on these points, the lack of sterna only demonstrates the absence of ossified sternal elements in some paravian taxa, but cannot rule out the existence of cartilagenous

ones. The chances for cartilage preservation in the fossil record are taphonomically biased, and this tissue might only be demonstrated indirectly, as shown in the *Archaeopteryx* example. Accordingly, it would be essential to know how common cartilage preservation is in the tetrapod fauna of the Jehol Biota in general to interpret the current results in the way Zheng et al. do (1). Here, a fossil examination under UV light (5) may help to find respective traces in a future approach.

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1 Zheng X, et al. (2014) On the absence of sternal elements in *Anchiornis* (Paraves) and *Sapeornis* (Aves) and the complex early evolution of the avian sternum. *Proc Natl Acad Sci USA* 111(38): 13900–13905.

2 Weishampel DB, Dodson P, Osmólska H (2004) *The Dinosauria* (Univ of California Press, Berkeley, CA).

3 Li Q, et al. (2014) Melanosome evolution indicates a key physiological shift within feathered dinosaurs. *Nature* 507(7492): 350–353.

4 Wellnhofer P (2009) *Archaeopteryx: The Icon of Evolution* (Dr. Friedrich Pfeil, Munich).

5 Tischlinger H, Unwin DM (2004) UV-Untersuchungen des Berliner Exemplars von *Archaeopteryx lithographica* H. v. Meyer 1861 und der isolierten *Archaeopteryx*-Feder. *Archaeopteryx* 22:17–50.

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