

preservation of shallow-tier biogenic and physical sedimentary structures was still open as late as the Middle Cambrian. The anactualistic lack of complex ichnofabrics and rarity of even simple ichnofabrics in the Pioche Formation, Torrearboles Sandstone and similarly-aged strata may hold important implications for contemporaneous taphonomic and geochemical phenomena accompanying the radiation of early metazoan ecosystems. Detailed study of the trace fossil record, by providing a semi-quantitative log of substrate conditions, may give us our most direct means of testing and resolving competing models for Paleozoic substrate evolution.

WHAT PNEUMATICITY TELLS US ABOUT SAUROPODS, AND VICE VERSA

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Postcranial skeletal pneumaticity (PSP) is present in extant birds and in extinct theropod and sauropod dinosaurs and pterosaurs. PSP has important implications for sauropod paleobiology, and sauropods allow investigation of this unusual anatomical system in a long-lived, diverse clade of morphologically extreme animals.

What pneumaticity tells us about sauropods:

1. PSP allowed sauropods to exploit a wider range of postcranial bone densities than mammals, which are constrained to fill their bone spaces with marrow rather than air.
2. By replacing marrow with air, PSP lightened some of the bones and possibly the entire bodies of sauropods.
3. Lightweight pneumatic vertebrae facilitated the evolution of very long (5-15 meter) necks in sauropods, which were a key innovation in the evolution of giant size.
4. The distribution of PSP in sauropod skeletons implies a bird-like air sac system, which probably allowed efficient gas exchange and heat exchange.

What sauropods tell us about pneumaticity:

1. The evolution of PSP in basal sauropodomorphs was complex, and not consistent with a simple recapitulatory model. Multiple pneumatic invasions of the vertebral column suggest multiple sources of opportunistically invading diverticula.
2. Gaps in pneumatization in the tails of some sauropods show that "cryptic" diverticula could leapfrog over bones without leaving obvious traces. This implies that the extent of the diverticular system

will always be underdetermined by skeletal evidence. The same is true in birds, in which most visceral, intermuscular, and subcutaneous diverticula leave no skeletal traces.

3. PSP in sauropodomorphs shows an evolutionary progression from fossae to large simple chambers to small complex chambers; the reasons for this are not yet known.

4. Bone-to-air ratios in the vertebrae and ribs vary among sauropods and are very high in some long-necked taxa, which suggest that this character was subject to selection. The same is probably true in birds, but the magnitudes of the selective effects are unknown.

5. Sauropod vertebrae are sometimes incompletely pneumatized, especially in basal taxa. This contradicts the predictions of the "epithelial hypothesis" of pneumatization, but is consistent with incomplete pneumatization in some extant birds and in the sinuses of some mammals. The epithelial hypothesis, while useful, is an incomplete description of pneumatization.

6. Some vertebral laminae in sauropods are embossed, showing concavities on one side but corresponding convexities on the other. These embossed laminae contain slightly more bony material than smooth ones would have, so pneumatization did not always produce minimum-mass structures.

BIO- AND CHEMOSTRATIGRAPHIC RECORD THROUGH THE UPPER KELLWASSER ANOXIC EVENT (APPALACHIAN BASIN)

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Most researchers agree that oxygen is limited in association with Late Devonian biotic crises because of the pervasiveness of black shale preservation in Devonian Age stratigraphic units, but the duration and extent of marine anoxia, and its association to depressed origination rates and targeted extinction, are not well-constrained (Joachimski and Buggisch, 1993; Bond et al., 2004). Increasingly, it is recognized that black shales do not represent homogenous conditions, but may in fact capture a range of bottom water redox conditions (Boyer et al., 2011).

Potential evidence for rapid fluctuations justifies a high resolution study of the bio- and chemostratigraphy of Devonian black shale units,