

# Discovery of dermal spines reveals a new look for sauropod dinosaurs

Stephen A. Czerkas

P.O. Box 277, Monticello, Utah 84535

## ABSTRACT

The smooth, quasi-elephantine form of the huge, long-necked sauropods is a familiar image widely repeated in both scientific and general literature. Recent discovery of fossilized sauropod (diplodocid) skin impressions reveals a significantly different appearance for these dinosaurs. The fossilized skin demonstrates that a median row of spines was present over the tail and may have continued anteriorly along the body and neck.

## INTRODUCTION

Exactly what a live dinosaur may have looked like has long captured the imaginations of both scientists and artists as well as the general public. Recently, fossilized skin impressions were discovered that revealed previously unknown details of what one of the most famous groups of dinosaurs would have actually looked like when alive. These dinosaurs are the sauropods, the long-necked giants.

The earliest discovery of a skin impression from a dinosaur was made in 1852 and consisted of a patch ~20 cm in diameter directly overlying a forelimb of the sauropod *Pelorosaurus* (Mantell, 1852). Although representing only a tiny fraction of the entire skin surface, this small patch revealed that the animal was at least partly covered with a scaly hide of nonoverlapping rounded tubercles, the largest of which were ~3 cm in diameter. They were arranged in rosette patterns.

Several genera of dinosaurs are fairly well represented by skin impressions and, in the case of hadrosaurs, by nearly complete mummies. Although all known dinosaur skin impressions are generally similar, being composed of tubercles, there are also distinct ornamental patterns of scalation that can often be differentiated between the various types of dinosaurs. Notably, several specimens of hadrosaurs exhibit indications of an ornamental frill running along the

dorsal midline of the neck, back, and tail. The three best examples of these frills consist of fleshy lobes or conical spines.

Until recently, only ten small pieces of sauropod skin impressions were known, including a footprint (Lockley et al., 1992). The greatest known quantity of sauropod skin impressions was discovered by Barnum Brown at the Howe Quarry, Wyoming, in 1933–1934. Unfortunately, most of the impressions were sacrificed while excavating the bones from the quarry. Only three small fragments of skin from the original quarry still exist.

## FOSSILS INDICATE A NEW BODY PROFILE

In 1990, the Howe Quarry was reopened by professional collector Kirby Siber, and, once again, fossil skin impressions were found together with numerous sauropod bones. The latter are as yet undescribed but pertain to diplodocids resembling *Diplodocus* and *Barosaurus*. The partial skeletons represent individuals of sizes ranging from ~2–3 m up to 14 m in length (Fig. 1). Numerous skin impressions were preserved throughout the quarry, including many small pieces several centimetres in diameter and larger sections measuring up to 25 × 75 cm.

Most of the skin impressions closely resemble the few previously known examples, consisting of comparatively large tubercles ~3 cm in diam-

eter. In addition, though, it was observed that each large tubercle was covered with many smaller tubercles ~2–3 mm in diameter, creating a rugose, pebbly surface. Much of the skin was collected in both positive and negative molds as it naturally separated. As previously observed (Brown, 1935), a thin carbonaceous layer conforming to the surface of the skin impressions appears to represent the altered substance of the actual epidermis.

Significantly, many conical, or spinelike elements were found throughout the quarry (Figs. 2–5). Some were isolated, and others were connected together, indicating that their natural positions in life formed a continuous line (Fig. 6). Some were found loosely associated with semi-articulated tail vertebrae. Several pieces of skin have been preserved in place around the vertebrae of the distal, whiplash part of the tail. These skin impressions clearly indicate the original dimensions of the tail both in profile and in cross section. They further confirm that the spines were located along the dorsal midline structure, at least along the whiplash part of the tail. Exactly how far the spines continued up the tail is not known. And the precise pattern and full extent of the ornamentation also remain unknown. But, as with the hadrosaurs, it is likely that the spines continued beyond the tail and along the sauropod's body and neck as well.

The spines are smallest over the distal part of

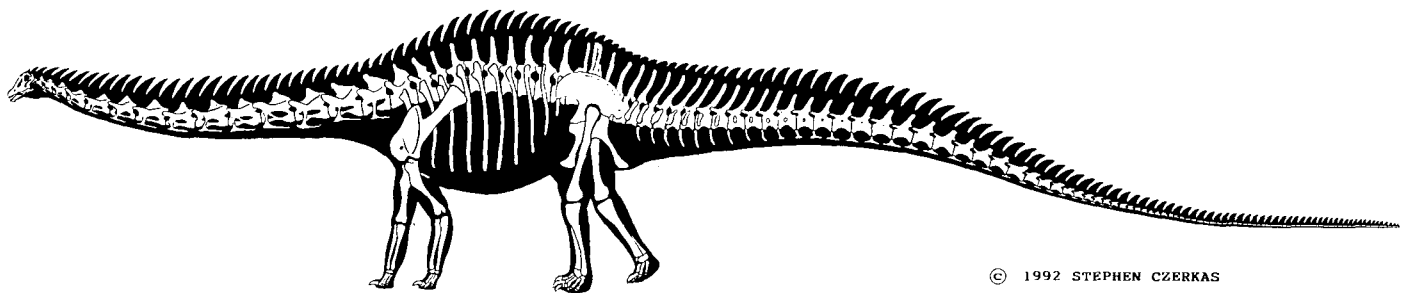
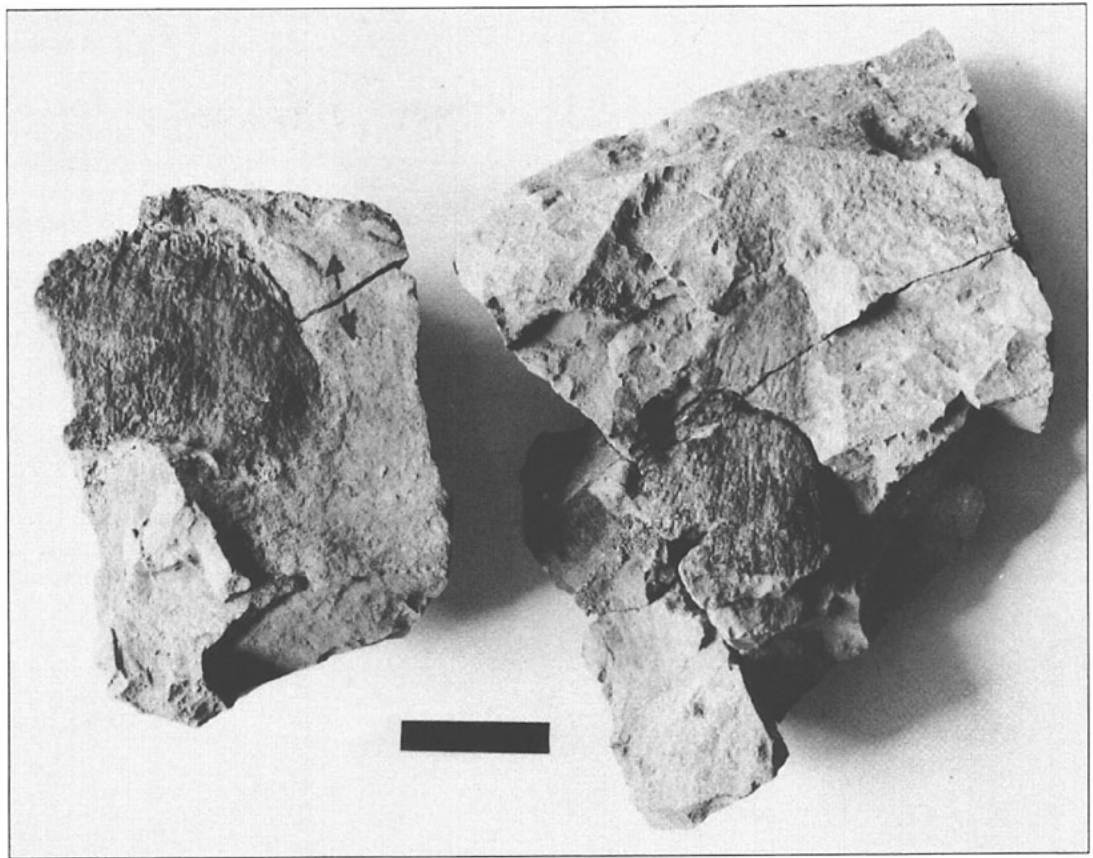


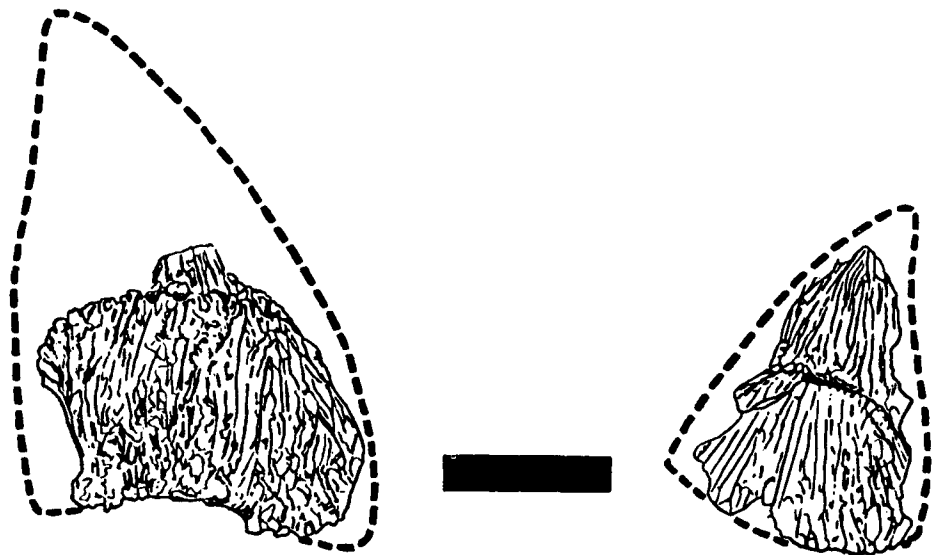
Figure 1. Skeleton and body outline of a diplodocid sauropod demonstrating ornamented profile of dermal spines. The partial skeletons associated with skin impressions indicate a subadult body length of ~14 m.

**Figure 2. Photographs of two dermal spines within surrounding matrix. Left: spine seen in right-lateral view. Right: left-lateral view. Scale bar = 5 cm.**



the tail and increase in size anteriorly. The apex of the largest preserved spine is missing, but a comparison of the size of its base with more complete specimens suggests a total height of ~18 cm. No fewer than 14 spines of various sizes are preserved, and considering the randomness of the sampling, it is quite possible that even larger spines existed.

Some of the dermal spines are preserved in profile, whereas others were prepared in the round. There appears to be a variable range in the shape of the dermal spines. Some are quite narrow, and others are broader and more conical. Also, although some spines are sharply pointed and straight, others are recurved and may have blunter tips. The surface of the spines is covered with hypertrophied tubercles, about 2–3 mm in diameter, that reach to the apex of the spines and together form a fluted or combed texture of parallel lines. One peculiar characteristic of the preservation is that, while the bottom third to half of the spine is usually rounded and dimensional, the upper half or more is strongly compressed into a flat profile. Also significant is that despite the large size of some of the spines, there is no respective bony core or scute within the spine, more commonly found as an obvious sign of dermal ornamentation—for example, on armored dinosaurs such as the stegosaurs or ankylosaurs.



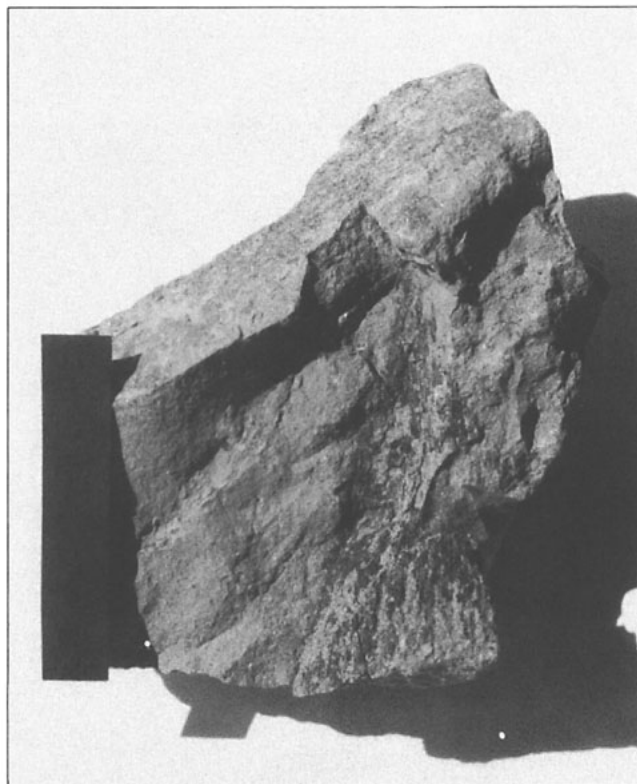
**Figure 3. Corresponding drawings of dermal spines shown in Figure 2 without matrix. Outlines (dashed lines) are generalized upon additional examples of spines. However, the outlines vary and may be more sharply pointed. Scale bar = 5 cm.**

#### **DISCUSSION AND CONCLUSIONS**

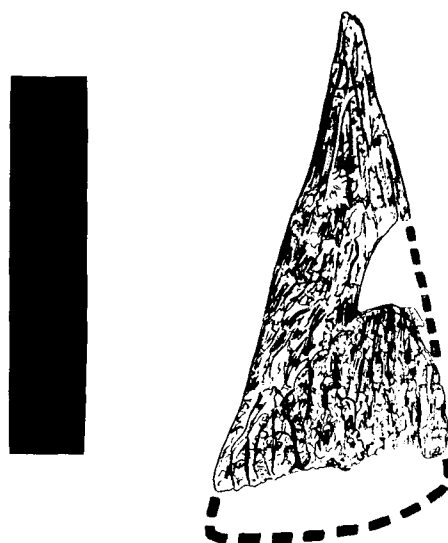
Traditionally, sauropods have been portrayed as having small scales or a rather smooth, leathery skin notably devoid of any obtrusive ornamentation. Ironically, some cartoon restorations often added an ornamented midline for which

there was previously no evidence. The current discovery of dermal spines on the Howe Quarry sauropods implies, but does not prove, that other types of sauropods were similarly equipped. Indeed, it is more logical to assume that there would have been a considerable range of varia-

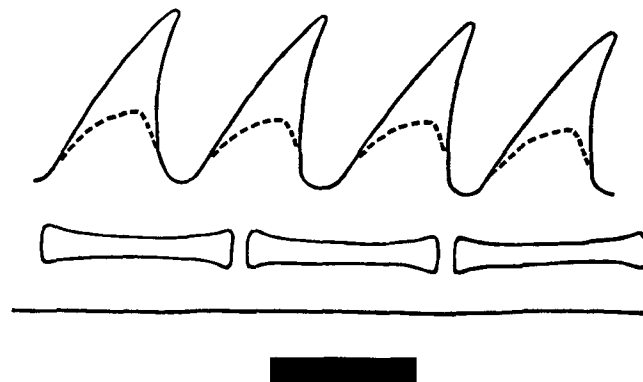
**Figure 4. Photograph of small, sharply pointed dermal spine in matrix. Spine seen in left-lateral view. Scale bar = 5 cm.**



**Figure 5. Corresponding drawing of dermal spine in Figure 4 without matrix. Scale bar = 5 cm.**



**Figure 6. Drawing of distal caudal vertebrae with skin outline. Seen in left-lateral view. Drawing is composite from two individual specimens of tails with spines and isolated spines of similar size. Dashed lines represent questionable profile of smallest dermal spines. Scale bar = 5 cm.**



bility in size, pattern, and extent of dermal spines among the numerous and highly diversified group of sauropods. This presents a quandary as to how the various types of sauropods should be portrayed. Depictions of sauropods without dermal spines would automatically imply that the interpretations are based upon verifiable evidence while still only being conjectural speculation. Therefore, until additional physical evidence demonstrates otherwise, the traditional imagery of sauropods without dermal spines is contrary to the evidence at hand and the current understanding of what these dinosaurs actually looked like. Future restorations of sauropods will require the addition of a medially placed row of dermal spines at least along the tail so as to maintain accuracy as reflected by the fossil record. Precisely what any sauropods must have looked like, including those from the Howe Quarry, is still a mystery. It is, however, certain that the integument of the Howe Quarry diplodocid was far more complex than was previously suspected. This also strongly suggests that other sauropod taxa may well have differed significantly in appearance from previous interpretations.

#### ACKNOWLEDGMENTS

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