



HADROSAURID DINOSAUR SKIN IMPRESSIONS FROM THE UPPER CRETACEOUS KAIPAROWITS FORMATION OF SOUTHERN UTAH, USA

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ABSTRACT

Skin impressions from hadrosaurid dinosaurs are relatively common finds throughout the Cretaceous Western Interior of North America. A recently discovered specimen from the late Campanian-aged Kaiparowits Formation of southern Utah is typical for hadrosaurs, with randomly arranged polygonal tubercles averaging around 4 mm in length and 3 mm in width. Based on the associated bones, these impressions likely originated on the thorax of the animal. In contrast with most previously published finds, the skin is not preserved in perfect articulation with the skeleton. This suggests a taphonomic mode in which the skeleton and soft tissues were partially disarticulated prior to burial.

Introduction

The hadrosaurs, or 'duck-billed' dinosaurs, present one of the best-known records of fossil skin impressions for any dinosaur group. These impressions range from small patches to entire 'mummies,' allowing confident reconstruction of virtually the entire body's surface texture (*e.g.* Lull & Wright, 1942). To date, skin impressions

have been described and figured for lambeosaurine and hadrosaurine hadrosaurs from throughout the Upper Cretaceous of western North America, including the Almond Formation of Wyoming (Gates & Farke, 2009), Dinosaur Park Formation of Alberta (Lambe, 1902; 1914a,b; Brown, 1916; Parks, 1920), Hell Creek Formation of Montana (Horner, 1984; Wideman & Lofgren, 2001), North Dakota (Manning *et al.*,

2009), and South Dakota (Cope, 1885), Judith River Formation of Montana (Negro & Prieto-Marquez, 2001), Lance Formation of Wyoming (Osborn, 1909; 1912; Versluys, 1923; Wegweiser *et al.*, 2006), Neslen Formation of Utah (Anderson *et al.*, 1999), and the Ringbone Formation of New Mexico (Anderson *et al.*, 1998). Although hadrosaur skin impressions are relatively common in the Kaiparowits Formation of Utah (*e.g.* Getty *et al.*, 2009; Lund *et al.*, 2009), only two brief descriptions (Gillette *et al.*, 2002; Gates *et al.*, in press) have been published prior to this paper.

The Kaiparowits Formation is particularly well-exposed within Grand Staircase-Escalante National Monument, southern Utah. The unit is late Campanian in age (76-74 Ma), and was deposited along the western coastal plain of North America's Cretaceous Interior Seaway (Roberts *et al.*, 2005; Roberts, 2007). Informally divided into three units (Lower, Middle, and Upper), the Kaiparowits Formation preserves a rich and unique vertebrate fauna ranging from small mammals to large non-avian dinosaurs. Hadrosaurs are perhaps the most common dinosaurs, known from isolated elements as well as nearly complete skeletons. Taxa include the lambeosaurine *Parasaurolophus* cf. *P. cyrtocris-tatus* (Weishampel & Jensen, 1978) as well as the hadrosaurines *Gryposaurus monumentensis* and *Gryposaurus* cf. *G. notabilis* (Gates & Sampson, 2007).

The specimen described here is a fragmentary and disarticulated skeleton of a generically indeterminate hadrosaurid, preserved with numerous patches of skin impressions. It was discovered in 2006 by a field crew from the Raymond M. Alf Museum of Paleontology, and additional collections were made at the site in 2009. Although the specimen does not preserve much of the skeleton, this description of skin impressions adds important information on the soft tissue anatomy and taphonomy of a hadrosaur from the Kaiparowits Formation. Furthermore, it provides an important data point for ongoing studies of vertebrate taphonomy within this rock unit.

Institutional Abbreviations

RAM, Raymond M. Alf Museum of Paleontology, Claremont, California, USA.

SYSTEMATIC PALEONTOLOGY

Dinosauria Owen, 1842
Ornithischia Seeley, 1888
Hadrosauridae Cope, 1869

Genus and species indeterminate

Material – RAM 9137, a disarticulated skeleton preserving a partial scapula, coracoid, a nearly complete sternal plate, ribs, dorsal vertebrae, pedal phalanx, and natural molds and casts of skin impressions (25 pieces in total; figure 1). The specimen was heavily weathered upon discovery, and most of the elements (including the majority of the skin impressions) were collected as float.

Locality – RAM V200606, Grand Staircase-Escalante National Monument, Garfield County, Utah, USA. Detailed locality data are on file at the RAM and available to qualified researchers upon request.

Stratigraphic Horizon and Lithology – Upper portion of the middle unit of the Kaiparowits Formation (*sensu* Roberts *et al.*, 2005; Roberts, 2007), Upper Campanian. The specimen is preserved within a well-indurated, fine-grained, poorly sorted, immature channel sandstone.

Description

Identification

RAM 9137 is identified as a hadrosaurid based on the morphology of the incomplete scapula, sternal plate, and pedal phalanx. The hatchet-shaped sternal plate, with its flared, triangular proximal end and narrow, elongate distal end, is restricted to hadrosauroid dinosaurs, and particularly distinguishes RAM 9137 from other large ornithischians known in the Kaiparowits Formation (ceratopsids and ankylosaurs). Although both hadrosaurine and lambeosaurine hadrosaurids are known from the Kaiparowits Formation (Gates & Sampson, 2007; Gates *et al.*, in press), the recovered elements are not sufficient to identify the specimen more precisely.

Skin Impressions

Consistent with previously described examples from hadrosaurs (see citations above), the skin impressions of RAM 9137 exhibit raised, non-imbricating tubercles (figure 1A-C). Some of the tubercles were moderately abraded by ero-

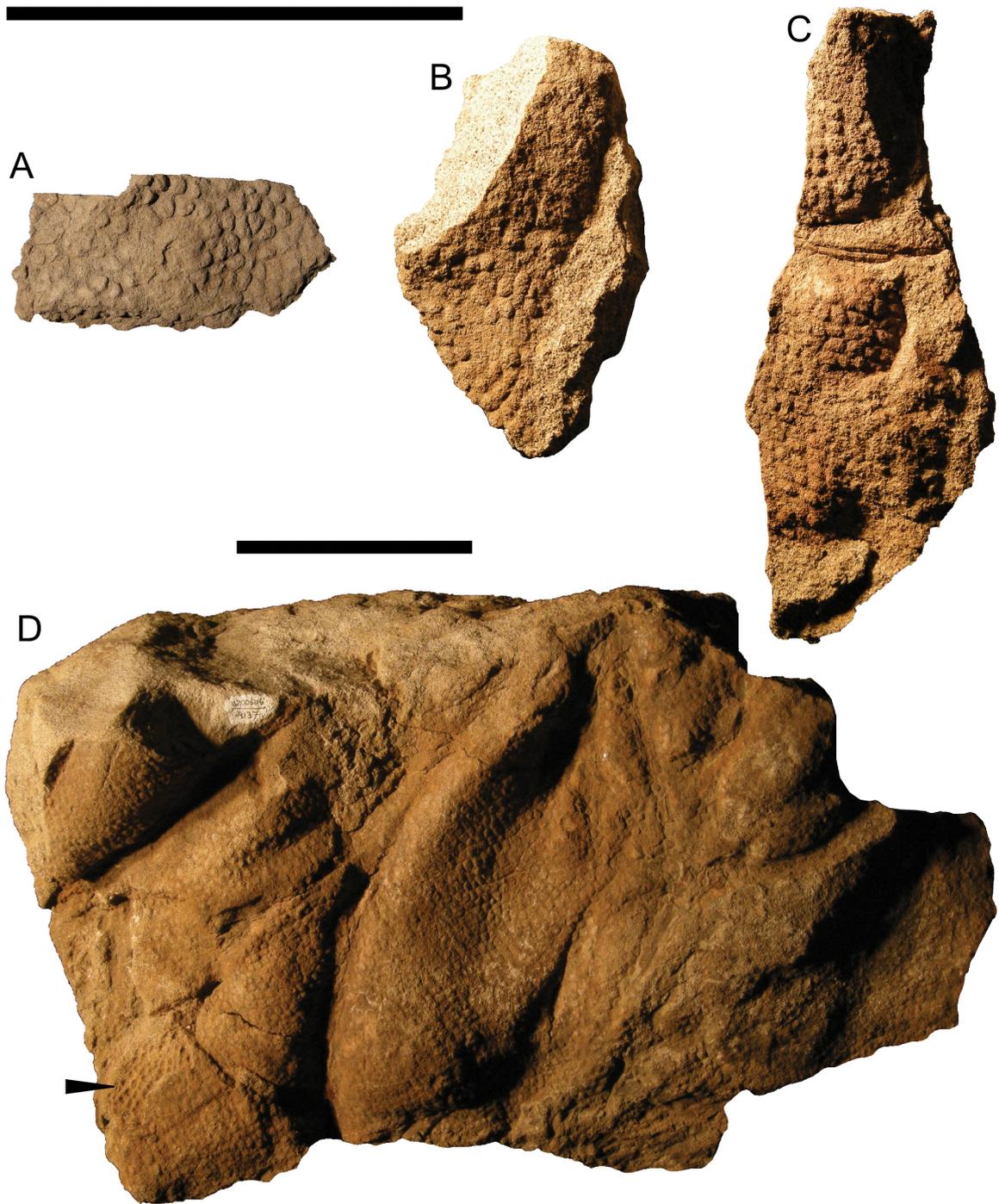


Figure 1. Representative skin impressions from a hadrosaurid dinosaur, RAM 9137. Lighting is from the upper left in all cases, and all specimens are natural casts (except for a small portion of D, where a natural mold is indicated by an arrow). The apparent large tubercle in the center of A is in fact an abraded area. The scale bars equal 10 cm; the upper bar is for A-C, and the lower bar is for D. Photography by Lucia Herrero. Courtesy of Raymond M. Alf Museum of Paleontology.

sion prior to collection, although most show full relief. These raised tubercles are randomly aligned and primarily elliptical to polygonal, although some variation in shape does occur (with occasional near-circular tubercles). Based on a measured sample of 50 tubercles, they range from 2.8 to 5.7 mm in maximum length (mean = 4.2 mm, standard deviation = 0.64) and 1.9 to 4.1 mm in maximum width (mean = 2.9 mm, standard deviation = 0.52). The length : width ratio ranges from 1.0 to 2.3 (mean = 1.5, standard deviation = 0.28). Unfortunately, the sediment is not sufficiently fine-grained to preserve fine-scale surface detail of the individual tubercles. None of the tubercles, as preserved, shows grooves or ridges seen in some other specimens (*e.g.* Anderson *et al.*, 1998), even when viewed under low angle lighting. The largest patch of impressions measures 360 mm by 220 mm (figure 1D).

Unfortunately, it cannot be determined if all of the impressions collected were from one originally contiguous piece of skin. Most of the impressions form smooth, flat sheets. Folding and bunching occur on some pieces, and in one case the skin was so folded that a natural mold and cast are immediately adjacent to each other (*e.g.* figure 1D). The disassociation of the skin from the bones indicates that this folding probably is a result of taphonomic processes and thus not necessarily representative of morphology in the living animal. The best preserved tubercles lay nearest to these folds, whereas the flatter areas of integument were exposed to more abrasion after exposure prior to collection. In the field, skin impressions were observed in place below a partial rib, with the tubercle surface facing away from the bone (*i.e.* the lateral surface of the skin was still in its correct orientation relative to the bones). This, along with the anatomical location of the recovered skeletal elements, suggests that at least some, if not all, of the integument originated on the trunk of the animal. However, the disarticulated nature of the skeleton indicates that the skin was moved at least slightly prior to burial.

Discussion and Conclusions

The skin impressions from RAM 9137 are broadly similar to previously described examples from hadrosaurs, especially in the tuberculate nature of the scales. The random distri-

bution of uniformly-sized tubercles in RAM 9137 is similar to that previously noted for the lateral surface of the body in other hadrosaurs (*e.g.* *Corythosaurus casuarius*, *Parasaurolophus walkeri*, *Lambeosaurus lambei* and *Gryposaurus incurvimanus*) as opposed to the clusters of 'pavement tubercles' found on the torso in *Edmontosaurus spp.* (Lull & Wright, 1942; Osborn, 1912). The former similarity is consistent with the association between skin impressions and ribs in RAM 9137. A lack of ornamentation on individual tubercles in the preserved specimen may simply reflect the portion of the body from which the impressions originated, or a general characteristic of the animal. The former case is more likely, because expression of this trait varies across the body in a single individual (*e.g.* Lull & Wright, 1942; Gates *et al.*, in press).

Taphonomically, RAM 9137 differs sharply from the majority of described hadrosaur skin impressions from other formations, which are typically in presumed life position relative to articulated skeletons (*e.g.* Brown, 1916; Osborn, 1912). The only previously published exception is isolated skin impressions from a *Brachylophosaurus* bonebed in the Judith River Formation (Negro & Prieto-Marquez, 2001). Skin impressions are known from other partially articulated or disarticulated, undescribed dinosaur skeletons from the Kaiparowits Formation (*e.g.* Gillette *et al.*, 2002; Gates *et al.*, in press). Such an occurrence with a disarticulated skeleton suggests that the skin was relatively durable, capable of surviving separation from the carcass and minor weathering (Lund *et al.*, 2009). The preservational pattern seen in RAM 9137 and other specimens may reflect a taphonomic mode unique to the Kaiparowits Formation, or more likely a lack of recognition of skin impressions with disarticulated dinosaur skeletons from other units. Much additional work is required on the taphonomy of skin preservation in order to test the latter hypothesis.

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