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# A LATE CRETACEOUS (CAMPANIAN) HADROSAUR SACRUM FROM THE CAPE SEBASTIAN SANDSTONE, CURRY COUNTY, OREGON

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**Abstract—**This paper describes a partial dinosaur sacrum of Campanian age from the shallow marine Cape Sebastian Sandstone in Curry County, Oregon. It is the first dinosaur fossil from the State. The specimen is from a hadrosaurid because it possesses at least eight sacral vertebrae and has lamellar sacral ribs characteristic of hadrosaurs. The morphology of the sacral ribs suggests a hadrosaurine.

## INTRODUCTION

Mesozoic strata in Oregon are marine, and, as a result, there has been only one dinosaur find to date from the state. This paper describes that specimen. Bourgeois (1980) reported that the specimen was first discovered by paleontologists of the U. S. Geological Survey in a sea-cliff exposure at the southwestern tip of Cape Sebastian (Fig. 1), in shallow-marine Upper Cretaceous beds referable to the Cape Sebastian Sandstone.

In March 1969, a party from the Department of Paleontology, University of California, Berkeley, visited the site. At that time, the crew relocated and made a sketch of the specimen (Fig. 2A) and recognized that the bones were from a dinosaur. The Northwest Museum of Natural History Association excavated the specimen in 1994 (Fig. 2B) and ascertained that the fossil is a sacrum. Preliminary preparation revealed at least eight sacral vertebrae, which suggested a hadrosaur. The specimen was fully prepared between 2013 and 2016.

While remains of terrestrial vertebrates such as dinosaurs are not common in marine sediments, they do occur sporadically. Morris (1973), in his review of hadrosaurs from the Pacific Coast, cited numerous occurrences in marine sediments in California and Baja California Norte (Mexico). Horner (1979) reviewed Late Cretaceous dinosaur remains in marine sediments in North America and found that hadrosaurine remains outnumber those of other coeval dinosaurs. Similarly, Schwimmer (1997) reviewed the occurrences of Late Cretaceous dinosaurs from the East Coast and found hadrosaur abundance over most other dinosaurs in marine sediments. Again, most identifiable hadrosaur specimens were of hadrosaurines. It is not well understood why hadrosaurines are so well represented in the marine sediments. This note adds to the record of hadrosaurs from marine rocks.

## GEOLOGY AND STRATIGRAPHY

The area from which the sacrum came was first mapped in detail by Howard and Dott (1961). This included a “massive sandstone” unit at Cape Sebastian that Hunter et al. (1970) subdivided into lower and upper sandstone units separated by an angular unconformity. Dott (1971) provided the formal name Cape Sebastian Sandstone, which included the “massive sandstone” rocks at the Cape. Bourgeois (1980) confined the Cape Sebastian Sandstone, about 200 m thick, to those beds above the unconformity, and later (Bourgeois and Dott, 1985) allocated the beds subjacent to the unconformity to a newly named Houstenaden Creek Formation, having a cumulative thickness of about 500 m.

The Cape Sebastian Sandstone unconformably overlies the Houstenaden Creek Formation and transitionally grades upsection into the approximately 300 m thick Hunters Cove Formation (Fig. 3), a turbiditic sequence consisting of alternating mudstone and sandstone. The Cape Sebastian Sandstone represents a fining upward succession trending from foreshore to offshore depositional environments (Bourgeois, 1980; Bourgeois and Dott,1985). The formation was divided into four facies based on lithology, bedding structures, and trace fauna. These

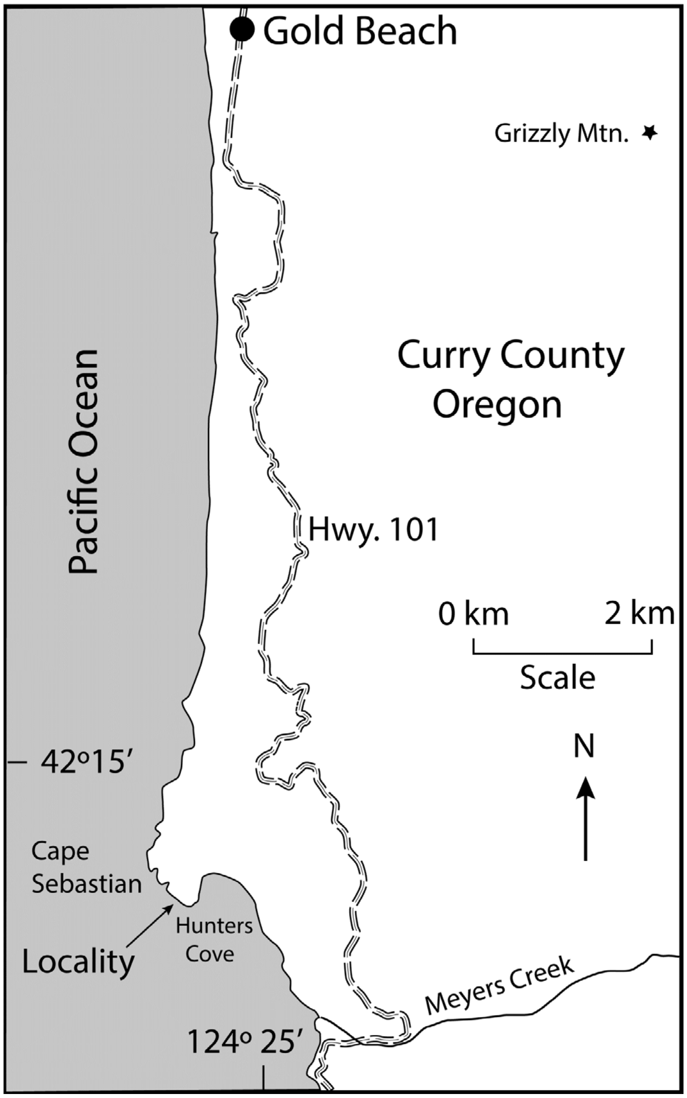
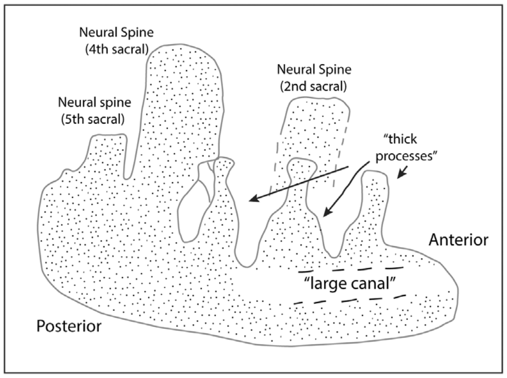
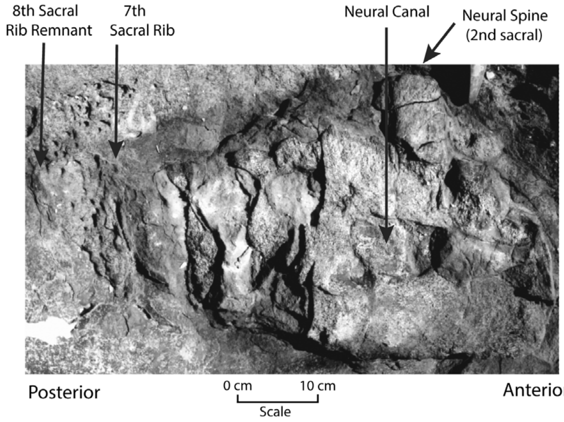


FIGURE 1. Map showing locality at Cape Sebastian, Oregon.



(A) 1969 field sketch



(B) 1994 photopgraph (in matrix)

FIGURE 2. NWM 2150, hadrosaur sacrum *in situ*. **A,** 1969 field sketch of sacrum made by the late Donald Savage, formerly with the University of California, Berkeley. The specimen was estimated to have been about 60 cm long. "Thick processes" appear to represent cross-sections of transverse processes and sacral ribs from the right side of the sacrum; and **B,** 1994 photograph of specimen in situ prior to excavation.

include the: (a) conglomeratic, (b) lower hummocky-bedded, (c) upper hummocky-bedded and burrowed, and the (d) parallel-laminated and burrowed facies, in ascending stratigraphic order (Bourgeois, 1980). Bourgeois (1980) reported the "reptilian vertebrae" (the sacrum described herein) as being from near the base of the upper hummocky-bedded and burrowed facies. The facies was deposited in an inner shelf environment in a water depth of up to about 50 m (Bourgeois, 1980; Bourgeois and Dott, 1985).

Hunter and Clifton (1982) gave a detailed description of a part of the upper hummocky-bedded and burrowed facies. They depicted a 20-m thick section measured at the southern end of Cape Sebastian from which the sacrum was found. They recognized 14 depositional cycles within their section, each consisting of a lower, hummocky cross-stratified sandstone, a middle, planar- and ripple-bedded sandstone (may include a shale bed), and an upper, bioturbated sandstone. The sacrum (=NWM 2150) came from one of the bioturbated beds, most likely in the lower part of the section given in Hunter and Clifton (1982; Fig. 3). The lithology in which it was found is a fine, well-sorted, "structureless" sandstone with abundant carbonized woody debris and occasional rip-up mudstone clasts several centimeters in diameter.

### Tectonic Displacement of the Cretaceous Section

The Gold Beach tectonostratigraphic terrane was proposed by Blake (1984) and Blake et al. (1985) to encompass the Upper Jurassic Otter Point Formation and the Upper Cretaceous formations described above, which crop out along the southwestern Oregon Coast. The Upper Cretaceous sequence is an overlap assemblage on the Otter Point Formation. Latitudinal displacement of the Gold Beach Terrane is of interest for paleobiogeographic reconstruction. Bourgeois and Dott (1985) considered the provenance of conglomerates from the Upper Cretaceous sequence problematic and proposed latitudinal displacement of 1000 km or more to match up with formations now in California. Latitudinal displacement of the Otter Point Formation of up to 1200 km has been proposed based on paleomagnetic work (Blake et al., 1985). Further, preliminary paleomagnetic work by Housen (2015) gave tentative results based on a few samples from the Houstenaden Creek Formation, these suggesting the possibility of a Late Cretaceous paleolatitude of 36°N (present day Southern California) versus the present latitude of 42.3°N for Cape Sebastian. Thus, the Gold Beach and associated terranes are implicated in large-scale paleotectonic reconstructions for the western cordillera, and the range of possibilities for many terranes commonly falls between several hundred to a few thousand kilometers of latitudinal displacement, with a range of 1000 to 1400 km being most likely (Butler et al., 2001; Dickinson, 2004, 2008; Hildebrand, 2015).

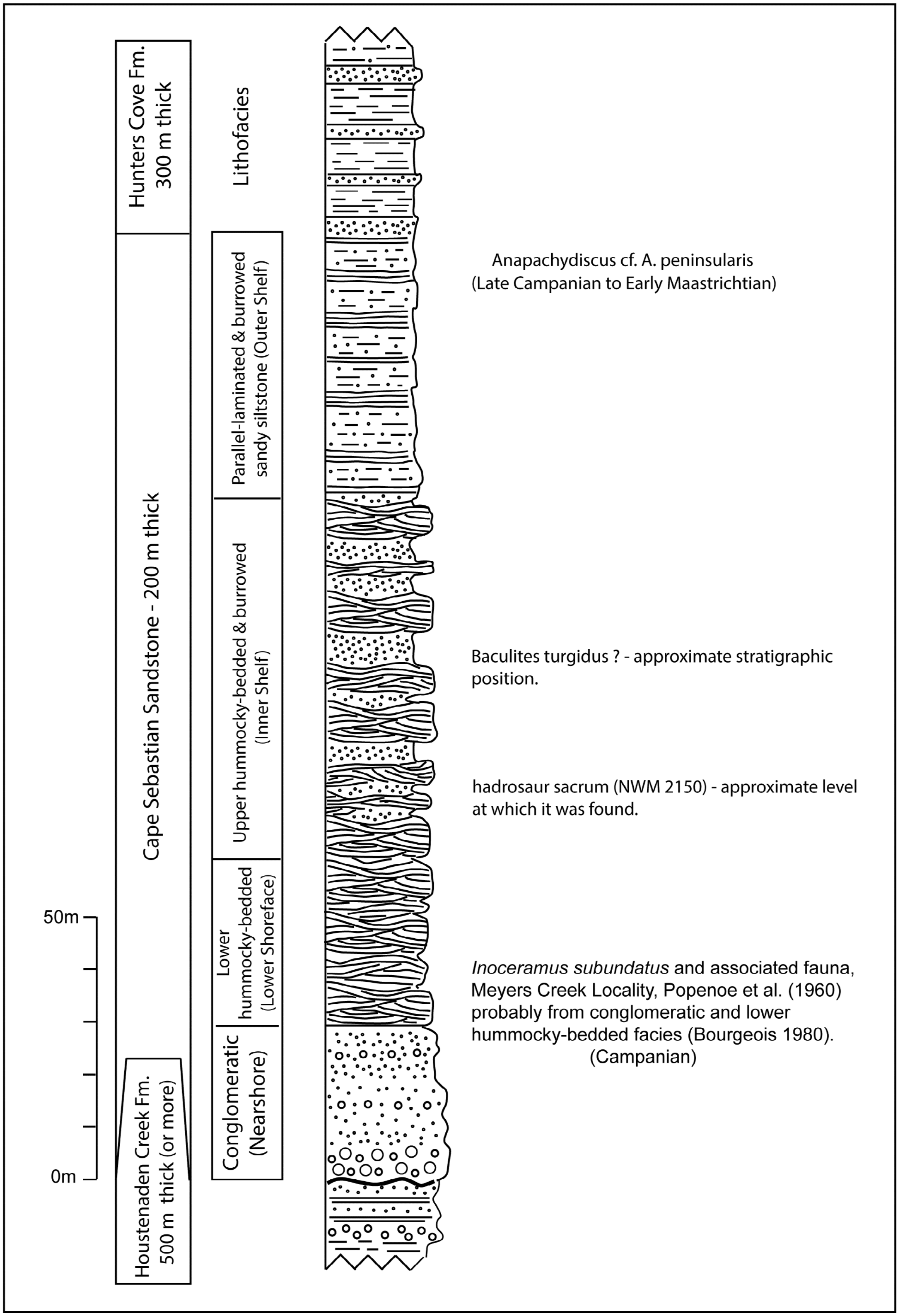
While the magnitude of displacements remains an open question, they need to be considered to infer the relative Cretaceous proximity of the Oregon hadrosaur (NWM 2150) with other locations that are now geographically distant. A recent proposal (Hildebrand, 2015) would place the Gold Beach terrane in relative proximity to hadrosaur localities in Mexico (Ramírez-Velasco et al., 2014) that were tied to the continent, such as those in the states of Sonora, Coahuila, and Chihuahua. It would also have brought the Oregon occurrence closer to sites in New Mexico (Lucas et al., 2000; Sullivan and Lucas, 2015) and the Big Bend occurrences in Texas discussed below (Davies, 1983; Wagner, 2001; Barnes, 2014). At least the more outboard hadrosaur occurrences in California (Hilton, 2003) as well as those in Baja, California Norte (Ramírez-Velasco et al., 2014) would themselves have undergone latitudinal displacement and may have remained south of the Gold Beach Terrane in the Cretaceous.

## AGE

Deposition of the Late Cretaceous stratigraphic succession of 1000 m or more in thickness in the Gold Beach Terrane may have begun as early as the Albian Stage, took place predominantly in the Campanian Stage, and ranged into the Maastrichtian Stage.

The Houstenaden Creek Formation is considered to be largely Campanian in age based on dinoflagellates and angiosperm pollen and reworked bivalves, although the basal shales might be Albian in age based on poorly preserved palynomorphs and foraminiferans (Bourgeois and Dott, 1985).

Age-diagnostic shelly faunas are uncommon and scattered in the Cape Sebastian Sandstone. Subdivision of the stage follows that of Haggart et al. (2009). A locality at Meyers Creek (Fig. 1), just south of the Cape, yielded molluscs (Popanoe et al., 1960) that Bourgeois (1980) considered mostly likely to have come from the lower two facies of the formation (Fig. 3). The fauna includes *Inoceramus subundatus* and *I. vancouverensis* (Popanoe, 1960; Dott, 1971), which have ranges that may extend from the lower to upper part of the Campanian Stage (Matsumoto, 1960; Jeletzky, 1970; Haggart, 1984). Dott (1971) reported both species of *Inoceramus* from the southeast end of Cape Sebastian, as well. A specimen tentatively referred to *Inoceramus turgidus* (Howard and Dott, 1961) was found a



Anapachydiscus cf. A. peninsularis
(Late Campanian to Early Maastrichtian)

Baculites turgidus ? - approximate stratigraphic position.

hadrosaur sacrum (NWM 2150) - approximate level at which it was found.

*Inoceramus subundatus* and associated fauna, Meyers Creek Locality, Popenoe et al. (1960) probably from conglomeratic and lower hummocky-bedded facies (Bourgeois 1980).
(Campanian)

FIGURE 3. Composite stratigraphic section of the Upper Cretaceous, Houstenaden Creek Formation, Cape Sebastian Sandstone, and Hunters Cove Formation. Modified from Bourgeois (1980) and Bourgeois and Dott (1985).

short distance stratigraphically above the hadrosuar bones (Fig. 3). That species is reported (Anderson, 1958) to have occurred in California above *I. chicoensis* and *Mortoniceras chicoensis* (=*M. randalli sensu* Matsumoto, 1959b) and could, therefore, be either lower or upper Campanian.

The ammonoid *Anapachydiscus* cf. *A. peninsularis* occurs near the top of the Cape Sebastian Sandstone (Bourgeois, 1980). Anderson and Hanna (1935) described this species from the Catarina Formation, Baja California, together with a large fauna including *Pachydiscus catarinae*, *P. ootacodensis* and *Nostoceras sternbergi*. This is an assemblage of Late Campanian to Maastrichtian age (Ward et al., 2012). *P. ootacodensis* is thought to be of latest Campanian or Early Maastrichtian in age (Matsumoto, 1959b; Jones, 1963; Ward, 1978). *A. peninsularis* occurs stratigraphically below *N. hornbyense* in the Rosario Formation at San Antonio del Mar, Baja California, which suggests a Late Campanian age for the former (Ward et al., 2012, = their "middle Campanian").

Finally, *Metaplacenticeras pacificum* in the Hunters Cove Formation (Dott, 1971) indicates Late Campanian (Matsumoto, 1960; Ward, 1978), while *Baculites* cf. *B. teres* (Dott, 1971) suggests latest Campanian to Maastrichtian (Matsumoto, 1959a, 1960; Jones, 1963).

The sacrum, therefore, is Campanian in age based on the occurrences of the Late Campanian species of *Metaplacenticeras pacificum* and *Anapachydiscus* cf. *A. peninsularis* substantially above it and the inoceramids below and just above it. The few associated inoceramid species do not permit a clear interpretation as to whether the sacrum can be allocated to the lower or upper part of the stage.

## MATERIALS AND METHODS

The specimen is conserved in the collections of the Northwest Museum of Natural History Association, Portland, Oregon, U. S. A. (NWM). It was collected from the southern end of Cape Sebastian at SW ¼, NE ¼, NW ¼, sec. 1, R15W, T38S, USGS Gold Beach 15 min. quadrangle, 1954. The specimen came from within the stratigraphic interval given in Hunter and Clifton (1982, fig. 3).

Terminology used for description as well as measurement landmarks are slightly modified as needed from those of Davies (1983). Modifications of measurements is as follows: the width of the neural spines is measured at a distance of 3 cm above the level of the transverse processes, and the width of transverse process is measured from its distal end to the middle of the neural spine.

## SYSTEMATIC PALEONTOLOGY

### ORNITHISCHIA Seeley, 1887
### ORNITHOPODA Marsh, 1881
### HADROSAURIDAE Cope, 1869
### ?HADROSAURINAE Lambe, 1918
### Figure 4

**Material:** NWM 2150. Partial sacrum (left side) with parts of eight sacral elements.

**Stratigraphic Distribution:** Cape Sebastian Sandstone, lower part of upper hummocky-bedded and burrowed facies, Cape Sebastian Sandstone.

**Age**: Campanian.

**Description:** A 1969 field sketch (Fig. 2A) made by the late Donald Savage during a site visit to the fossil locality by a crew of paleontologists from the University of California, Berkeley, indicates that the specimen was more complete then than when it was excavated in 1994. In the intervening 25 years, the 4th and 5th neural spines, the centra to the 5th and 6th vertebrae, and transverse processes and sacral ribs from the right side of the sacrum had been lost (the "thick processes" in the field sketch are cross sectional views of transverse processes and sacral ribs). The specimen when collected in 1994 preserved part of the left side of the sacrum and was exposed on the upper surface of the bed in which it was found (Fig. 2B).

The specimen consists of the well-preserved left side of the sacrum. In addition to the first six vertebrae, there is a significant portion of the 7th sacral rib and a remnant of the 8th sacral rib. Parts of the first four centra are preserved, which are co-ossified. The anterior centrum is the most complete, and its cranial articular surface is gently convex in its periphery, whereas the central portion is flattened. None of the centra preserve the entire ventral surface. The cranio-caudal lateral profiles of the first two centra are gently concave, although the third preserves a possible aberrant bone-growth, making the profile an uneven one. The centra are subequal in length (Table 1).

The sacral ribs arise at or near the intervertebral sutures. While the anterior sacral ribs are slightly inclined posteriorly, the posterior ones are nearly vertical. Sacral ribs two through six are most inflated at mid-height, especially on their anterior sides. The caudal side of the second rib has a concave surface. The preserved portion of the seventh sacral rib shows no indication of thickening in its mid-height region. In cranial view, sacral ribs two through six are nearly vertical in profile, and most flare distally only a few centimeters prior to reaching the transverse processes. The iliac bar runs along the second through sixth vertebrae, and the anterior end of the bar is fused to the 1st and 2nd sacral centra at their juncture. The iliac bar appears to have been thick, although worn, and is slightly undulose as it runs along the ventro-lateral edges of the sacral centra. The ventral ends of the sacral ribs are fused to the iliac bar.

There are three tear-shaped foramina for the spinal nerve between the first through fourth vertebrae. Jointly they form a descending series in a posterior direction. The neural canal (H = 36 mm) of the first vertebra is nearly subcircular in cranial view. Posteriorly, by the second sacral vertebra, the height of the neural canal expands to at least 60 mm (maximum height is indeterminate).

The transverse processes are short (although certainly the first and second were shortened slightly during post-mortem transport). The diapophyses are stout and thick. The third and fourth transverse processes have a slight anterior projection, whereas the others are more laterally disposed. The fifth transverse process is short, as it is expanded at its distal end into a rounded, rugose, tuber-like distal extremity. The sixth transverse process is not as complete but has a morphology similar to that of the fifth. The first transverse process forms an angle of approximately 97° with the neural spine. The angle decreases with the second and third transverse processes, and the remainder were oriented approximately at right angles to their neural spines. In lateral view, the dorsal side of the six transverse processes forms a strong convex profile.

The articular surfaces of the zygapophyses are fused where they are preserved between the first through fourth vertebrae. The left prezygapophysis on the first sacral has a length of 54 mm and a width of 43 mm.

The incomplete neural spines abut tightly against one another but are not fused at their bases. They are modestly broad cranio-caudally (Table 1). The second neural spine reveals a gentle posterior inclination. It is about 22 mm as measured 3 cm above its base, and it is slightly wider at its posterior compared to its anterior end.

## DISCUSSION

Hadrosaurs typically have 8-10 co-ossified sacral vertebrae. Although NWM 2150 indicates at least eight vertebrae, it might be incomplete and may have had more. It is characteristically hadrosaurid in having had at least the eight vertebrae, having an undulose iliac bar, and possessing tall strut-like sacral ribs with fusion to the vertebral centra ventrally.

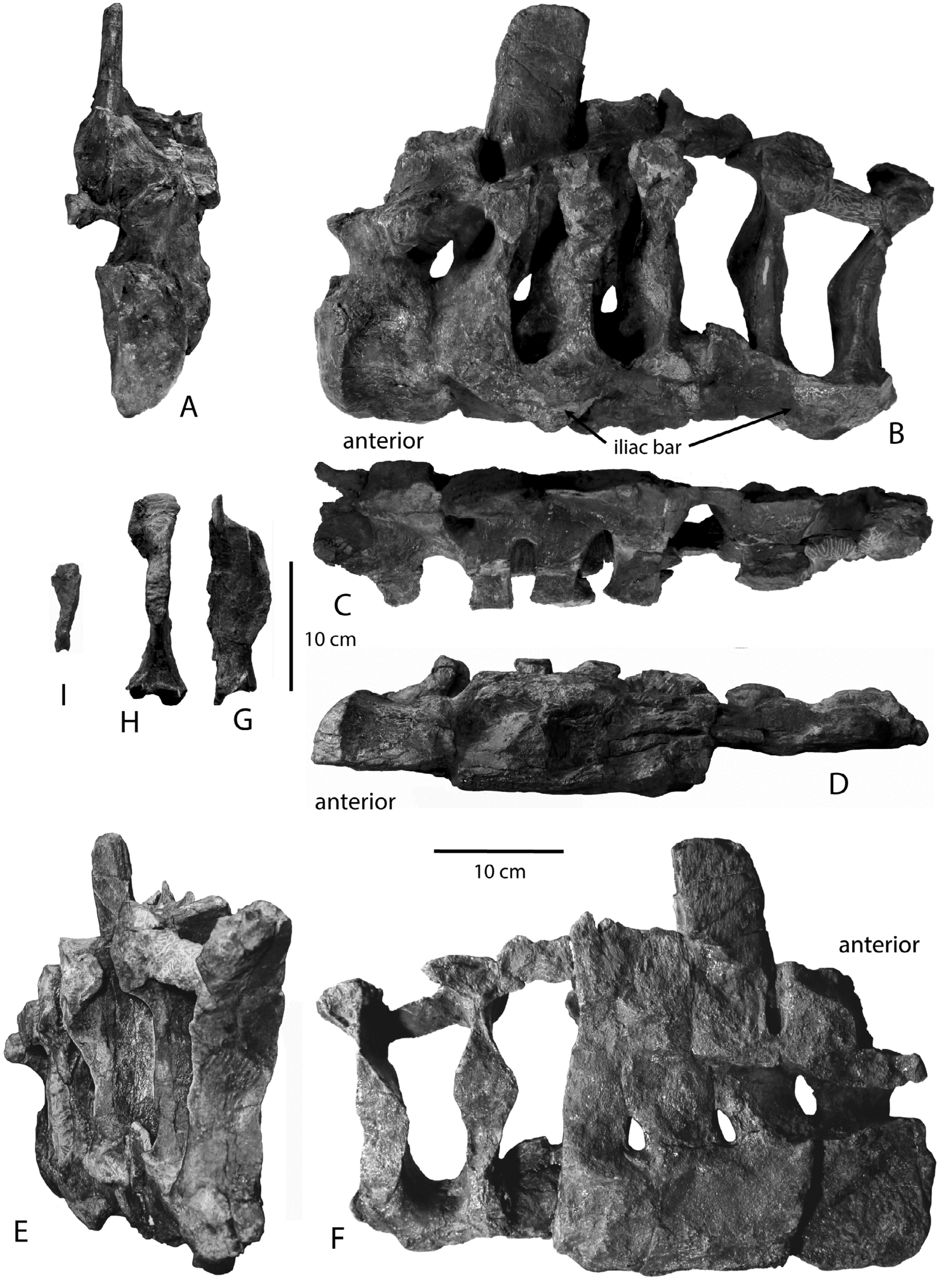


FIGURE 4. NWM 2150, hadrosaur sacrum. **A,** sacrum, cranial view; **B,** sacrum, left lateral view; **C,** sacrum, dorsal view; **D,** sacrum, ventral view; **E,** sacrum, oblique caudal view; **F,** sacrum, lateral view showing neural canal; **G,** 7th sacral rib, cranial view; **H,** 7th sacral rib, lateral view; **I**, 8th sacral rib. Scale = 10 cm.

TABLE 1. Measurements of hadrosaur sacrum, NWM 2150.

| Sacral Vertebrae Number | Centrum Height (cm) | Centrum 1/2 Width (cm) | Centrum Length (cm) | Transverse Process Length (cm) | Neural Spine Width (cm) | Neural Canal Height (anterior end) (cm) | Neural Canal 1/2 Width (anterior end) (cm) |
|---|---|---|---|---|---|---|---|
| 1 | ~118 | ~60 | ~95 | ~89 | 71 | 36 | ~18 |
| 2 | | | ~82 | ~95 | ~72 | | |
| 3 | | | ~80 | ~82 | ~71 | | |
| 4 | | | | | 76 est. | | |

While the hadrosaur sacrum is quite variable in morphology, to date few sacral characters have been recognized to differentiate hadrosaurs below the family level. The ventral surfaces of the more caudal sacral vertebrae commonly have a ventral groove in the hadrosaurines, while often there is a ventral ridge in the lambeosaurines (Horner et al., 2004; Prieto-Márquez, 2011). However, the centra on the Oregon specimen are not complete enough to evaluate this possible criterion. Davies (1983) also discussed the H/W ratio of the last sacral vertebra as being diagnostic as proposed by Brett-Surman (1975), although that character, as well, is missing in the Oregon specimen.

Horner et al. (2004) discussed the length of the transverse processes in hadrosaurs together with the associated sacral ribs. They noted that after the first couple of sacral vertebrae, the transverse processes decrease in length through the remainder of the sacral series (and may not make contact with the ilium) until the eighth is reached. The latter is massive and extends laterally to meet the ilium.

Within the lambeosaurines, Prieto-Márquez et al. (2012) provided a description of *Magnapaulia laticaudus* from the late Campanian of Baja California Norte and illustrated a partial sacrum having sacral ribs that differ from NWM 2150 in their obliquity, being thinner cranio-caudally, and having cranial surfaces that are strongly excavated. The sacrum of *M. laticaudus* also differs in that the lower part of the neural spines have an anterior projection, and the iliac bar is well separated from the centra.

The lambeosaurine *Pararhabdodon isonensis* from the Maastrichtian of Spain (Prieto-Márquez, et al., 2006) is readily differentiated in having markedly oblique sacral ribs. Bolotsky et al. (2014) described sacral material tentatively referred to *Amurosaurus riabinini* from the Maastrichtian of eastern Russia, one of which has more oblique sacral ribs. The iliac bar also is well separated from the centra following the first couple of sacrals.

There are several hadrosaurine genera for which well-preserved sacra have been illustrated. The Oregon sacrum is similar to that of *Saurolophus angustirostris* from Mongolia, in having transverse processes (except last one) that are comparatively short. Also, the distal extremity of some of those processes is strongly reminiscent of the 5th sacral on NWM 2150, which is rounded and tuber-like (Maryańska and Osmólska, 1984).

The Oregon specimen shows similarity to the approximately coeval and much larger *Shantungosaurus giganteus* from China (Hu, 1972) through the similar posterior deflection of the base of the neural spines, anterior sacral ribs that have a similar orientation as well as an apparent cranial thickening near their mid-height, and transverse processes that at least do not increase in length as the they progress from the first to eighth vertebrae.

Campione (2014) described the postcrania of *Edmontosaurus regalis*, based on late Campanian type material from Alberta. Compared to the Oregon specimen, the sacrum of that species has longer transverse processes and perhaps more oblique sacral ribs that flare markedly as they approach the transverse processes. However, the obliquity of the sacral ribs may have resulted in part from diagenesis or pathology, as some of those on the right side of the sacrum are much more slanted than those of the left side.

*Bonapartesaurus rionegrensis* Cruzado-Caballero and Powell (2017), from the late Campanian-early Maastrichtian of Argentina, has a sacrum with more-or-less upright sacral ribs. It differs from the Oregon specimen in having more separated and upright neural spines, and a concave rather than convex articular cranial face on the first sacral vertebra. *Barsboldia sicinskii*, from Mongolia, also has the upright sacral ribs (Maryańska and Osmólska, 1981; Prieto-Márquez, 2011)

*Kritosaurus* cf. *K. notabilis* (Lull and Wright, 1942) from Alberta is similar in appearance to the Oregon specimen in inclination of neural spines and sacral ribs, but has longer transverse processes, thinner (3rd through 5th) sacral ribs, and an iliac bar more separated from the centra.

Two well preserved hadrosaurine sacra are illustrated from the Big Bend area of Texas (Wagner, 2001; Barnes, 2014): one, referred by Wagner (2001) to *Kritosaurus* cf. *K. navajovius* (TMM 42309-1), and another, an indeterminate hadrosaurine according to Barnes (2014). They have an overall appearance similar to the Oregon specimen in the orientation and height of the sacral ribs (except the 7th one in the indeterminate hadrosaurine), orientation (and cranial-caudal width) of the neural spines, and the strongly convex arch formed by the transverse processes. The sacrum assigned to *K.* cf. *K. navajovius* does show the foramina for the spinal nerve but differs from the Oregon specimen in that the first three have an ascending rather than a descending trend. That specimen also has thinner sacral ribs than the specimen from Oregon.

The overall resemblance of NWM 2150 clearly lies with the Hadrosaurinae, in particular through the shortness of the transverse processes, similar morphology of the distal ends of some (such as in *Saurolophis angustirostris*), and the more upright sacral ribs. The sacrum of NWM 2140 is most readily distinguished from those of lambeosaurines in that the latter have more oblique sacral ribbing. However, the assignment of the Oregon specimen to the Hadrosaurinae remains tentative until comparison is made with a larger number of lambeosaurines.

## CONCLUSIONS

The specimen (NWM 2150) described here is a partial hadrosaurine ? sacrum of Campanian age, and is the first documented dinosaur fossil from Oregon, USA. The sacrum came from a part of the Cape Sebastian Sandstone characterized by inner shelf deposits, the upper hummocky-bedded and burrowed facies of Bourgeois (1980).

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