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Taphonomy of a monodominant Gryposaurus sp. bonebed from the Oldman Formation (Campanian) of Alberta, Canada

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1 **Description of the first definitive *Corythosaurus* (Dinosauria, Hadrosauridae)**  
2 **specimens from the Judith River Formation in Montana, USA and their**  
3 **paleobiogeographical significance**

4  
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20

21 **ABSTRACT**

22 The late Campanian Judith River Formation in northern Montana, USA has long been  
23 recognized as a dinosaur-bearing rock unit. ~~ever since the first North American~~  
24 ~~dinosaur discovery from this unit.~~ Despite the long ~~study~~ history ~~of research~~ in this  
25 formation, most of the vertebrate fossils are represented by fragmentary remains,  
26 making precise taxonomic identifications difficult. Contrary to this, the partially  
27 contemporaneous Dinosaur Park Formation, Alberta, Canada is known for its  
28 tremendous fossil preservation, permitting rigorous studies of dinosaur diversity,  
29 evolution, and biostratigraphy. Hadrosaurids comprise one of the most abundant  
30 dinosaur clades in the Dinosaur Park Formation, but taxonomic affinities of hadrosaurid  
31 specimens remain poorly understood in the Judith River Formation. *Corythosaurus* is  
32 the most common hadrosaurid in the Dinosaur Park Formation ~~and, to date,~~ ~~and~~ has  
33 been restricted to this formation ~~to date~~. This study reports the first definitive  
34 *Corythosaurus* specimens from the Judith River Formation, which were discovered on  
35 two private ranches in northern Montana. The attribution of the most complete skeleton  
36 to *Corythosaurus* is indicated by ~~the combination of the following characters~~: wide  
37 crest-snout angle, presence of premaxilla-nasal fontanelle, dorsoventrally expanded  
38 nasal, laterally exposed ophthalmic canal of the laterosphenoid, and tall neural spines. A  
39 second specimen preserves a largely ilium that can ~~be~~ positively identified as  
40 *Corythosaurus* ~~based on its associated skull, which is now in a private handhands~~ ~~due to~~  
41 ~~its association with a largely complete articulated skull~~. The specimens were recovered  
42 from the Coal Ridge Member of the Judith River Formation, which is approximately  
43 time equivalent to the Dinosaur Park Formation. Thus, the discovery of *Corythosaurus*  
44 in the Judith River Formation extends the biogeographic range of this genus and

45 establishes a framework for future interformational biostratigraphic studies of Late  
46 Cretaceous dinosaur faunas in North America. Further discoveries of the shared  
47 dinosaur taxa between these two formations are expected to ~~construct~~establish the an  
48 interformational biostratigraphic framework.

49

50 Keywords: Late Cretaceous, Hadrosaur, Dinosaur, Judith River Formation

51

## 52 INTRODUCTION

53 Outcrops of the late Campanian Judith River Formation (JRF) exposed in  
54 northern Montana, USA, have produced abundant vertebrate fossils. Since the discovery  
55 of the first dinosaur in North America by Ferdinand Vandever Hayden in 1854 (Leidy,  
56 1856), rigorous effort has been put into collecting vertebrate fossils from the JRF. As a  
57 result of this, several relatively complete skeletal specimens have been collected and  
58 described (Dodson, 1986; Prieto-Márquez, 2005; Murphy et al., 2006; Prieto-Marquez,  
59 2007; Freedman, 2015; Mallon et al., 2016; Arbour and Evans, 2017) and have  
60 contributed to understanding dinosaur evolution of the Late Cretaceous of North  
61 America. Nonetheless, ~~the majority of~~most of the dinosaur remains from the JRF are  
62 represented by isolated or partial materials, hindering detailed taxonomic evaluations.  
63 This pattern of fossil occurrences in the JRF is strikingly differents from those in the  
64 partially contemporaneous Dinosaur Park Formation (DPF) of southern Alberta, where  
65 a plethora of dinosaur remains have been discovered with various taphonomic modes,  
66 including numerous complete skulls and skeletons (Eberth and Currie, 2005). Due to the  
67 excellent preservation and rich fossil occurrences, the dinosaur faunas of the DPF have  
68 been well-studied, and ~~the the dinosaur~~biostratigraphy of dinosaurs has been  
69 established at the species level (Ryan and Evans, 2005; Mallon et al., 2012; Cullen et  
70 al., 2021), unlike the situation in the JRF.

71 Lambeosaurine hadrosaurids are ~~one of the dinosaur groups that are~~ well-known  
72 from the DPF, but ~~its~~their presence remains ambiguous in the JRF. Currently, at least  
73 five valid lambeosaurine taxa are known from the DPF: ~~Corythosaurus casuarius,~~  
74 ~~C.~~Corythosaurus intermedius, *Lambeosaurus lambei*, ~~Lambeosaurus L.~~Lambeosaurus L. *magnicristatus*,  
75 and *Parasaurolophus walkeri*). *Corythosaurus* is represented by over 25 relatively

76 complete skulls and skeletons (Currie and Russell, 2005) and is the most abundant  
77 genus among the five lambeosaurine taxa (Ryan and Evans, 2005). Although abundant  
78 in the DPF in the Dinosaur Park area, Alberta, Canada, there is no definitive record of  
79 this genus from other time equivalent strata such as the JRF. Here, we report the first  
80 well-preserved lambeosaurine skeleton identifiable to *Corythosaurus*, collected from the  
81 JRF, northern Montana, USA. We also report a second, less complete specimen with a  
82 complex provenance that can ~~be~~ also be positively assigned to this genus based on an  
83 articulated skull now lost to a private collection ~~also from the JRF of Montana~~. Both  
84 specimens contribute significantly toward a more comprehensive understanding of the  
85 dinosaur fauna of this formation and ~~the paleobiogeographical significance of~~  
86 [Campanian dinosaurs in North America](#).

87

#### 88 **Institutional abbreviations**

89 AMNH, American Museum of Natural History, New York; CMN, Canadian  
90 Museum of Nature, Ottawa, Canada; MOR, Museum of the Rockies, Montana, USA;  
91 NMMNH, New Mexico Museum of Natural History & Science, New Mexico, USA;  
92 OUSM-FV, Okayama University of Science, Museum of Dinosaur Research, fossil  
93 vertebrate collection, Japan; ROM, Royal Ontario Museum, Toronto, Canada; TMP,  
94 Royal Tyrrell Museum of Palaeontology, Drumheller, Canada; UALVP, University of  
95 Alberta Laboratory for Vertebrate Paleontology, Alberta, Canada; USNM, United States  
96 National Museum, Smithsonian Institution, Washington, DC, USA.

97

#### 98 **MATERIAL AND METHODS**

99 OUSM-FV-001, discovered and excavated from private land in Montana by the  
100 commercial company Phoenix Fossils in 1990, was legally purchased by [the](#)  
101 Hayashibara Museum of Natural Sciences in 1991. When the museum closed ~~down~~ in  
102 2015 [subsequent to](#) ~~after~~ the bankruptcy of its parent company, OUSM-FV-001 was  
103 transferred to the Okayama University of Science Museum. The pathological jugal and  
104 the basisphenoid of OUSM-FV-001 were scanned using X-ray CT Latheta (LCT-200) at  
105 the Okayama University of Science. The images were acquired at a voltage of 80kV and  
106 a current of 0.5 mA. Both the pixel sizes and interslice thicknesses are 120 and 120 um  
107 resulting in voxel sizes of 120 um (Supplemental Data S1). Photogrammetric models of  
108 the partial nasals and the partial left premaxilla were made using Agisoft Metashape  
109 Professional (Supplemental Data S2-S4). Selected measurements of OUSM-FV-001 are  
110 provided as Supplemental Data S5.

111 ROM 77978 was also discovered and legally collected from a private ranch in  
112 Hill County, Montana in 2015. The articulated skull and lower jaws were mounted and  
113 sold into a private collection. Prior to the sale, the original skull was inspected firsthand  
114 by DCE on January 29, 2016. The collector was not interested in obtaining the  
115 associated postcranial elements, which were subsequently acquired by the Royal  
116 Ontario Museum and accessioned as ROM 77978; and described here. Photographs, CT  
117 scans, and a high-resolution surface scan together with a 3D print of the skull are also  
118 deposited at the ROM. As part of the acquisition of ROM 77978, the landowner agreed  
119 to allow scientific access to the field site in order for the ROM to gather detailed  
120 contextual sedimentological and stratigraphic information and document the host



121 paleoenvironment. DCE and FF visited the quarry where ROM 77978 was collected on  
122 August 10, 2017, along with the person who discovered and collected the specimen.

123

#### 124 **Systematic paleontology**

125 Dinosauria Owen, 1842

126 Ornithischia Seeley, 1887

127 Lambeosaurinae Parks, 1923

128 Lambeosaurini Sullivan et al., 2011

129 *Corythosaurus* Brown, 1914

130 *Corythosaurus* sp.

131

#### 132 **Referred Specimen**

133 OUSM-FV-001, a partial disarticulated skeleton including: partial left and right  
134 premaxillae, a complete left and posterior two-thirds of the right maxillae, partial nasals  
135 around the prefrontal-nasal fontanelle, a nearly complete left jugal and a partial right  
136 jugal, posteromedial portions of both quadrates, partial right squamosal, partial left  
137 postorbital, a left frontal, a right laterosphenoid, a left exoccipital ~~other than~~missing the  
138 paroccipital process, the main body of the basisphenoid, both dentaries, both  
139 surangulars, both angulars, right splenial, partial axial elements, a nearly complete right  
140 scapula, blade of the left scapula, both coracoids, nearly complete right sternum, a  
141 complete left humerus, nearly complete ulnae, nearly complete ~~radiaeradii~~, both ~~manus~~  
142 ~~mani~~ missing a few phalanges, a nearly complete right ilium, both pubes with  
143 incomplete anterior and posterior processes, nearly complete left ischium, nearly

144 complete left femur, both tibiae missing the distal ends, nearly complete fibulae, a  
145 complete right astragalus, and both pedes missing a few phalanges (Fig. 1C).

146

#### 147 **Locality and horizon**

148 OUSM-FV-001 was discovered on a private ranch approximately 8 km north of  
149 Winifred, Montana (Fig. 1). The locality data ~~is~~ are cataloged in the OUSM collection  
150 database and is available upon request. The specific locality data was initially  
151 unavailable since the private company that sold this specimen provided only a rough  
152 quarry location (within a 4 x 4 km range) and has since ceased operation. Recently, the  
153 authors noted that the location of a historical quarry on property now leased by Triebold  
154 Paleontology, Inc. nicknamed “Japanese dig” by local ranchers fell exactly within this  
155 area. According to recollections of those ranchers as well as ~~from~~ dates found on  
156 beverage cans found ~~at~~ the quarry ~~by one author~~, a 1990 date for that excavation  
157 matches information provided with OUSM-FV-001. Together with the fact that a nearly  
158 complete lambeosaurine skeleton is extremely rare from the Judith River Formation, we  
159 tentatively consider that OUSM-FV-001 was collected from this quarry. The OUSM-  
160 FV-001 quarry is located near the reference section of the Judith River Formation  
161 (Rogers et al., 2016). Since the quarry is positioned no lower than the top 50 m of the  
162 badlands, and the Coal Ridge Member occupies the upper ~90m of the formation, the  
163 horizon yielding the quarry likely belongs to the Coal Ridge Member. The quarry is  
164 located approximately 8.5 km NNE of the *Spiclypeus shipporum* holotype locality  
165 (Mallon et al., 2016), and is also several hundred meters away from the “Ava”  
166 centrosaur quarry, which was collected by Triebold Paleontology, Inc.

167

168 **Description of OUSM-FV-001**

169 **Premaxilla.** The anterior right premaxilla and a small portion of the left  
170 premaxilla are preserved (Fig. 2C-F). The oral margin of the right premaxilla is slightly  
171 ~~lost-damaged~~ but has a gently rounded outline. Posteriorly, the posterodorsal process is  
172 laterally everted to form a ridge that dorsally defines the external naris. Although  
173 incomplete, the dorsal process of the left premaxilla is gently ~~curved~~concave unlike in  
174 *Parasaurolophus* which is straight or convex. The posterodorsal end of the dorsal  
175 process is curved posterodorsally (Fig. 2D; Data S4), suggesting a wide crest-snout  
176 angle as in *Corythosaurus* and *Hypacrosaurus*, rather than *Lambeosaurus* in which the  
177 dorsal process is recurved anteriorly to form an acute crest-snout angle less than 120  
178 degrees (e.g., ROM 794, TMP 66.04.01) and forms a crest snout angle of approximately  
179 150 degrees along its dorsal margin (Fig. 2D). The angle is markedly wider than that of  
180 *Lambeosaurus*, in which the crest snout angle is generally less than 120 degrees in large  
181 specimens (e.g., ROM 794, TMP 66.04.01). Instead, the wide crest snout angle of  
182 OUSM FV 001 resembles that of *Corythosaurus* and *Hypacrosaurus*. Internal to the  
183 curvature, a septum intercepts the dorsal half of the nasal passage to form an S-loop, as  
184 in other members of Lambeosaurini (Evans et al., 2009). The posterodorsal process of  
185 the left premaxilla is medially flat to contact its counterpart and dorsally grooved,  
186 possibly due to postmortem deformation.

187 **Maxilla.** A complete left maxilla and the posterior two-thirds of the right  
188 maxilla are mounted for display (Fig. 2A, B, G). Although the anterior process of the  
189 maxilla is dorsally covered by the reconstructed premaxilla, a part of the premaxillary  
190 shelf exposed at the anterior end is angled at approximately 15 degrees relative to the  
191 ventral margin. The lateral exposure of the dorsal process of the maxilla is located

192 approximately at the midline of the maxilla. It is dorsoventrally tall and tapers to a point  
193 dorsally. Ventral to the dorsal process, the lateral surface of the left maxilla bears two  
194 large and two small foramina, whereas the right maxilla bears one large and four small  
195 foramina. A well-developed ectopterygoid ridge emerges posterodorsal to the most  
196 posterior foramen, where the maxilla and the ventral margin of the anterior process of  
197 the jugal contact. The ectopterygoid ridge occupies approximately 40% of the maxilla  
198 length. It is oriented nearly parallel to the alveolar margin of the posterior maxilla, and  
199 is approximately 1.5 times as wide as the height of the maxilla anterior to the pterygoid  
200 process. The alveolar margin of the maxilla is shallowly concave. It should be noted  
201 that the alveolar margin of the left maxilla is slightly swollen at around the midpoint of  
202 the maxilla. The swollen area has a rugose surface that resembles the lesion identified  
203 on a *Parasaurolophus* maxilla (Bertozzo et al., 2020). Medially, the gently arched row  
204 of alveolar foramina ~~are~~ is located dorsal to the midline of the maxilla. At the  
205 posterodorsal end of the maxilla, a small triangular pterygoid process projects  
206 dorsomedially.

207           The left maxilla bears approximately 38 tooth positions within the 298 mm  
208 long dental battery. Although the labial-most tooth is not preserved in most of the tooth  
209 positions, the remaining positions suggest that the majority of the tooth row had two  
210 functional teeth in life. All ~~of the~~ preserved maxillary teeth have a prominent primary  
211 ridge and lack other ridges. The primary ridge is straight or slightly curved and  
212 positioned at the midline of each tooth. The mesial and the distal margins of the ~~coronal~~  
213 apical half of each tooth have mammilliform denticles.

214           *Nasal.* The posterior regions of both nasals are preserved (Fig. 2H-K). Both  
215 nasals retain the posterior margin of the premaxilla-nasal fontanelle (PNF), unlike in

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216 *Hypacrosaurus* in which the PNF is closed early in ontogeny (Brink et al., 2014). The  
217 nasal is thick around the PNF and becomes thinner distal to the PNF, forming a  
218 medially concave space for the lateral diverticulum (Evans et al., 2009). Since the  
219 broken posterior end is still mediolaterally thick, the nasal is likely to extend further  
220 posteriorly in life. The elongation of the dorsoventrally high nasal posterior to the PNF  
221 differs from the nasal of *Corythosaurus intermedius*, in which the cranial crest is  
222 anteroposteriorly shorter than *Corythosaurus-C. casuarius* and forms a rod-like  
223 structure at the posteroventral end of the crest (e.g., ROM 776, 777, 845, UALVP 13).  
224 Although the nasal is incomplete, the preserved region is much taller than the strip-like  
225 nasal of *Lambeosaurus* (e.g., ROM 1218). The lateral surface of the nasal is generally  
226 flat except for the concavity dorsal to the posteroventral margin of the crest. The lateral  
227 and the ventral surfaces meet at an acute angle, forming a sharp ridge. Ventrally, the  
228 nasal bears a shallow concavity for the prefrontal contact (Fig. 2I, Data S3) as in  
229 *Corythosaurus. intermedius* (e.g., ROM 776). The ventral surface of the crest, posterior  
230 to the prefrontal contact, is smooth and shallowly ~~concave~~ convex (Data S2, 3), as in  
231 *Corythosaurus casuarius* (e.g., AMNH FARB 5240).  
232 **Jugal.** A nearly complete left jugal and a partial right jugal are mounted (Fig  
233 2A, B, Fig. 3A). The anterior process of the jugal is expanded dorsoventrally as in other  
234 lambeosaurines (Evans, 2010). The medial palatine process is inclined posterodorsally,  
235 resulting in ~~the a~~ posteriorly located dorsal apex of the anterior process relative to the  
236 ventral apex. The ventral margin of the jugal forms a posteriorly skewed deep arch,  
237 although this region may be slightly eroded. The ventral flange of the jugal posterior to  
238 the ventral arch is trapezoidal unlike the pointed ventral flange of *Hypacrosaurus*

239 *altispinus* (Evans, 2010). The anterodorsal and posteroventral margins of the posterior  
240 process are oriented nearly parallel to each other.

241 In addition to the mounted ~~two~~-jugals, a posterior process of another hadrosaurid  
242 jugal is present (Fig. 3B, C). The length along the ventral margin of the infratemporal  
243 fenestra is nearly 1.5 times as long as the other two jugals, whereas the posterior  
244 constriction of the third jugal is only half as wide as the other two. While the differences  
245 may indicate the third jugal belongs to a different hadrosaurid taxon, these anomalies  
246 are more likely pathological. The lateral and medial surfaces of the anterior region are  
247 more porous than the posterior region, and the anterior fracture surface is rugose and  
248 bears multiple small cavities which may suggest resorption (Supplemental Data S1).

249 **Quadrate.** The posteromedial portions of both quadrates are preserved (Fig 2A,  
250 B, Fig. 3D, E). The quadrate is gently bowed posteriorly as in *Corythosaurus C.*  
251 *casuarius* (e.g., AMNH FARB 5240) and *Lambeosaurus L. lambei* (e.g., ROM 1218), at  
252 approximately 144 degrees. Dorsally, a faint squamosal buttress is present on the  
253 posterior margin of the quadrate. The posterolateral spur is located at about one-third  
254 the height of the quadrate. The posterior surface of the pterygoid wing is slightly  
255 excavated to contact the posteroventral ramus of the pterygoid. The ventral end of the  
256 quadrate is much wider mediolaterally than the anteroposterior length of the lateral  
257 condyle, which is typical in hadrosaurids (Prieto-Márquez, 2010). The lateral and the  
258 medial condyles form a deep groove on the posterior surface of the quadrate as in  
259 *C. erythosaurus intermedius* (e.g., ROM 777) and *Hypacrosaurus stebingeri* (e.g., MOR  
260 549). The medial condyle appears to be elevated compared to the lateral condyle,  
261 although the medial condyle is slightly damaged.

262           **Squamosal.** The main body of the right squamosal is preserved (Fig. 3F). The  
263 lateral surface of the postorbital process of the squamosal bears a contact surface for the  
264 squamosal process of the postorbital. The contact surface extends dorsal to the apex of  
265 the quadrate cotylus of the squamosal. The contact surface for the postorbital suggests  
266 that the squamosal process of the postorbital is bifurcated, unlike in *Hypacrosaurus H.*  
267 *altispinus* (Evans, 2010). The preserved portion of the precotyloid process is shorter  
268 than the anteroposterior width of the quadrate cotylus. In posterior view, the medial  
269 process of the squamosal is dorsoventrally expanded as in other lambeosaurines (Evans,  
270 2010).

271           **Postorbital.** The left postorbital is partially preserved (Fig. 3G). Although the  
272 anteromedial process is partly missing, the base of the anteromedial process is deeply  
273 depressed, as in derived lambeosaurines such as *Corythosaurus C. casuarius* (Brown,  
274 1914). Posterolateral to the depression, the dorsal surface of the base of the squamosal  
275 process forms a mediolaterally compressed protuberance as in some *Corythosaurus*  
276 (e.g., CMN 34825, ROM 776) and *Lambeosaurus* (ROM 1218) specimens. Although  
277 the squamosal process is incomplete, it makes a gentle curvature with the main body of  
278 the postorbital, unlike in *Velafrons* in which the squamosal process elevates abruptly  
279 (Gates et al., 2007). Ventrally, the jugal process of the postorbital and the anteromedial  
280 process form the semicircular posterodorsal margin of the orbit. The orbital margin has  
281 a rugose texture. The anteromedial surface of the jugal process is shallowly concave.

282           **Frontal.** The left frontal is nearly complete except for the posteromedial region  
283 (Fig. 3H-J). The anterior region of the frontal forms the anteroposteriorly striated  
284 contact surface for the nasal. The contact surface occupies the anterior half of the frontal  
285 and is deeper laterally than medially. The contact surface for the nasal is angled at

286 approximately 20 degrees relative to the skull table. The anteromedial end of the nasal  
287 contact surface does not reach the skull midline and forms a deep median cleft unlike in  
288 *Parasaurolophus* (Evans et al., 2007). The posterolateral margin of the nasal sutural  
289 surface is slightly everted to support the supracranial crest, unlike in large  
290 parasaurolophines in which the nasal contact surface extends above the skull table  
291 (Evans et al., 2007). Posteriorly, the skull table is slightly elevated to form a median  
292 dome as in other lambeosaurines (Ostrom, 1961), although the region is partially  
293 missing. Ventrally, the frontal bears three depressions: the olfactory depression, the  
294 orbital depression, and the cerebral fossa. The cerebral fossa is the deepest among the  
295 three depressions. Its posterodorsal surface shows vascular valliculae.

296 ***Laterosphenoid.*** A right laterosphenoid is missing its dorsolateral process (Fig.  
297 [3K4A](#)). The sulcus for the ophthalmic ramus (CN V<sub>1</sub>) is laterally fully open and forms a  
298 horizontal groove as in *Corythosaurus* and *Hypacrosaurus*, but differs from  
299 *Lambeosaurus* in which CN V<sub>1</sub> is laterally covered by the laterosphenoid (Ostrom,  
300 1961; Evans and Reisz, 2007). In lateral view, relative to the ophthalmic sulcus, the  
301 dorsal margin of the laterosphenoid where it contacts the parietal is nearly parallel or  
302 only slightly divergent from the line of the ophthalmic sulcus, resulting in a  
303 dorsoventrally short laterosphenoid where it contacts the parietal. This is consistent with  
304 the laterosphenoids of *Corythosaurus-C. casuarius* (ROM 1933), *Corythosaurus-C.*  
305 *intermedius* (ROM 776), and *Hypacrosaurus-H. stebingeri* (MOR 549). In contrast, it  
306 but differs from the laterosphenoid of *Parasaurolophus tubicen* (NMMNH P25100), in  
307 which the dorsolateral process is dorsally directed; therefore, the dorsal margin is  
308 strongly divergent from the ophthalmic sulcus. The In dorsal view, the dorsolateral  
309 process margin of the laterosphenoid strongly curves laterally as in *Prosaurolophus*



310 *maximus* (Horner, 1992), small *Edmontosaurus annectens*, and small *Hypacrosaurus H.*  
311 *stebingeri* (Takasaki et al., 2020).

312 ***Exoccipital.*** The left exoccipital is nearly complete other than its paroccipital  
313 process (Fig. [3L, M4B, C](#)). The occipital plate of the exoccipital is pierced by the  
314 openings for the glossopharyngeal nerve (CN IX), the vagus nerve (CN X), and the  
315 hypoglossal nerve (CN XII) (Ostrom, 1961; Evans et al., 2009). While CN IX and X are  
316 associated close together laterally, they are well-separated medially. Dorsally, the  
317 exoccipital has a horizontal shelf as the contact surface for the supraoccipital. The  
318 horizontal shelf is slightly wider than its anteroposterior length. The laterodorsal margin  
319 of the supraoccipital contact is medially overhung, indicating that the exoccipital  
320 "locked" into the supraoccipital in articulation. Dorsolateral to the horizontal shelf, a  
321 squamosal boss is present on the lateral half of the exoccipital unlike the indeterminate  
322 lambeosaurine from the Prince Creek Formation, Alaska, in which the exoccipitals do  
323 not participate in forming a squamosal boss (Takasaki et al., 2019).

324 ***Basisphenoid.*** The posterodorsal surface of the basisphenoid and the cultriform  
325 process are missing (Fig. [3-4 ND-PF](#)). On the lateral surface of the long and massive  
326 basiptyergoid process, two ridges run proximodistally, emerging from the anteroventral  
327 and posterodorsal margins of the foramen for the internal carotid artery at base of the  
328 basiptyergoid process. The alar process is bifurcated as in *Amurosaurus riabinini*  
329 (Godefroit et al., 2004) and borders the anteroventral margin of the foramen for the  
330 carotid artery. Posterodorsally, the basisphenoid is enlarged to form the sphenoccipital  
331 tubera with the basioccipital. The basiptyergoid processes meet at approximately 90  
332 degrees in anterior or posterior views. A part of a small median protuberance is present  
333 at the base of the basiptyergoid processes as in derived lambeosaurines (Gates and

334 Sampson, 2007), although it is partly broken. ~~Right-lateral T~~to the median protuberance  
335 is deeply incised on the right lateral side, and the surface surrounding the incision is  
336 porous and slightly elevated, which may be pathological.

337 **Mandible.** Both dentaries are nearly complete, although most of the anterior  
338 and the medial regions are reconstructed (Fig. ~~3Q4G-TJ~~). Anteriorly, the dentary is  
339 curved ventrally, starting approximately from the level of the anteriormost reconstructed  
340 tooth, at an angle of 159 degrees relative to the posterior half of the dentary. The  
341 symphyseal process is markedly curved medially to contact the counterpart as in typical  
342 lambeosaurines. The mediolateral width of the symphyseal process is slightly less than  
343 twice the non-symphyseal anterior dentary mediolateral width. Posterior to the  
344 symphyseal process, the edentulous diastema is shallowly sloped anteroventrally  
345 relative to the main body of the dentary. The lateral surface of the main body of the  
346 dentary is pierced by at least ten randomly -distributed foramina. Posteriorly, the  
347 coronoid process is inclined anterodorsally at approximately 80 degrees relative to the  
348 alveolar margin. The coronoid process is separated from the main body of the main  
349 dentary body by a wide lateral shelf, typical for hadrosaurids. The dorsal apex of the  
350 coronoid process is expanded anteroposteriorly, and its posterior surface is deeply  
351 grooved to contact the anterodorsal process of the surangular.

352 A fragmentary bone is cataloged as the left lateral process of the prementary,  
353 but its detail is unavailable since it is embedded within the mounted skull (Fig. ~~3Q4G~~).  
354 Both surangulars are preserved, although ~~itstheir~~ medial and anterior regions are also  
355 embedded within the ~~plaster~~reconstruction. The surangular is dorsoventrally flat at the  
356 level of the glenoid. The posterior process of the surangular is strongly curved dorsally  
357 and tapers into a point. Ventral to the surangular, the angular is visible in lateral view,

358 although this configuration is likely to be an artifact of misplacement upon mounting  
359 the specimen. The right splenial is mediolaterally thin and becomes taller anteriorly,  
360 although the anterior end is missing.

361 **Vertebrae.** Eleven post-axial cervical, 17 dorsal, and 34 caudal vertebrae are  
362 cataloged as containing original bone (Fig. 45), although most retain only either the  
363 centrum or neural spine. The preserved vertebrae exhibit general conditions of  
364 Hadrosauridae. Centra of the cervical vertebrae are opisthocoelous and slightly concave  
365 lateroventrally. The articular facets of the prezygapophyses are subcircular in the  
366 anterior cervicals and become mediolaterally wide and elliptical posteriorly. The  
367 postzygapophyses are acutely divergent from each other in the anterior cervicals, while  
368 the angle becomes wider in the posterior cervicals. Dorsally, the neural spine is small  
369 and becomes slightly more prominent in the posterior cervical vertebrae. All of the  
370 preserved dorsal centra are amphiplatyan. The best-preserved dorsal centrum is a middle  
371 dorsal centrum cataloged as “D-4”. Although the neural spine corresponding to this  
372 centrum is missing, a neural spine of a posterior dorsal vertebra (cataloged as “D-16”) is  
373 2.3 times longer than the height of the middle dorsal centrum (“D-4”). Since dorsal  
374 centra of hadrosaurids become higher posteriorly, the ratio between neural spine length  
375 and centrum of the OUS specimen is likely to be much less than 2.3. The short neural  
376 spine differs from *Hypacrosaurus*, which has a long neural spine relative to the centrum  
377 (Lull and Wright, 1942; Evans, 2010). The neural spine of the posterior dorsal vertebra  
378 is long and gracile, being 5.5 times higher than its anteroposterior width. Centra of the  
379 caudal vertebrae are amphiplatyan and are much higher and wider than its lengths in the  
380 anterior caudal vertebrae, while they become elongated posteriorly. The transverse

381 processes lie nearly horizontally, unlike the acutely angled transverse processes of the  
382 dorsal vertebrae.

383 **Pectoral girdle.** The right scapula is nearly complete other than the glenoid and  
384 the distal end of the scapular blade (Fig. [5A6A](#)). The acromion of the scapula is oriented  
385 laterally, forming a flat dorsal surface of the anterior end of the scapula. Posterior to the  
386 acromion, a poorly developed deltoid ridge is present along the lateral surface of the  
387 scapular blade. The scapula curves ventrally at the neck, although the curvature is less  
388 prominent than *Brachylophosaurus canadensis* (Prieto-Marquez, 2007) and  
389 *Gryposaurus latidens* (AMNH FARB 5465). The posterior end of the scapular blade is  
390 at least 1.5 times as high as the neck, although ~~the further~~ detail is unavailable due to ~~the~~  
391 poor preservation. Both coracoids are nearly complete, exhibiting a slightly shorter  
392 contact surface for the scapula compared to the [length of the](#) glenoid (Fig. [5B6B](#)). The  
393 anterodorsal margin of the coracoid is concave and ventrally continues to a well-  
394 developed biceps tubercle. Distally, the ventral hook of the coracoid is 0.64 times as  
395 high as its width. The medioventral margin of the coracoid is rugose for cartilage  
396 contact. The right sternum is also nearly complete, [except that the medial portion of the](#)  
397 [proximal plate is missing](#) (Fig. [5C6C](#)). [The sternum is “hatchet” shaped, as is typical](#)  
398 [for hadrosaurids](#). The proximal plate of the sternum is thickest along the anterolateral  
399 and the posterolateral margins, while the proximal plate is thin medially. The proximal  
400 plate of the sternum is shorter than the distal process. [The distal process is nearly](#)  
401 [straight and slightly expanded in the distal end distally](#).

402  
403 **Forelimb.** The left humerus is complete (Fig. [5D6D](#)). The deltopectoral crest is  
404 half as wide as its length and reaches approximately 60% of the humerus length. The

405 anterior and the ventral margins of the deltopectoral crest meet at approximately 103  
406 degrees. The ulna and radius are at least 1.2 times as long as the humerus, although the  
407 ulna is missing a small portion of the distal midshaft, and the radius is missing its  
408 proximal end (Fig. [5E6E](#), F). The ulna is slender, being more than 10 times longer than  
409 its anteroposterior width as in other members of Lambeosaurini. The right manus is  
410 missing only the phalanges II-2, III-1, IV-2, IV-3, and V-3 (Fig. [5G6G](#)). The manus  
411 shows general hadrosaurid features. Metacarpals II-IV are long and slender, with the  
412 metacarpal III approximately eight times as long as its width. The manual phalanges are  
413 stout other than II-1, which is mediolaterally flat and elongated. The ungual phalanges  
414 II-4 and III-4 are hoof-shaped. It may be worth noting that the ungual phalanx II-4 is  
415 notably smaller than the ungual phalanx III-4 unlike some hadrosaurids (Brown, 1912;  
416 Parks, 1922; Suzuki et al., 2004).

417 ***Pelvic girdle.*** The right ilium is missing the distal half of the preacetabular  
418 process, the distal end of the postacetabular process, the supracetabular process, the  
419 acetabular margin, and the ischial peduncle (Fig. [6A7A](#)). The preacetabular process is  
420 curved downward at its base relative to the dorsal margin of the main plate. A small  
421 ridge develops along the ventral margin of the base of the preacetabular process.  
422 Posterior to the acetabulum, the ischial peduncle is composed of two protuberances. The  
423 postacetabular process is oriented posterodorsally. It is mediolaterally compressed in the  
424 dorsal half, whereas the ventral half is expanded to form the brevis shelf that is facing  
425 medioventrally. Medially, the sacral ridge is positioned along the dorsal rim of the  
426 ilium. The left pubis is missing most of its prepubic and postpubic processes (Fig.  
427 [6B7B](#)). A faint ridge is present on the lateral surfaces of the iliac and the ischial  
428 peduncles along the acetabulum. The left ischium is missing its pubic process and the

429 distal end (Fig. ~~6C7C~~). The proximal tip of the iliac peduncle is deflected posteriorly.  
430 The short obturator process is located close to the base of the pubic peduncle. Although  
431 the distal end of the ischium is missing, the ischial shaft is distally divergent, suggesting  
432 the presence of the ischial boot.

433 **Hindlimb.** The left femur is nearly complete, although it is mediolaterally  
434 compressed (Fig. ~~6D7D~~). Proximally, the lesser trochanter is small and fused to the  
435 greater trochanter. Although the distal end of the femur is posteriorly curved, the  
436 curvature is likely due to postmortem distortion. The fourth trochanter is proximally  
437 skewed and subtriangular in lateral view with a smooth apex. The fourth trochanter is  
438 positioned slightly distal to the midpoint of the femur. The left tibia is missing its distal  
439 end (Fig. ~~6E7E~~). The cnemial crest of the tibia is much more developed than the medial  
440 condyle and distally extends over the midpoint of the tibia. The left fibula is complete,  
441 and both the proximal and the distal ends are expanded anteriorly (Fig. ~~6F7F~~). The  
442 anterodorsal process of the astragalus is medially ~~skewed~~~~offset~~, and its anterior surface  
443 is shallowly excavated (Fig. ~~6G7G~~). No calcaneum is preserved. Although both pedes  
444 are missing several pedal phalanges, they show general hadrosaurid features (Fig.  
445 ~~6G7G~~). Metatarsal III is approximately six times as long as its width. The pedal  
446 phalanges III-2, III-3, IV-2, and IV-3 are disc-like and more than three times as wide as  
447 their lengths. The unguis phalanges are hoof-shaped and have a flat ventral surface.

448  
449 *Corythosaurus* sp.

450  
451 **Referred Specimen**

452 ROM 77978 includes the angular, left ilium, several mid-caudal vertebrae, and  
453 associated fragments of ossified tendons. An incomplete articulated skull and lower  
454 jaws preserved from the orbits forward was also associated with this material, but is  
455 currently in private hands.

456

#### 457 **Locality and Horizon**

458 ROM 77978 was excavated from strata of the upper Judith River Formation  
459 (Coal Ridge Member) approximately 9 kilometers to the East of the town of Havre, Hill  
460 County, Montana. The quarry is located in badlands along the Little Boxelder Creek,  
461 on the west arm of a north-south oriented coulee system and on the east side of a large  
462 dry island, approximately 3 km upstream from its merger with the Milk River  
463 (~~Supplemental-Fig. S18~~). Detailed locality data is on file at the Royal Ontario Museum.  
464 The quarry itself is located in a shallow saddle low in the local section, approximately  
465 10 m from the valley floor and about 10 m below prairie level of the dry island. The  
466 partially disarticulated but closely associated specimen occurred at the base of a coarse-  
467 grained channel sandstone unit approximately 60 cm in thickness ~~specimen~~. The host  
468 stratum is in the fourth ~~finding-fining~~ upward sequence in the immediate section where  
469 the quarry is located. The paleochannel is estimated to have been about 1.8 m in depth,  
470 and paleochannel flow direction was approximately to the north.

471 The general area is largely undocumented from a stratigraphic perspective, with  
472 the closest published measured sections on the north side of the Milk River at Havre  
473 (Eberth and Hamblin, 1993; Arbour and Evans, 2017). However, continuous bedrock  
474 exposures along Little Boxelder Creek to the exposures at the Milk River allow  
475 identification of key surfaces and marker beds useful to infer the stratigraphic

476 occurrence of ROM 77978; In ascending order (~~see Supplemental Fig. S18~~): 1. a sharp  
477 lithological contact marking the onset of light-colored, Inclined Heterolithic Strata-  
478 dominated, channelized sandstones on top of a thick, paleosol-dominated interval, and  
479 2. a laterally extensive, coaly-lignite rich interval. Observations carried out north of  
480 Havre (i.e. at the Zuul crurivastator quarry, Arbour and Evans, 2017; FF pers.obs.)  
481 suggest the sand-dominated deposits ~~as~~are part of the Coal Ridge Member of the Judith  
482 River Formation (Rogers et al., 2016), and the coaly interval at the top of the Coal  
483 Ridge Member as the palaeoenvironmental equivalent of the Lethbridge coal zone  
484 (Eberth and Hamblin, 1993) ~~occurring at the top of the Coal Ridge Member.~~  
485 Furthermore, the overall thickness of strata in ~~the the area ROM 77978 area~~ is  
486 approximately 45 meters, allowing comparison with the measured composite section of  
487 Eberth and Hamblin (1993) to the north of Havre, where they inferred the top of the  
488 sequence to represent the southernmost occurrence of the Dinosaur Park Formation  
489 (Belly River Group), including the base of the Lethbridge Coal Zone.

490 Based on comparisons ~~to~~with the more complete stratigraphic sequence  
491 exposed on the east side the coulee system, the ROM 77978 host stratum is located  
492 approximately 40 meters below the base of the coaly deposits, and by extrapolation  
493 approximately 10-20 meters lower than the interval that hosted the skeleton of Zuul Z.  
494 crurivastator (Arbour and Evans, 2017; FF pers.obs.). Therefore ROM 77978 is from  
495 approximately the middle of the Coal Ridge Member of the Judith River Formation  
496 (Rogers et al., 2016). ROM 77978 is therefore chronostratigraphically correlative with  
497 the uppermost beds of the Oldman Formation in southern Alberta and the lower  
498 Dinosaur Park Formation in Dinosaur Provincial Park (Belly River Group; see Eberth  
499 and Hamblin, 1993; Eberth, 2005; Freedman Fowler and Horner, 2015; Arbour and

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500 Evans, 2017; Fowler, 2017), thus to be considered, from a stratigraphic perspective,  
501 representative of the *Corythosaurus*-dominated zone of Ryan and Evans (2005) and  
502 Mallon et al. (2012).

503

#### 504 **Description of ROM 77978**

505 *Skull.* Since the skull is in private hands, it will not be described in detail.

506 However, inspection of the original fossil before reconstruction by DCE, and the  
507 repositied CT scans, surface scans, and 3D print in the ROM collection reveals key  
508 morphological features that allow it to be identified as *Corythosaurus* (Supplemental  
509 Fig S29). These include a cranial crest that extends supraorbitally and prescribes a  
510 partial hemispherical-semicircular outline in lateral view with its apex positioned above  
511 the orbits. The preserved region of the crest is comprised of the premaxilla anteriorly  
512 and nasal bones posteriorly with a prominent premaxilla-nasal fontanelle occurring  
513 between these bones in the central region of the crest; below the PNF, the sinuous  
514 dorsal margin of the posterolateral process of the premaxilla formed by a caudal lobe  
515 that extends further dorsally than the rostral lobe, is diagnostic of *Corythosaurus* (Evans  
516 et al., 2005). The wide crest-snout angle is approximately 142 degrees, which is within  
517 the range of *Corythosaurus* (Evans, 2010). Since the caudal region of the crest is not  
518 preserved, and therefore the relative size and the shape of the caudal margin of the crest  
519 are not known, ROM 77978 cannot be positively assigned to the specific level. The  
520 morphology of the external narial opening, the shape of both the rostral process and free  
521 ventral flange of the jugal, shape of the maxilla, and degree of deflection of the  
522 edentulous rostral region of the dentaries are all within the range of variation of the

523 sample of *Corythosaurus* from the [Dinosaur Park Formation](#) [DPF](#) (e.g., Ostrom, 1961;  
524 DCE pers.obs.; Evans, 2010)

525 **Mandible.** ROM 77978 includes an almost complete left angular (Fig. [7A10A-](#)  
526 [D](#)), which is missing only the posteriormost region where it forms the base of the  
527 retroarticular process. It is a thin, splint-like bone with contact surfaces for the dentary  
528 anteriorly and laterally, the splenial medially, and the surangular posteriorly. The  
529 exterior surface is smooth, and it is rugose internally at its posterior terminus, where it  
530 contacts the surangular in an interdigitating joint. As preserved, the splenial has a  
531 maximum length of 198 mm, with a maximum mediolateral width at the contact with  
532 the surangular of 27 mm.

533 **Vertebrae.** Two relatively complete distal caudal vertebrae (Fig. [7E10E-J](#)) are  
534 typically hadrosaurid in morphology, with subhexagonal centrum faces, prominent  
535 chevron facets ventrally, and highly raked neural spines. The vertebral bodies of both  
536 vertebrae lack facets or protrusions for caudal ribs, and the zygapophyses are present  
537 but poorly developed. Based on comparisons with a mounted skeleton of *Corythosaurus*  
538 [C. intermedius](#) (ROM 845), the largest caudal vertebra is [approximately](#) from  
539 [approximately](#) caudal position 45, and the smaller vertebra is from position number 51.  
540 The largest vertebra has a centrum length of 45mm, with an anterior width of 57 mm  
541 and height of 47 mm. The incomplete, highly raked neural spine is 64 mm in length.  
542 The left prezygapophysis is preserved and projects anteriorly from the neural arch, and  
543 there are faint facets that represent postzygapophyses on the posterior base of the neural  
544 spine. The smaller vertebra has a centrum length of 39.8 mm, anterior width of 47 mm  
545 and height 41 mm. The incomplete highly raked neural spine is 63 mm as preserved.

546 **Pelvic girdle.** The almost complete right ilium is only missing the distal half of  
547 the strongly downcurved preacetabular process (Fig. 10-K, L). It has a total length of  
548 855 mm in length as preserved, with a depth above the acetabulum of 198 mm. The  
549 acetabular margin (175 mm in length) is a shallowly incised arch in the ventral margin  
550 of the bone between the pubic and ischiac peduncle. The postacetabular process is  
551 elongate, with a length of 270 mm and a dorsoventral height of 128 at its midpoint in  
552 lateral view; the elongate postacetabular process (L/H ratio of 2.1) falls within the  
553 expected range of Lambeosaurinae, and not Saurolophinae (Brett-Surman and Wagner,  
554 2007). The dorsal margin of the ilium is strongly sigmoidal with a sharp dorsal  
555 curvature over the supracetabular crest and a ventrally deflected preacetabular process,  
556 as is characteristic of Lambeosaurinae (Horner et al., 2004; Brett-Surman and Wagner,  
557 2007). The prominent supracetabular crest extends ventrally on the lateral surface of the  
558 body to a point approximately halfway between the dorsal margin and the base of the  
559 ischiac peduncle. The morphology the ilium in ROM 77978 is almost identical to the  
560 type series of AMNH 5240 and AMNH 5338 and compares well to OUSM-FV-001,  
561 with a strongly sigmoidal dorsal margin, robust suprailiac crest, and elongate  
562 postacetabular process that falls into ilium type four of Brett-Surman and Wagner  
563 (2007).

564

## 565 **DISCUSSION**

### 566 **Taxonomic assignments**

567 Hadrosaurid remains have long been recognized from the Judith River  
568 Formation, ever since the discovery of "*Trachodon mirabilis*" (Leidy, 1856). Since then,  
569 ~~three-two~~ hadrosaurine taxa, *Brachylophosaurus canadensis* (Sternberg, 1953; Prieto-

570 ~~Márquez, 2005; Murphy et al., 2006; Prieto-Marquez, 2007~~), (Sternberg, 1953; Horner,  
571 1988; Prieto-Márquez, 2005; Murphy et al., 2006; Prieto-Marquez, 2007)  
572 ~~*Brachylophosaurus goodwini* (Horner, 1988)~~, and *Probrachylophosaurus bergi*  
573 (Freedman Fowler and Horner, 2015), have been described from the McClelland Ferry  
574 Member of the Judith River Formation. On the other hand, lambeosaurines from the  
575 formation are poorly understood, although their presence has been suggested by several  
576 poorly preserved specimens. A maxilla and a squamosal (USNM 5457) collected from  
577 Dog Creek (~10 km northwest of OUSM-FV-001 quarry) were originally reported as  
578 "*Hadrosaurus paucidens*" (Marsh, 1889), and later renamed as "*Lambeosaurus*  
579 *paucidens*" (Ostrom, 1964). While the bones clearly belong to Lambeosaurinae, ~~further~~  
580 ~~their~~ taxonomic status is now considered ambiguous due to ~~their~~ incompleteness  
581 (Prieto-Márquez et al., 2006). Another such specimen, an isolated tooth (AMNH FARB  
582 8527) from the Clambank Hollow Quarry (~25 km northwest of OUSM-FV-001 quarry)  
583 originally identified as "*Procheneosaurus altidens*" (Sahni, 1972) obviously lacks  
584 diagnostic features useful for identifying it to a specific genus. Another incomplete  
585 specimen (pelvic and limb bones, AMNH FARB 3971) from near Cow Island, Montana  
586 (~ 40 km northeast of ~~the~~ OUSM-FV-001 quarry) was reported as "*Pteropelyx*  
587 *grallipes*" (Cope, 1889). Although this specimen was once treated as a senior synonym  
588 of *Corythosaurus* (Brett-Surman, 1989), it was later considered a nomen dubium  
589 (Horner et al., 2004). In addition to these dubious specimens, an ischium of an  
590 indeterminate lambeosaurine is also known from a multitaxic bonebed from the  
591 Careless Creek Quarry (Fiorillo, 1989; Prieto-Márquez and Gutarra, 2016).  
592 Furthermore, lambeosaurine egg clutches and embryonic remains *in ovo* have been  
593 described from the Judith River Formation (Horner, 1999), but their incompleteness and

594 embryonic nature obscure their taxonomic status. As such, while lambeosaurine  
595 material has continuously been reported from the Judith River Formation, ~~their~~ [its](#)  
596 taxonomic status remains ambiguous, largely due to the lack of taxonomically  
597 identifiable elements. The new lambeosaurine skeleton OUSM-FV-001 described in this  
598 study is therefore valuable in its reasonably well-preserved status, including [part of](#) the  
599 cranial crest, which makes genus-level taxonomic identification possible and  
600 contributes to a better understanding of the Judith River dinosaur fauna.

601 OUSM-FV-001 is markedly different from the members of Parasaurolophini in  
602 the angled dorsal margin of the posterodorsal process of the premaxilla (Fig. 2D),  
603 although it is missing most of its cranial crest. The frontal also differs from  
604 Parasaurolophini in the absence of the posteriorly elongated nasal platform of the frontal  
605 and the long interfrontal suture relative to the frontal width (Evans et al., 2007). Instead,  
606 the presence of the PNF (Fig. 2H-K), the S-loop internal to the posterodorsal process of  
607 the premaxilla (Fig. 2E, F), and the dorsoventrally tall nasal suggest an affinity with  
608 Lambeosaurini. Among Lambeosaurini, OUSM-FV-001 differs from *Hypacrosaurus* in  
609 the absence of tall dorsal neural spines, which is a diagnostic character of  
610 *Hypacrosaurus* (Lull and Wright, 1942; Evans, 2010). The presence of a PNF also  
611 differs from *Hypacrosaurus* because the PNF of *Hypacrosaurus* closes at an early stage  
612 of ontogeny (Horner and Currie, 1994; Brink et al., 2014). Additionally, OUSM-FV-  
613 001 differs from [Hypacrosaurus H. altispinus](#) in the trapezoidal ventral margin of the  
614 ventral flange of the jugal and the bifurcated squamosal process of the postorbital  
615 (Evans, 2010). OUSM-FV-001 also differs from *Lambeosaurus* in the wide crest-snout  
616 angle and the laterally exposed ophthalmic canal of the laterosphenoid, both of which  
617 are diagnostic characters of *Lambeosaurus* (Evans and Reisz, 2007). OUSM-FV-001

618 further differs from *Lambeosaurus* in the dorsoventrally tall nasal, which does not form  
619 the caudal process of the crest. OUSM-FV-001 differs from another member of  
620 Lambeosaurini, *Magnapaulia* (Prieto-Márquez et al., 2012) in the well-separated  
621 prezygapophyses of the proximal caudal vertebrae. OUSM-FV-001 also differs from the  
622 immature lambeosaurine *Velafrons* (Gates et al., 2007) in having the gently curved  
623 squamosal process of the postorbital (Fig. 3G). Although the incompleteness of OUSM-  
624 FV-001 hinders comparisons with the diagnostic characters of the Asian Lambeosaurini,  
625 the dentary of OUSM-FV-001 differs from those of *Amurosaurus* (Godefroit et al.,  
626 2004; Bolotsky et al., 2014) and *Sahaliyana* (Godefroit et al., 2008) in the absence of  
627 the strong ventral deflection of the anterior half of the dentary (Fig. 3Q4G-FI). OUSM-  
628 FV-001 also differs from another Asian ~~Lambeosaurini~~ lambeosaurine *Olorotitan*  
629 (Godefroit et al., 2012) in the relatively short ~~diastema edentulous region~~ of the dentary.  
630 Although the diagnostic character of *Corythosaurus* (i.e., large, bifurcated nasal; Evans  
631 et al., 2005) cannot be confirmed on OUSM-FV-001 due to incompleteness of the nasal,  
632 the unique set of characters listed above strongly suggests that OUSM-FV-001 is  
633 *Corythosaurus*. Whether OUSM-FV-001 is ~~Corythosaurus-C.~~ *C. casuarius*, ~~Corythosaurus~~  
634 *C. intermedius*, or a distinct species cannot be determined at this point; thus, OUSM-  
635 FV-001 is referred to *Corythosaurus* sp..

636 ROM 77978, although less complete, also contributes important new  
637 information on the distribution of *Corythosaurus*. The identification of ROM 77978 is  
638 more straightforward but is scientifically hindered because the associated articulated  
639 skull is currently in private hands (Supplemental-Fig. S29), although CT scans, surface  
640 scans, and photographs are deposited at the ROM. The skull clearly exhibits a number of  
641 diagnostic hallmarks of *Corythosaurus*, including a rounded, helmet-like supracranial

642 crest with its apex positioned above the orbits, a prominent premaxilla-nasal fontanelle  
643 between the premaxilla and nasal bones in the central region of the crest, and most  
644 importantly a sinuous dorsal margin of the posterolateral premaxillary process formed  
645 by a caudal lobe that extends further dorsally than the rostral lobe. The shape of the  
646 lateral process of ROM 77978 differs from that of *Hypacrosaurus-H. stebingeri*, which  
647 is dorsally arched (Brink et al., 2014). The wide crest-snout angle is approximately 142  
648 degrees, which is within the range of *Corythosaurus* (Evans, 2010) and similar to *H.*  
649 *stebingeri* (Brink et al., 2014), but outside that of most other lambeosaurines  
650 (*Lambeosaurus*, *Parasaurolophus* and *Hypacrosaurus-H. altispinus*) known from  
651 northern Laramidia during the Campanian-Maastrichtian (Evans, 2010). The caudal  
652 region of the nasal is not preserved, and therefore the skull cannot be positively  
653 assigned to either of the two known species of *Corythosaurus*, *C. casuarius* or *C.*  
654 *intermedius*. Fortunately, the almost complete, well-preserved ilium of ROM 77978  
655 (Fig. ~~7K-10K~~, L) exhibits a distinctive suite of morphologies that allow its taxonomic  
656 identification to the tribe Lambeosaurini, which is consistent with the identification of  
657 the skull as *Corythosaurus*. The ilium of ROM 77978 is almost identical to the holotype  
658 of *Corythosaurus* (AMNH 5240) and compares well to the plesiotype AMNH 5338 as  
659 well as OUSM-FV-001~~7~~. It has a strongly sigmoidal dorsal margin, large, pendant  
660 suprailiac crest, and elongate postacetabular process and can clearly be categorized as  
661 ilium type four of Brett-Surman and Wagner (2007). Recognizing that the~~se~~ five  
662 hadrosaurid ilium morphotypes that in-form a morphocline ~~and~~ are not strictly  
663 taxonomically ‘useful’, *Corythosaurus* is used to exemplify the~~se~~ fourth morphotype  
664 (Brett-Surman and Wagner 2007). Although the ilia of the Lambeosaurini  
665 *Corythosaurus*, *Hypacrosaurus-H. stebingeri*, and *Lambeosaurus* for example cannot be

666 reliably distinguished from each other, the ilium in the ROM collections serves  
667 minimally as a detailed stratigraphic record of Lambeosaurini in Montana, which based  
668 on the repositated data for the skull can reasonably be identified as *Corythosaurus* sp.

669         The taxonomic assignment of OUSM-FV-001 and ROM 77978 to  
670 *Corythosaurus* sp. in this study demonstrates that it is the first hadrosaurid specimen in  
671 the Coal Ridge Member identified below the subfamily level, and the first time a genus  
672 of lambeosaurine has been positively identified in the Judith River Formation as a  
673 whole.

674

#### 675 **Paleobiogeographical significance**

676         OUSM-FV-001 and ROM 77978 are notable for being the first *Corythosaurus*  
677 specimens from outside the DPF and for extending the biogeographic range of  
678 *Corythosaurus* ~ 350 km southward. The late Campanian vertebrate assemblage  
679 represented in the DPF is the most diverse terrestrial fauna of the Late Cretaceous,  
680 including over 50 dinosaurian taxa (Currie and Koppelhus, 2005). Hadrosaurids are the  
681 most abundant in the dinosaur fauna of the DPF (Dodson, 1983; Brinkman, 1990;  
682 Cullen and Evans, 2016), and *Corythosaurus* is the most common hadrosaurid genus in  
683 the formation (Ryan and Evans, 2005). Despite its abundance in the DPF, the  
684 geographical occurrence of *Corythosaurus* ~~is~~ has been restricted to the Dinosaur  
685 Provincial Park area in Alberta, Canada, with one exception from Hilda, Alberta,  
686 approximately 80 km east of the park (Evans, 2002; Ryan and Evans, 2005). Although  
687 there are some ambiguities in the locality and stratigraphical data, the horizon yielding  
688 OUSM-FV-001 is ~~supposed~~ likely to be within the Coal Ridge Member of the JRF,  
689 which is approximately time equivalent to the DPF (Rogers et al., 2016; Fowler, 2017).



690 ROM 77978 can be definitively traced to the middle of the Coal Ridge Member of the  
691 JRF. Thus, OUSM-FV-001 and ROM 77978 are therefore at least  
692 penecontemporaneous to the *Corythosaurus* population from the DPF and likely  
693 represent an extension of its biogeographical range rather than a temporal habitat shift.  
694 The shared occurrence of *Corythosaurus* in the Coal Ridge Member of the JRF and the  
695 DPF is congruent with previous knowledge ~~on~~of the paleoenvironment and the  
696 vertebrate fauna of these strata. The Coal Ridge Member of the JRF and the DPF are  
697 within a continuous clastic wedge, and both are interpreted to represent a wet and humid  
698 coastal plain environment along the Western Interior Seaway (Eberth and Hamblin,  
699 1993; Eberth, 2005; Rogers et al., 2016). Although there is only one shared dinosaur  
700 species (*Mercuriceratops gemini*, Ryan et al., 2014) between the two strata, plus some  
701 theropod teeth assigned to *Dromaeosaurus albertensis*, *Troodon formosus*, and *Zapsalis*  
702 *abradens* (Mallon et al., 2016), the terrestrial and freshwater fauna of the JRF and the  
703 DPF resemble each other as a whole compared to other Campanian formations in North  
704 America (Gates et al., 2010). Based on the limited biogeographical extent of  
705 *Corythosaurus* and other late Campanian megaherbivorous dinosaurs, it has been  
706 suggested that they have specific habitat preferences and/or limited environmental  
707 tolerances (Lehman, 2001). The extension of the *Corythosaurus* biogeographical  
708 distribution revealed in this study does not readily disagree with this idea because of the  
709 paleoenvironmental similarities of these two strata, ~~but~~Additional specimens and  
710 further taxonomic studies of megaherbivorous dinosaurs as well as the construction of a  
711 rigorous temporal framework of the time equivalent beds ~~yet~~ deposited in different  
712 environmental conditions, such as the more xeric Two Medicine Formation (Rogers,  
713 1990), are necessary to test this hypothesis.

Formattato: Tipo di carattere: Corsivo

714 Even though our study demonstrates the paleobiogeographical extension of  
715 *Corythosaurus*, the ~~*Corythosaurus*~~ remains of the genus in the JRF are still  
716 overwhelmingly outnumbered by those in the DPF, which is potentially driven by the  
717 limited temporal occurrence of *Corythosaurus* in the fossil record. Due to its rich fossil  
718 record and intense research history, the stratigraphic distribution of dinosaur taxa in the  
719 DPF is well understood (Ryan and Evans, 2005; Mallon et al., 2012; Cullen et al.,  
720 2021), and *Corythosaurus* is only ~~discovered in~~known from the lower part of the  
721 Dinosaur Park Formation (*Centrosaurus-Corythosaurus* faunal zone [Ryan and Evans,  
722 2005], or the megaherbivore assemblage zone 1 [MAZ-1, Mallon et al., 2012]). If such  
723 a tight stratigraphic distribution of megaherbivorous dinosaurs is also present in the  
724 JRF, it is implied that the horizon directly comparable to the lower half of the DPF is  
725 exposed in the outcrop around the OUSM-FV-001 and ROM 77978 localities, and so  
726 would have high potential for new discoveries of dinosaurs known from these faunal  
727 zones of the DPF. The faunal zones defined within the Dinosaur Park Formation at  
728 Dinosaur Provincial Park have been shown to extend across a large regional area of  
729 southern Alberta (Evans et al., 2014) (~~Evans, 2002~~), and some ornithischian taxa such  
730 as *Centrosaurus apertus* have been shown to occur in time equivalent portions of the  
731 upper muddy unit of the Oldman Formation (Chiba et al., 2015), which is both  
732 lithostratigraphically and chronostratigraphically correlative to the Coal Ridge Member  
733 of the JRF. We therefore predict that many dinosaur taxa currently known only from the  
734 Dinosaur Park Formation will be discovered in the upper Judith River Formation, which  
735 will further elucidate paleobiogeographic and ~~32~~biostratigraphic comparisons across the  
736 Western Interior Basin.

737

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757  
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