

A NEW DROMAEOSAURID (THEROPODA: DROMAEOSAURIDAE) FROM THE LATE CRETACEOUS OF NEW MEXICO

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Abstract— A left frontal from the Upper Cretaceous Kirtland Formation (De-na-zin Member), San Juan Basin, New Mexico, is diagnosed as *Saurornitholestes sullivanii* n. sp., a new species of dromaeosaurid (Theropoda: Dromaeosauridae). The frontal is similar to *Saurornitholestes langstoni* in being triangular in shape, not basined between the median suture and the orbital rim, and having the caudal portion of the frontal well-rounded and slightly inflated, without evidence of a frontoparietal crest. It is distinct from *S. langstoni* in being more constricted anteriorly, possessing less prominent nasal facets, possessing a less prominent anterior projection between the nasal and lacrimal facet regions, having a deeper and less strongly demarcated orbital rim, possessing a deeper and more prominent olfactory bulb surface, possessing a more pronounced and longer ventrally-directed ridge between the olfactory bulb surface and the cerebral hemisphere surface, possessing a more robust frontal-frontal sutural surface, and while being slightly smaller in overall size, still being more robust than *S. langstoni*. The enlarged olfactory bulb surface is believed to convey a greater olfactory sense in this dinosaur, in particular in comparison to *S. langstoni*, and may have been important for its predatory behavior. *Saurornitholestes sullivanii* represents the only known dromaeosaurid from the Late Cretaceous of southern Laramidia, and specifically the San Juan Basin of New Mexico, and shows geographic and temporal differences between the two currently recognized species of *Saurornitholestes*.

INTRODUCTION

Late Cretaceous vertebrates from the San Juan Basin of New Mexico have undergone a tremendous amount of revision over the last few decades. This revision has included numerous newly named taxa over the last 22 years. Newly named species from the Fruitland, Kirtland, and Ojo Alamo formations include the nanhsiungchelyid turtle *Basilemys gaffneyi* (Sullivan et al., 2013); the †azhdarchid pterosaur *Navajodactylus boerei* (Sullivan and Fowler, 2011); and several dinosaurs including the tyrannosaurid *Bistahieversor sealeyi* (Carr and Williamson, 2010); the dromaeosaurid *Saurornitholestes robustus* (Sullivan, 2006); the caenagnathid *Ojoraptorsaurus boerei* (Sullivan et al., 2011); the hadrosaurine hadrosaurids *Anasazisaurus horneri* and *Naashoibitosaurus ostromi* (Hunt and Lucas, 1993); the ankylosaurids *Nodocephalosaurus kirtlandensis* (Sullivan, 1999), *Ziapelta sanjuanensis* (Arbour et al., 2014); and *Ahshislepelta minor* (Burns and Sullivan, 2011); the nodosaurids *Edmontonia australis* and *Glyptodontopelta mimus* (Ford, 2000); the ceratopsid *Ojoceratops fowleri* (Sullivan and Lucas, 2010); and the pachycephalosaurids *Sphaerotherolus goodwini* (Williamson and Carr, 2002) and *Stegoceras novomexicanum* (Jasinski and Sullivan, 2011). Newly named genera for existing species include *Denazinemys* for the baenid turtle *D. nodosa* (Lucas and Sullivan, 2006); *Scabremys* for the baenid turtle *S. ornata* (Sullivan et al., 2013); and *Denazinosuchus* for the goniopholidid mesoecrocodylian *D. kirtlandicus* (Lucas and Sullivan, 2003). Dedicated collecting efforts by several institutions, namely The State Museum of Pennsylvania and the New Mexico Museum of Natural History and Science, have been key to finding and describing these new taxa.

The Fruitland through Ojo Alamo formations span the Upper Campanian through the end of the Cretaceous. The Ojo Alamo Formation actually has Paleocene sediments as well (Jasinski et al., 2011), although these younger strata are not believed to contain in-situ dinosaur fossils (Lucas et al., 2009; Koenig et al., 2012; contra Fassett and Lucas, 2000; Fassett et al., 2002, 2011; Fassett, 2009). Nevertheless, the majority of the recently named taxa have come from the Upper Campanian Fruitland and Kirtland formations, as these are also more richly fossiliferous than the younger Maastrichtian Naashoibito Member of the Ojo Alamo Formation (Jasinski et al., 2011).

Sullivan and Lucas (2000) described a left frontal (SMP VP-1270) from the De-na-zin Member of the Kirtland Formation from a dromaeosaurid and attributed it to *Saurornitholestes langstoni*. *Saurornitholestes langstoni* was named by Sues (1978) and was reviewed by Norell and Makovicky (2004), who concluded it belonged to the Dromaeosauridae based, in part, on its possession of a “T-shaped frontal with large postorbital processes”. Sullivan and Lucas



FIGURE 1. Map showing the type locality of *Saurornitholestes*. **A**, Location of *Saurornitholestes langstoni* (TMP 1974.010.0005, holotype) from the Judith River Formation in Dinosaur Provincial Park, south-central Alberta; **B**, Location of *Saurornitholestes sullivanii* (SMP VP-1270, holotype) from the Kirtland Formation (De-na-zin Member) in the San Juan Basin, north-west New Mexico.

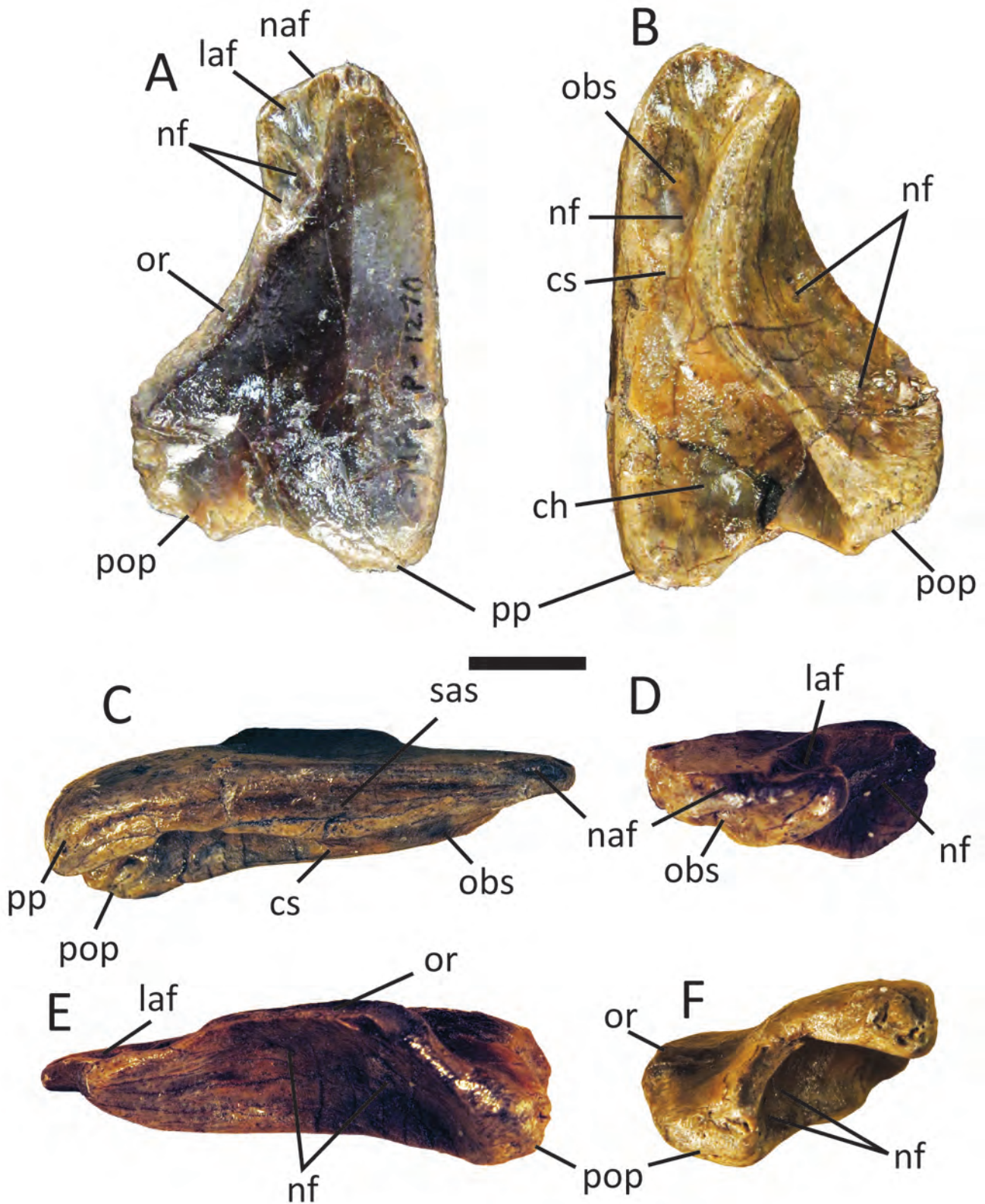


FIGURE 2. *Saurornitholestes sullivanii* (SMP VP-1270, holotype), nearly complete left frontal. **A**, dorsal view; **B**, ventral view; **C**, medial view; **D**, anterior view; **E**, left lateral view; and **F**, posterior view. **A** and **B**, anterior is up; **C**, anterior to right; and **E**, anterior to left. **Abbreviations:** **ch**, cerebral hemisphere surface; **cs**, convex surface between olfactory bulb surface and cerebral hemisphere surface; **laf**, lacrimal facet; **naf**, nasal facet; **nf**, nutrient foramen (or foramina); **obs**, olfactory bulb surface; **or**, orbital rim; **pop**, postorbital process (peduncle); **pp**, parietal process (peduncle); and **sas**, sagittal articular surface. Bar scale = 1 cm.

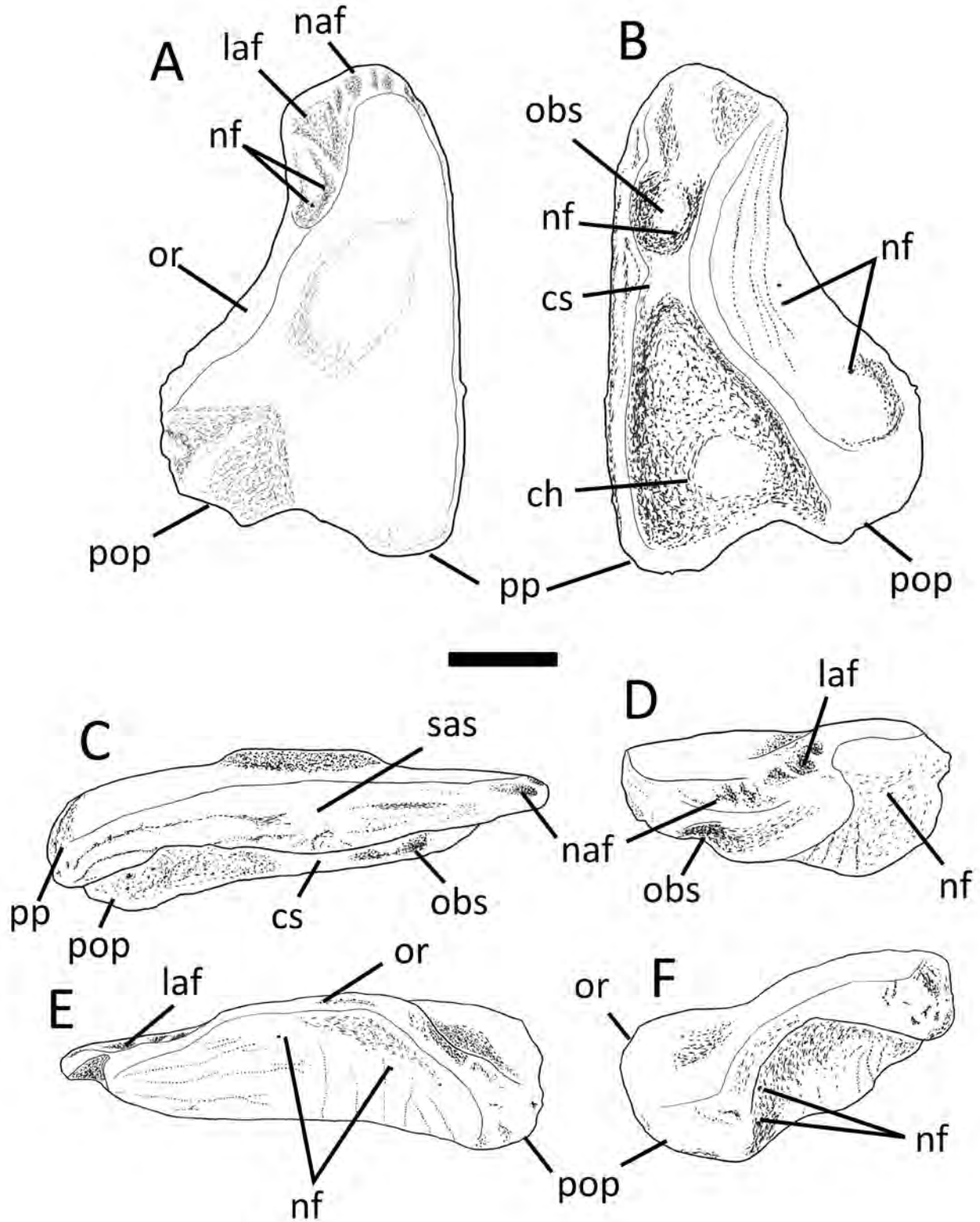


FIGURE 3. *Saurornitholestes sullivanii* (SMP VP-1270, holotype), illustrations of nearly complete left frontal. **A**, dorsal view; **B**, ventral view; **C**, medial view; **D**, anterior view; **E**, left lateral view; and **F**, posterior view. **A** and **B**, anterior is up; **C**, anterior to right; and **E**, anterior to left. **Abbreviations:** **ch**, cerebral hemisphere surface; **cs**, convex surface between olfactory bulb surface and cerebral hemisphere surface; **laf**, lacrimal facet; **naf**, nasal facet; **nf**, nutrient foramen(a); **obs**, olfactory bulb surface; **or**, orbital rim; **pop**, postorbital process (peduncle); **pp**, parietal process (peduncle); and **sas**, sagittal articular surface. Bar scale = 1 cm.

(2000) concluded that SMP VP-1270 was morphologically similar to the holotype of *S. langstoni* (TMP 1974.010.0005), and referred it to that taxon, marking the first occurrence of *Saurornitholestes* in the Late Cretaceous of New Mexico (Fig. 1). Later, Sullivan (2006) described a second specimen of *Saurornitholestes* from the De-na-zin Member (SMP VP-1955, left frontal); however, he felt this frontal was distinct enough from *S. langstoni* to warrant naming a new species, *S. robustus*. Material previously attributed to *S. langstoni* from the Upper Cretaceous strata of the San Juan Basin in New Mexico was then attributed to *S. robustus* (Sullivan, 2006). *Saurornitholestes robustus* was later reviewed, along with many other dromaeosaurids, by Turner et al. (2012), who concluded that *S. robustus* (SMP VP-1955) was a nomen dubium and did not preserve any of the synapomorphies of *Saurornitholestes*, and potentially of Dromaeosauridae. More recently, Evans et al. (2014a) found the holotype of *S. robustus* (SMP VP-1955) to represent an indeterminate troodontid. The conclusion by Turner et al. (2012), however, does not take into account the taxonomic affinities of the frontal (SMP VP-1270) earlier referred to *S. langstoni*. Indeed, Evans et al. (2014a) mention that, unlike SMP VP-1955, SMP VP-1270 appears to represent a dromaeosaurid. While Turner et al. (2012) mention the need for descriptions of further material of *S. langstoni* to fully understand this Late Cretaceous dromaeosaurid, this paper will carefully examine the frontal (SMP VP-1270) described by Sullivan and Lucas (2000) and discuss its implications for dromaeosaurids from the Late Cretaceous of New Mexico.

Institutional abbreviations: AMNH, American Museum of Natural History, New York, New York; GIN (IGM), Mongolian Institute of Geology, Ulan Bataar; HIII, Henan Geological Museum, Zhengzhou; IVPP, Institute of Vertebrate Paleontology and Paleoanthropology; Beijing, China; MPCA, Museo Carlos Ameghino, Cipolletti, Rio Negro Province, Argentina; SMP, State Museum of Pennsylvania, Harrisburg, Pennsylvania; TMP, Royal Tyrrell Museum of Paleontology, Drumheller, Alberta, Canada; UALVP, University of Alberta Laboratory for Vertebrate Paleontology, Edmonton, Alberta, Canada.

SYSTEMATIC PALEONTOLOGY
DINOSAURIA Owen, 1842
SAURISCHIA Seeley, 1888
THEROPODA Marsh, 1881
DROMAEOSAURIDAE Matthew and Brown, 1922
VELOCIRAPTORINAE Barsbold, 1983
SAURORNITHOLESTES Sues, 1978
Saurornitholestes sullivanii, n. sp.

Fig. 2-3, 4A

Holotype: SMP VP-1270, nearly complete left frontal.

Type Locality: SMP loc. No. 311 (head of the east branch of Hunter Wash [southeast]), Hunter Wash, San Juan Basin, New Mexico. Precise GPS coordinates available to qualified researchers.

Formation/Age: Kirtland Formation (De-na-zin Member), Late Campanian (late Kirtlandian Land Vertebrate Age or LVA) (Sullivan and Lucas, 2003, 2006).

Etymology: The species name honors Robert M. Sullivan, who discovered the holotype specimen, and whose work in the Late Cretaceous of the San Juan Basin, New Mexico has been instrumental in furthering knowledge of this key region for understanding the Late Cretaceous of North America.

Diagnosis: A member of the Dromaeosauridae based on a demarcated postorbital process (based on the portion that is preserved), a somewhat sigmoidal ridge on the postorbital process, and a sinuous demarcation of the supratemporal fossa (as discussed by Currie, 1995 and Turner et al., 2012). *Saurornitholestes* and *Bambiraptor* are differentiated by a rostromedial projection and of the frontals and a long orbital rim in the latter, and a shallow basin situated rostrocaudally and a posterolateral basin near the postorbital process in the former. Additionally the overlap of the lacrimal on the frontal is more pronounced in *Bambiraptor* than in *Saurornitholestes*. A member of *Saurornitholestes* based on characters listed by Sues (1978), including "Frontal triangular, not basined between the median suture and the orbital rim. Posterior of frontal well rounded and slightly inflated, without frontoparietal crest." Distinguished from *Saurornitholestes langstoni* by (1) being more constricted anteriorly (as noted by Sullivan, 2000); (2) possessing less prominent nasal sutures (facets); (3) possessing less prominent anterior projection between the nasal and lacrimal facet regions; (4) having a deeper and less strongly demarcated orbital rim; (5) having a deeper and more prominent olfactory bulb surface; (6) possessing a more pronounced and longer ventrally-directed ridge between the olfactory bulb surface and the cerebral hemisphere surface; (7) possessing a more robust frontal-frontal sutural surface; and (8) while slightly smaller, still being more robust than *S. langstoni*.

Description: The holotype (SMP VP-1270) is a nearly complete, slightly water-worn, left frontal (Fig. 2). Despite its condition, SMP VP-1270 preserves key features that allow it to be distinguished from other dromaeosaurid taxa. The frontal is 42.8 mm long along the midline, has a maximum width of 27.8 mm and a minimum width of 14.1 mm (see Table 1). Thus, viewed dorsally, the bone is far longer than wide and has a triangular shape dominated by the long, concave-lateral orbital rim (Figs. 2A, 3A).

The anterior end of the frontal is water-worn, but preserves two small furrows on its dorsal edge near the medial margin. These furrows are the sutural surface (facet) for the left nasal. Lateral to these is an

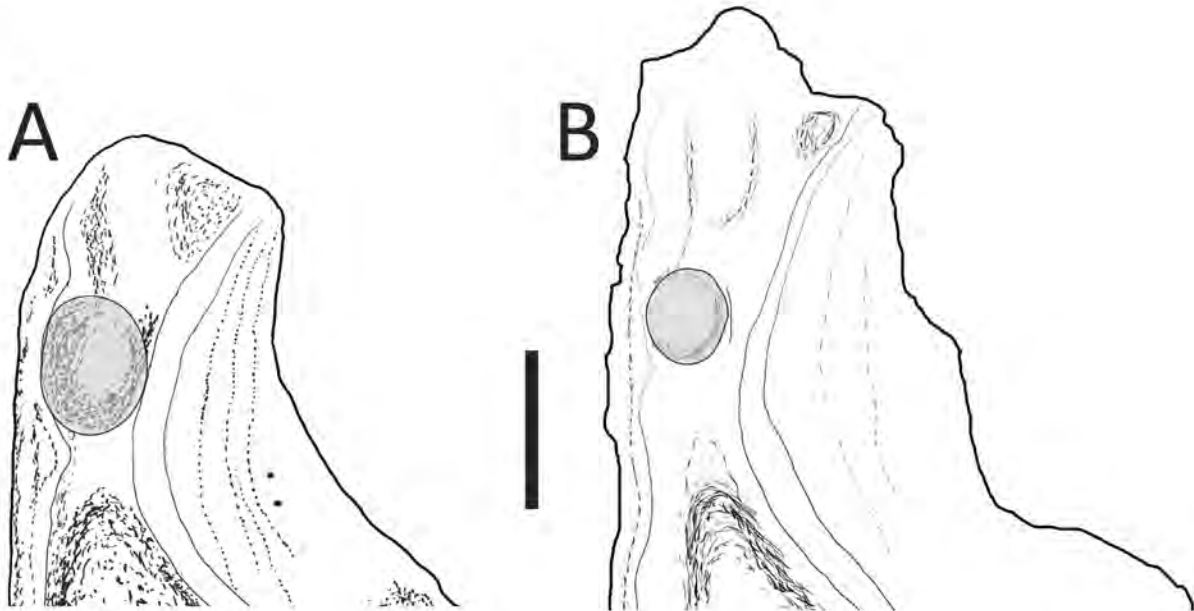


FIGURE 4. Anterior portion of left frontals illustrated in ventral view. **A**, *Saurornitholestes sullivanii* (SMP VP-1270, holotype); **B**, *S. langstoni* (TMP 1974.010.0005, holotype). Olfactory bulb surface is highlighted in grey to better focus on the structure and show that *S. sullivanii* has a larger olfactory bulb surface both relatively and in actual size/dimensions. Bar scale = 1 cm.

TABLE 1. Comparisons of dromaeosaur (Dromaeosauridae) frontals. Measurements were taken from specimens and various previous studies, including those of Currie (1995), Barsbold and Osmólska (1999), Burnham et al. (2000), Xu and Wu (2001), Burnham (2004), Makovicky et al. (2005), Lü et al. (2007), Turner et al. (2012) and Xu et al. (2015). All specimens are holotypes except GIN 100/25, which is a referred specimen of *Velociraptor mongoliensis* (see Barsbold and Osmólska, 1999). Make note that '*Saurornitholestes*' *robustus* is now considered an indeterminate troodontid (see Evans et al., 2014a), and *Luanchuanraptor henanensis*, which was originally thought to be a dromaeosaurid by Lü et al. (2007), has since been considered a member of the Averaptora rather than the Dromaeosauridae by Agnólin and Novas (2013). Measurements in millimeters. Abbreviations: **lt**, midline length minus nasal + lacrimal-frontal sutural surface/maximum thickness at posterior portion of the frontal; **maxw**, maximum width; **minw**, minimum width; **mll**, midline length minus nasal + lacrimal-frontal sutural surface; **mmll**, maximum midline length; **obs**, olfactory bulb surface dimensions; **orl**, orbital rim length in dorsal view (note this measurement deals with the portion of the frontal that makes up part of the orbital rim and not the entire orbital rim length); **>**, greater than; *****, measurement is incomplete due to breakage or lack of preservation of a specimen; **-**, measurement unavailable or unknown.

Taxon	Specimen #	mll	mmll	maxw	minw	orl	obs	lt
<i>Saurornitholestes sullivani</i>	SMP VP-1270	36.1	42.8	27.8	14.1	28.4	6.4 x 13.5	7:1
' <i>Saurornitholestes</i> ' <i>robustus</i>	SMP VP-1955	52.2	61.5	>30.1*	18.2	36.8	3.9 x 6.4	6:1
<i>Saurornitholestes langstoni</i>	TMP 1974.010.0005	39.9	54.5	33.4	15.3	27.8	4.7 x 7.4	10:1
<i>Velociraptor mongoliensis</i>	GIN 100/25	45.1	49.2	26.8	14.1	45.5	-	-
<i>Bambiraptor feinbergi</i>	AMNH 001	43.6	-	21.8	8.1	33.0	-	-
<i>Dromaeosaurus albertensis</i>	AMNH 5356	35.7	53.8	36.3	18.9	34.4	-	-
<i>Tsaagan mangas</i>	IGM 100/1015	39.4	45.1	24.5	11.4	24.3	-	-
<i>Linheraptor exquisitus</i>	IVPP V 16923	56.5	-	30.0	13.1	36.1	-	-
<i>Adasaurus mongoliensis</i>	IGM 100/20	96.8*	105.1*	37.4*	15.2*	53.2*	-	-
<i>Buitreraptor gonzalezorum</i>	MPCA 245	>33.9*	-	>14.4*	7.2	27.1*	-	-
<i>Mahakala omnogovae</i>	IGM 100/1033	24.9	27.0	10.1	3.3	23.1	-	-
<i>Sinornithosaurus millenii</i>	IVPP V12811	36.3	48.4	20.7	8.0	30.1	-	-
<i>Luanchuanraptor henanensis</i>	4HIII-0100	51.4	57.2	36.4	19.4	31.3	-	-

irregular surface incised below the dorsal surface of the bone. An arcuate, anteroposteriorly-oriented edge delimits this incised surface, which is where the lacrimal overlaps the dorsal surface of the frontal.

The dorsal surface of the frontal is smooth (Figs. 2A, 3A). In dorsal view the orbital rim is 28.4 mm long (note this refers to the portion of the orbital rim surrounded by the frontal and not the entire orbital rim). The orbital rim is a convex-dorsal, raised surface of bone with a slightly concave dorsolateral edge. Medial to the orbital rim, the dorsal surface of the frontal is slightly concave to form a shallow anteroposterior sulcus. The bone then becomes convex posterodorsally along its median half.

The entire posterior edge that contacts the parietal is water-worn and marks the frontoparietal suture. The frontoparietal suture is distinguished, in part, by two blunt, irregular, sub-rounded processes (a lateral process, or peduncle, for the postorbital, and a median parietal process) that project posteriorly and are divided by a concavity. This, the articular surface for the parietal and postorbital, forms the anterior margin of the supratemporal fenestra. Although the left lateral process that joins with the postorbital is slightly water-worn, the portion that is preserved does not appear as pronounced as in *Velociraptor mongoliensis* or *Saurornitholestes langstoni*, and instead is more similar to that feature in *Bambiraptor feinbergi* (Burnham et al., 2000; Burnham, 2004), and some species of troodontid (e.g., *Stenonychosaurus inequalis* (= *Troodon formosus*) of Currie [1985]).

The ventral surface of SMP VP-1270 (Figs. 2B, 3B) is dominated by three features: (1) the concave and arcuate orbital rim laterally; (2) a narrow, ovoid sulcus anterolaterally (olfactory bulb surface in the frontal); and (3) a much larger, subtriangular-shaped (widening posteriorly) surface for the cerebral hemisphere. A blunt (water-worn), somewhat sigmoidal and concave-lateral ridge separates the orbit from the endocranial surfaces. However, the olfactory bulb and cerebral surfaces are partially separated by a shallow, convex ventrally-projecting surface.

Viewed laterally, SMP VP-1270 (Figs. 2E, 3E) is wedge-shaped, as it is taller posteriorly than anteriorly. Almost the entire lateral surface makes up the dorsomedial wall of the orbit, which has a dorsal margin that overhangs a concave lateral surface. A row of six, anteroposteriorly-oriented foramina is present near the greatest point of curvature of the

orbit. These foramina probably represent nutrient foramina, but may represent neurovascular foramina as well. Three similar foramina are also present near the posterodorsal margin of the orbit.

The medial (sagittal) articular surface (Figs. 2C, 3C) is grooved, water-worn and slants laterally. There are a number of small nutrient foramina, some concomitant with the grooves, which extend intermittently for the entire length of the frontal. A pronounced, ventrally-directed ridge is present between the anterior edge of the cerebral surface and the posterior edge of the olfactory surface, marking the limits between these two regions. This constriction is slightly greater than in the holotype of *S. langstoni* (TMP 1974.010.0005).

Less information can be gathered from the frontal in anterior and posterior views. In anterior view, the nasal and lacrimal facets are prominent, along with some nutrient foramina within the orbital rim (Figs. 2D, 3D). Anteriorly the deep basin of the olfactory bulb impression can be seen medially deep to the nasal facet. Posteriorly, the frontal appears to exhibit greater curvature for the cerebral hemisphere and further nutrient foramina are present within the orbital rim (Figs. 2F, 3F).

DISCUSSION

Currie (1987, p. 52) noted that "the frontal is one of the more useful isolated bones of theropods as there is only a single pair in any individual, they tend to be found relatively frequently and they are diagnostic at the species level." It is noted that while troodontid material is known from the Late Cretaceous San Juan Basin, New Mexico (e.g. Jasinski et al., 2011; Evans et al., 2014a), SMP VP-1270 is not referable to this family. Compared to SMP VP-1270, the frontals of troodontids tend to have less strongly concave orbital rims (in dorsal aspect), more strongly tapered postorbital processes distally, and less prominent depressions for the olfactory bulb surface (in ventral aspect) (e.g. Russell, 1969; Currie, 1985). In these respects, *Saurornitholestes sullivani* (SMP VP-1270) agrees more strongly with dromaeosaurids than troodontids, and as such is considered a member of the former.

The left frontal of *Saurornitholestes sullivani* is similar to those of *S. langstoni*, except for several features discussed above (see Table 1). As was mentioned above, '*Saurornitholestes*' *robustus* has been

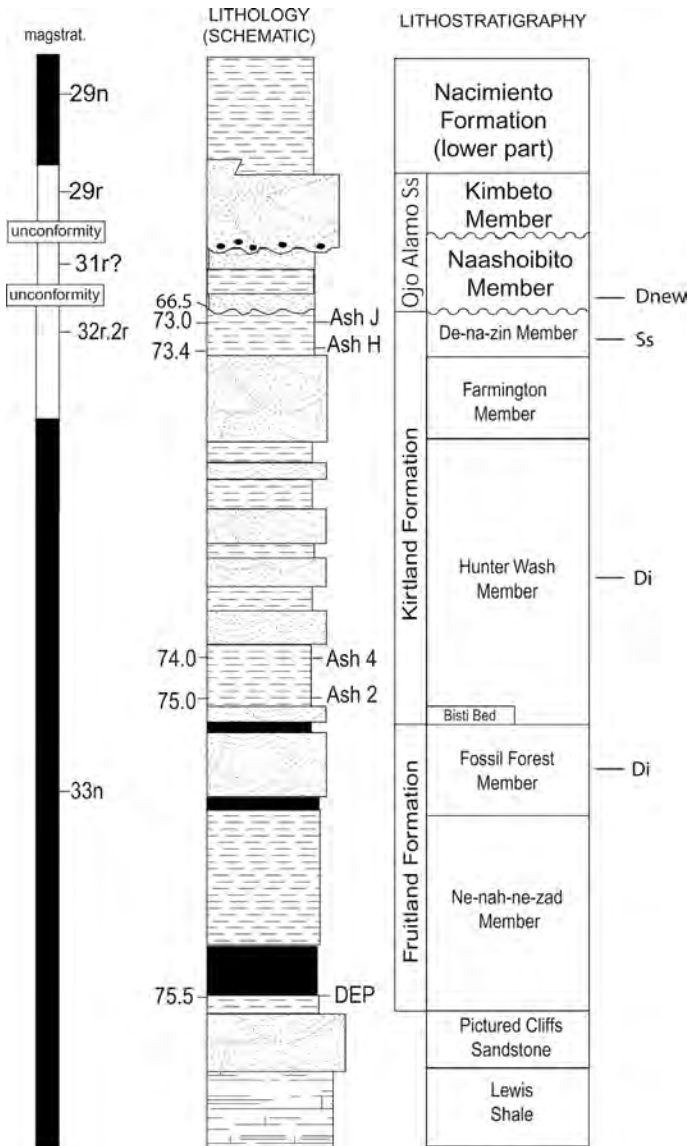


FIGURE 5. Stratigraphic schematic of the dromaeosaurids from the Late Cretaceous Fruitland, Kirtland, and Ojo Alamo formations, San Juan Basin, New Mexico. The numbers on the left side of the lithology schematic refer to millions of years ago. Ash dates show for the Fruitland and Kirtland formations are from Fassett and Steiner (1997), and the 66.5 Ma date (base of the Naashoibito Member) is from Mason et al. (2013a; 2013b). **Abbreviations:** **Di**, indeterminate dromaeosaurids; **Dnew**, new dromaeosaurid taxon; **Ss**, *Saurornitholestes sullivanii*. It is noted that indeterminate dromaeosaurids have also been found in the De-na-zin Member, although these may be referable to *S. sullivanii*, or another taxon.

considered a nomen dubium (see Turner et al., 2012). Additionally, Evans et al. (2014a) found that SMP VP-1955 (*S. robustus* holotype) represented a member of the Troodontidae, and conservatively referred it to an indeterminate troodontid. Nevertheless, comparisons between *S. sullivanii* (SMP VP-1270) and *S. robustus* (SMP VP-1955) are warranted as they both represent small theropods from the same strata (De-na-zin Member of the Kirtland Formation). Some of the characters mentioned by Turner et al. (2012) that characterize dromaeosaurids, and some of the features that they mentioned that SMP VP-1955 (*S. robustus* holotype) did not possess are present in SMP VP-1270 (*S. sullivanii* holotype), including a demarcated postorbital process and a somewhat sigmoidal ridge on the postorbital process. This is despite the fact that a portion of the postorbital process is not preserved on SMP VP-1270 (*S. sullivanii* holotype). Even so, SMP VP-1270 (*S. sullivanii* holotype) agrees more strongly with TMP 1974.010.0005 (*S. langstoni*

holotype) and dromaeosaurids than SMP VP-1955 (*S. robustus* holotype). Compared to SMP VP-1955 (*S. robustus* holotype), SMP VP-1270 (*S. sullivanii* holotype) is smaller and less robust, with the ratio of length measured along the midline to the thickness at the posterior portion of the frontal being 6:1 in the former and 7:1 in the latter. Both are more robust than TMP 1974.010.0005 (*S. langstoni* holotype), in which the ratio is approximately 10:1. Additionally, in contrast to SMP VP-1955 (*S. robustus* holotype), SMP VP-1270 (*S. sullivanii* holotype) has a more concave orbital rim, a more gracile anterior facet region, less strongly pronounced nasal facets, a slightly more pronounced depression along the mid-length of the frontal, a deeper depression on the postorbital process, a deeper and more prominent olfactory bulb surface, a relatively smaller cerebral hemisphere surface, a more sigmoidal ventral orbital rim surface, and a more prominent and deeper orbital surface.

In comparison to other dromaeosaurs, some, particularly basal members such as *Mahakala omnogovae*, possess anteroposteriorly elongate, thin, and gracile frontals (Turner et al., 2007, 2012), which is distinct from *Saurornitholestes sullivanii* (SMP VP-1270) (see Table 1). *Saurornitholestes sullivanii* is distinguished from *Sinornithosaurus millenii* by a more elongate anterior facet region and a medial constriction of the orbital rim of the frontal in the former (Xu et al., 2001). Additionally, the triangular to sub-triangular shape of the frontal (in dorsal view) distinguishes *Saurornitholestes langstoni* and *S. sullivanii* (SMP VP-1270) from *Dromaeosaurus albertensis* (AMNH 5356) as discussed by Currie (1995). As discussed above, the slight basin, along with the presence of the posterolateral basin, helps distinguish *S. sullivanii* from *Bambiraptor feinbergi*, *Linheraptor exquisitus*, *Tsaagan mangas*, and *Velociraptor mongoliensis* (e.g., Barsbold and Osmólska, 1999; Burnham et al., 2000; Burnham, 2004; Norell et al., 2006; Xu et al., 2010; 2015). However, based on the character list used in the phylogenetic analysis of Turner et al. (2012), four characters are derived from dromaeosaur frontals, and *S. sullivanii* is not distinguished from numerous other dromaeosaurs, including *S. langstoni*. Indeed, this subset of characters would need to be expanded to further distinguish dromaeosaur taxa with known frontals, particularly *Adasaurus mongoliensis*, *Bambiraptor feinbergi*, *Buitreraptor gonzalezorum*, *Deinonychus antirrhopus*, *Dromaeosaurus albertensis*, *Linheraptor exquisitus*, *Saurornitholestes langstoni*, *S. sullivanii*, *Tsaagan mangas*, and *Velociraptor mongoliensis*.

Sullivan and Lucas (2000) discussed the differences between *Saurornitholestes langstoni* and *Velociraptor mongoliensis* based on preserved frontals from a specimen referred of *V. mongoliensis* (IGM 100/976). This specimen was described by Norell and Makovicky (1999). Sullivan and Lucas (2000), in comparing the frontals of *S. langstoni* and *V. mongoliensis*, found that the frontals of the latter: (1) are more gracile; (2) sub-rectangular; and in ventral aspect have (3) a weakly-developed olfactory bulb depression; (4) have a weakly-developed cerebral hemisphere depression; (5) have a less concave orbital surface (in ventral aspect); and (6) have a weakly-developed posterior lateral wing. *Saurornitholestes sullivanii* in these aspects agrees with *Saurornitholestes langstoni* rather than with *V. mongoliensis*. Of note is that while the concave olfactory bulb surface is more prominent in *S. langstoni* than in *V. mongoliensis*, it is also more prominent and deeper in *S. sullivanii* than in *S. langstoni* (Fig. 4). This implies that *S. sullivanii* may have had a better sense of smell than either of the other taxa, and this sense may have been more important for this dinosaur during predation. Indeed, the dimensions of the olfactory bulb surface in *S. sullivanii* (SMP VP-1270) is approximately 6.4 mm by 13.5 mm, while that of *S. langstoni* (TMP 1974.010.0005) is approximately 4.7 mm by 7.4 mm, with the former having a distinct basin while the latter is not as distinctly defined (see Fig. 4). This is in addition to *S. langstoni* being larger (54.5 mm long along the midline frontal suture, 33.4 mm maximum width, 15.3 mm minimum width) while *S. sullivanii* is smaller (42.8 mm long along the midline frontal suture, 27.8 mm maximum width, 14.1 mm minimum width). Indeed, this means that, in addition to having a more definitive, basin-like olfactory bulb surface, *S. sullivanii* also has both a relatively and absolutely larger surface. It is also of note that the position of minimum width of the frontals also differs with that in *S. langstoni* being anterior and that in *S. sullivanii* being more posterior across the orbital rim.

Many of the significant aspects that Sullivan and Lucas (2000) listed for *Saurornitholestes langstoni*, and later Sullivan (2006) listed for *S. robustus* are now applicable to *Saurornitholestes* and to *S. sullivanii*. This new species becomes the second known valid species of *Saurornitholestes*, along with *S. langstoni*. *Saurornitholestes sullivanii*



FIGURE 6. Life reconstruction of *Saurornitholestes sullivanii* depicting a possible scene from the late Campanian (approximately 73 Ma) in the San Juan Basin New Mexico. A pair of *S. sullivanii* are shown attacking a subadult *Parasauroplophus tubicen*. Illustration by Mary P. Williams.

is known from the De-na-zin Member of the Kirtland Formation, which is from the late Kirtlandian LVA. Fassett and Steiner (1997) found that the De-na-zin Member was about 73 Ma based on $^{40}\text{Ar}/^{39}\text{Ar}$ dates. *Saurornitholestes langstoni*, on the other hand, is known from the Dinosaur Park and Two Medicine formations, and both are at least 75 Ma (Eberth, 2005). Both species are distinct geographically and temporally, lending further support to *S. sullivanii* being a distinct taxon.

Sullivan (2006), when naming '*Saurornitholestes*' *robustus*, referred two other specimens to cf. '*S.*' *robustus*. These included an isolated tooth (SMP VP-1901) and an incomplete left second pedal ungual (SMP VP-1741). Both specimens were also collected from the De-na-zin Member of the Kirtland Formation. The tooth (SMP VP-1901) is similar to "Dromaeosauridae Morphotype A" of Williamson and Brusatte (2014) and the "*Saurornitholestinae*" morphotype of Larson and Currie (2013). SMP VP-1901 is also similar in general shape and denticle morphology to the recently named *Acheroraptor temertyorum* (Evans et al., 2014b). Nevertheless, Zanno et al. (2013) discussed the identity of isolated dromaeosaurid teeth and felt that their referral to distinct species was unwarranted. As remaining conservative may be the best approach, SMP VP-1901 is currently better identified as Dromaeosauridae indeterminate. The left second pedal ungual (SMP VP-1741) is similar to those referred to *S. langstoni*, and differs from those of *Velociraptor mongoliensis*, as it is dorsoventrally deeper (proximally) than those of the latter (see Sullivan, 2006, fig. 3 and Norell and Makovicky, 1997, fig. 6B). As discussed by Sullivan (2006), if this referral is correct, this may be another distinction between *Saurornitholestes* and *Velociraptor*; regardless, further study is needed. However, without the proximal portion and articular surface preserved it is difficult to distinguish between manual and pedal unguals (Senter,

2007). Regardless SMP VP-1741 is herein conservatively referred to the ungual of a Dromaeosauridae indeterminate.

Saurornitholestes sullivanii represents the only valid dromaeosaurid known from the Late Cretaceous (Late Campanian-Late Maastrichtian) strata of the San Juan Basin, New Mexico (Fig. 5). Moreover, *S. sullivanii* currently represents the only named dromaeosaurid from the Late Cretaceous of southern Laramidia. In addition to some of the studies that have mentioned dromaeosaurids and dromaeosaurid teeth from the Late Cretaceous of the San Juan Basin (e.g., Lehman, 1981; Lucas, 1981; 1993; Lucas et al., 1987; 2000; Sullivan, 2000; 2006; Jasinski et al., 2009; 2011), Williamson and Brusatte (2014) recently reviewed the theropod teeth from these strata, and found there to be at least two dromaeosaurid taxa based on tooth morphotypes. Indeterminate dromaeosaurids are also known from teeth from the Late Cretaceous of Utah (e.g., Hutchison et al., 1997; Eaton, 1999; Eaton et al., 1999a, 1999b; Parrish, 1999; Kirkland, 2001; Zanno et al., 2005; 2010; 2013; Gates et al., 2010). Dromaeosaurid remains have also been found in the Late Cretaceous of Texas (e.g., Standhardt, 1986; Rowe et al., 1992; Sankey, 2001; 2008; 2010; Sankey et al., 2005), although these also are based on teeth and should be attributed to indeterminate dromaeosaurids as well. Additionally, dromaeosaurid teeth have been found in Late Cretaceous strata in Mexico as well (e.g., Rivera-Sylva et al., 2006; Torres-Rodríguez et al., 2010; Rivera-Sylva and Frey, 2012); however, these are best referred to indeterminate dromaeosaurids just as those above are. Moreover, some fragmentary non-tooth dromaeosaurid remains are known from the Late Cretaceous of Utah (Zanno et al., 2010; 2013) and Texas (Sankey, 2010), although these are also not diagnostic and considered to be from indeterminate dromaeosaurids as well. Now that '*S.*' *robustus* has been considered a nomen dubium

and/or a troodontid, other dromaeosaurid material from this stratum is attributed to indeterminate dromaeosaurids. However, dromaeosaurid material from the Naashoibito Member of the Ojo Alamo Formation was considered a new taxon by Jasinski et al. (2011) and is currently under further study. Nevertheless, *S. sullivanii* helps further define the distinct nature of the Late Cretaceous fauna of the San Juan Basin and southern Laramidia (Fig. 6).

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