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A Troodontid (Theropoda: Troodontidae) Neurocranium from the Cerro del Pueblo Formation (Late Campanian) of Coahuila, Mexico

Un neurocráneo de troodontido (Theropoda: Troodontidae) de la Formación Cerro del Pueblo (Campaniano superior) de Coahuila, México

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Abstract

The fossil record of Troodontidae from Mexico's Late Cretaceous is scarce since the majority of theropod specimens have not been identified beyond their family. In Coahuila's locality La Parrita, a neurocranium that contributes to our understanding of Late Campanian troodontids in the Cerro del Pueblo Formation has been found. It is the first non-dental material described in Mexico for the family.

Keywords: Troodontidae, neurocranium, Coahuila, Mexico.

Resumen

El registro fósil de Troodontidae del Cretácico Tardío de México es escaso, pues la mayoría de los especímenes de terópodo no han sido identificados más allá de su familia. En la localidad de La Parrita en Coahuila, se ha encontrado un neurocráneo que contribuye a nuestra comprensión de los troodóntidos en la Formación Cerro del Pueblo en Coahuila durante el Campaniano Tardío. Siendo el primer material no dental descrito en México de la familia.

Palabras clave: *Troodontidae, neurocráneo, Coahuila, México.*

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1. Introduction

Troodontids are a group of lightly built feathered maniraptoran dinosaurs, with unusually elongated legs, a large curved claw on their second toe, and the largest relative brain sizes within Dinosauria (Currie, 2005). They also had large orbits, a broad postorbital region, and a narrow snout, which helped their eyes face forward and attain overlapping fields of view (Currie, 2005). It has been proposed that the long legs and small sickle-shaped claws indicate an adaptation for capturing small prey while having a cursorial lifestyle, suggesting an ecological separation from dromaeosaurids (Fowler *et al.*, 2011).

They have elongated middle ear cavities that help them in the detection of low-frequency sounds (Currie, 1985). The extreme specialization of the ears may indicate that troodontids hunted in a similar manner to owls, in that they used their hearing to locate small prey (Castanhinha and Mateus, 2006).

The group is best known from Upper Cretaceous deposits of Asia and North America (Makovicky & Norell, 2004). Although, it was established in Asia since the Early Cretaceous (Barsbold *et al.*, 1987; Russell and Dong, 1993; Xu *et al.*, 2002).

The fossil record of troodontids from southern Laramidia is scarce (Zanno *et al.*, 2011; Zanno *et al.*, 2013) and mainly based on isolated teeth from microvertebrate localities within Upper Cretaceous beds of northern Mexico. The only referenced teeth of this family are from the Campanian of Coahuila from the Cerro del Pueblo Formation (Aguillón-Martínez, 2010) and the Aguja Formation (Torres-Rodríguez *et al.*, 2010). In addition, Troodontidae from El Gallo Formation (Campanian) of Baja California (Romo de Vivar, 2011) have been identified due to their teeth. Material referred to as a troodontid phalanx from the Cerro del Pueblo Formation by Rodríguez de la Rosa and Cevallos-Ferríz (1998) was later reassigned as a turtle (Evans *et al.*, 2014). Below, we describe the first cranial material of a troodontid from southern Laramidia. The specimen was collected from the Cerro del Pueblo Formation in the La Parrita locality, Coahuila, Mexico (Figure 1a).

1.1. Abbreviations

AMNH = American Museum of Natural History, New York, U.S.A.; **CPC** = Colección Paleontológica de Coahuila, Museo del Desierto, Saltillo, Mexico; **MPC** = Mongolian Paleontological Center, Ulaanbaatar, Mongolia; **MUDE** = Museo del Desierto, Saltillo, Mexico; **TMP** = Royal Tyrrell Museum of Palaeontology, Drumheller, Canada; **UALVP** = University of Alberta Laboratory for Vertebrate Palaeontology, Edmonton, Canada.

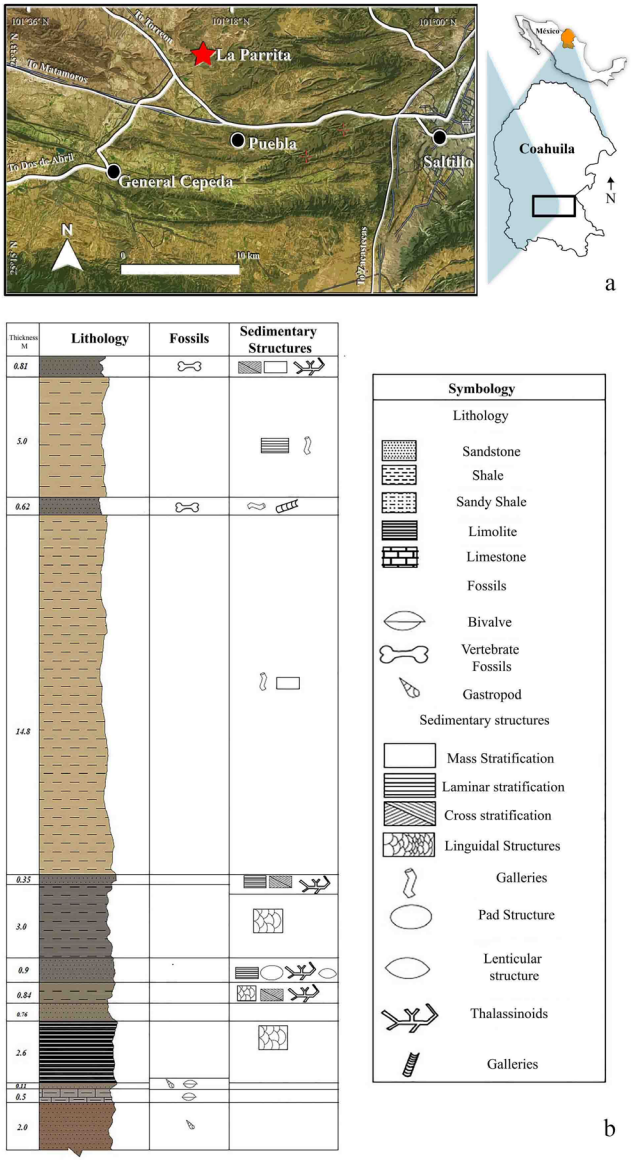

Figure 1. a) Map of La Parrita locality; b) Stratigraphic column of the Cerro del Pueblo Formation in southern Coahuila, Mexico (Illustration by Jorge Ortiz-Mendieta, 2023).

2. Geology

The Difunta Group is located in the northeastern Mexican states of Chihuahua, Coahuila, and northeastern Nuevo León. The sediment sequence is Late Campanian to Eocene in age (Soegaard *et al.*, 2003) and was deposited under deltaic conditions, representing marsh, lagoonal, and eulittoral to shallow marine environments (Eberth *et al.*, 2004). The delta drained into the ancient Gulf of Mexico to the East.

The Cerro del Pueblo Formation (Late Campanian) represents the basal unit of this sequence, and it appears as an outcrop in the southeast region of

Coahuila, northeast Mexico. It has a thickness of 162m, becoming thicker to the west, reaching 445m from Saltillo to Rincon Colorado (Eberth *et al.*, 2004). The Cerro del Pueblo Formation was dated with strontium isotope with an absolute age of 73+1 Ma (Vogt *et al.*, 2016), corresponding to the uppermost part of the Campanian. The Cerro del Pueblo Formation consists of shales, sandstones, and limestones deposited in a low gradient homogeneous coastal plain (Eberth *et al.*, 2004).

The stratigraphic sequence outcropping at La Parrita locality is composed of alternating layers of sandstone, siltstone and shale (Vivas-González, 2013; Figure 1b). At the base, Bed 1 consists of 0.20 m of ochre-gray shales with greenish tones. Marine taxa, such as the ammonite *Sphenodiscus* and some isolated weathered dinosaur bones, are associated with this layer. According to Eberth *et al.* (2004), *Sphenodiscus* is present in facies 1 corresponding to the Parras Shale, which is the base of the Cerro del Pueblo Formation (Vivas-González, 2013). Above the base is Bed 2, a 0.30m layer consisting of exfoliated siltstones with a high concentration of oysters of diverse size, which indicate a brackish environment. The Cerro del Pueblo Formation sandstone and siltstone deposits are characteristic of brackish conditions, indicated by oyster banks and abundant non-ostrean bivalves and gastropods (Stinnesbeck and Frey, 2014). Above the siltstone lies Bed 3, a 0.90m thick hard, massive, coarse-grained sandstone bed with high concentrations of gastropods at the top, which indicates marine coastal environments (Vivas-González, 2013). Bed 4 is a grit layer 1m thick, with a 0.40m thick concentration of gastropods. Bed 5 consists of 10m of ochre-gray shale characterized by a diverse fossil assemblage; here, the marine gastropods *Cerithium nodosa* and *Lissapiopsis* sp. are common, as well as oysters (*Flamingostrea* sp.), representing the most common invertebrates in this shale layer; wood fragments are also present, along with vertebrate fossils (Vivas-González, 2013). Eberth *et al.*, (2004) placed this fossil assemblage between facies 10-12. The assemblage is suggestive of overflooded coastal plains, and the marine and limnic faunal assemblages that coexist in this layer indicate an estuarine environment (Vivas-González, 2013; Stinnesbeck and Frey, 2014 ; Vogt *et al.*, 2016).

The next layer, Bed 6 consists of 0.40m of massive, gray, fine-grained sandstones, followed above by Bed 7, with 0.50m of dark-gray shale, and Bed 8, composed of 0.35m of fine-grained sandstones (Vivas-González, 2013). The Bed 9 is composed of 0.60m shale while Bed 10, has 0.20m of fractured sandstones. Above the fractured sandstone layer lies Bed 11, with 32m of shale, which is devoid of fossils. Above this shale layer, Bed 12, is a 3m layer of massive medium-grained sandstones with high concentrations of bivalves, referred to as *Inoceramus vamuxemi* in the top of the layer. No other fossils are reported in this layer. Bed 13 consists of 18m of shales, and the Bed 14 consists of 3m of medium-grained sandstones. No fossils were observed or reported in both top layers (Vivas-González, 2013).

The depositional setting at La Parrita locality was influenced by cyclically fluctuating paleoenvironments of intermittent shallow-marine, brackish to fresh water or even subaerial conditions. The abundance of oysters throughout the Formation displays the permanent mixing of salt and freshwater, generating intermittent brackish environmental conditions with changing salinities (Vogt *et al.*, 2016).

This alternating sediment suggests the La Parrita locality underwent a series of events related to marine regressions and transgressions during deposition, which is consistent with other localities associated with the Cerro del Pueblo Formation (Eberth *et al.*, 2004).

3. Material and methods

The material described herein was discovered by the first author during surface collecting in the field season of March 2007, and it is curated in the Museo del Desierto (MUDE). The specimen was mechanically prepared using pneumatic hand tools of various sizes, with the final preparation completed using dental picks and pin vises.

For anatomical comparisons, *Saurornithoides mongoliensis* (AMNH 6516), *Latenivenatrix mcmasterae* (TMP 1982.019.0023), *Gobivenator mongoliensis* (MPC-D 100/86), and *Stenonychosaurus inequalis* (UALVP 52611), were compared with CPC 2973. The specimen was measured using a digital caliper, to the nearest millimeter or 0.1 mm, and photographed using a Canon EOS Rebel T2i with a Canon Zoom Lens EF 35-80mm 1:4–5.6 III with filters close ups 1-3 and a Nikon COOLPIX P610 with a lens NIKKOR 60X Wide Optical Zoom ED VR (4.3–258mm 1:3.3–6.5).

4. Systematic paleontology

Theropoda Marsh, 1881
Deinonychosauria Colbert and Russell, 1969
Troodontidae Gilmore, 1924

Troodontidae indet.
Fig. 2 a–f

Material. Frontoparietal (CPC 2973).

Horizon and Locality. Cerro del Pueblo Formation (Upper Campanian), La Parrita locality, 54 km west of Saltillo; municipality of General Cepeda, Coahuila, Mexico.

Description. *Frontoparietal*. The fragment is the posterior portion of the frontal and the anteriormost section of the parietal. The frontal is strongly convex dorsally, with a bulbous appearance reflecting an expansion of the brain cavity accommodating the cerebrum.

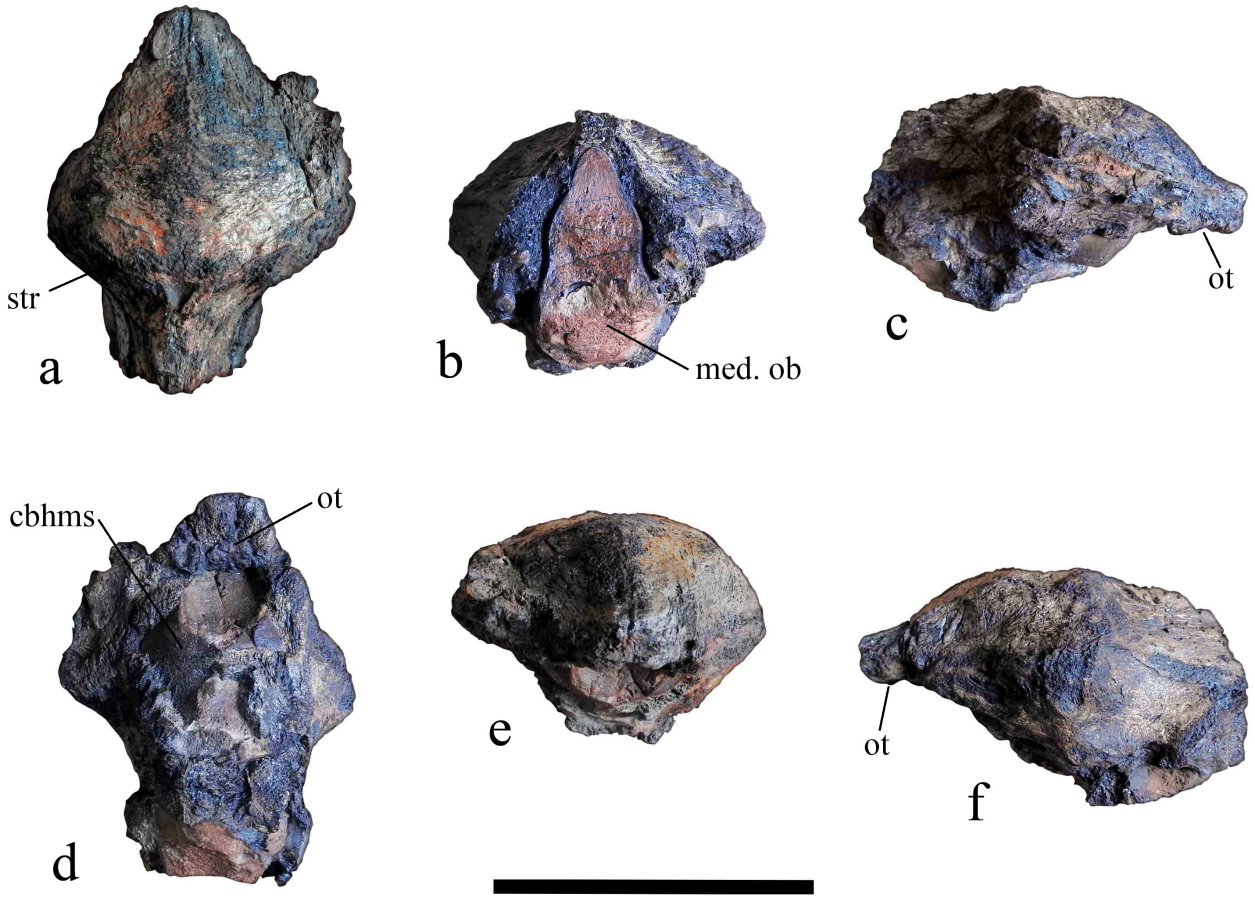

Figure 2. CPC 2973 neurocranium in: a) dorsal, b) caudal; c) right lateral; d) ventral; e) frontal; and f) left lateral views. Abbreviations: cbhms- cerebral hemispheres; ot- olfactory tract; med. ob.- medulla oblongata; str- supratemporal ridge. Scale = 10 cm.

The midline interfrontal contact has an interdigitated morphology, and posteriorly, it forms a 90° angle with a sigmoidal transverse suture to the parietal. The supratemporal fosses are delimited by a transversely oriented ridge. In ventral view, the parietal is broken away. On the anteriormost section, impressions of the olfactory tract are visible, as well as the ventral section of the cerebral hemispheres.

The cranial portion of the parietals is preserved; they are fused, and in the anteriormost section, the joint between the two forms an isosceles triangle shaped foramen. In the posterior section, there is a sagittal crest. In ventral and posterior views, the infilling of the medulla oblongata is visible.

Measurements are given in Table 1.

Discussion. Frontal morphology within Troodontidae is variable and preserves features considered diagnostic at relatively lower taxonomic levels (Currie, 1987; Evans *et al.*, 2014). The frontals in CPC 2973 (Fig 3a) are massive like those of *Latenivenatrix mcmasterae* (Fig. 3b, TMP 1982.019.0023). In troodontids, the supratemporal fossa does not extend onto the dorsal surface of the frontal, and the anterior margin of the supratemporal fenestra is defined by a prominent transverse ridge along with the posterodorsal margin of the frontal adjacent to the parietal (Evans *et al.*, 2014) as seen in CPC 2973, where the supratemporal fossa emargination is identical to the condition of other troodontids (Fig. 3b-e) (AMNH 6516; TMP 1982.019.0023; MPC-D 100/86). In CPC 2973 there is an interfrontal suture with an interdigitated morphology throughout its entire length, as observed in Troodontidae (Evans *et al.*, 2014), differing from the tongue and groove morphology seen in dromaeosaurids (Evans *et al.*, 2014). The frontal can be differentiated from ornithomimid frontals by the angle formed between the midline interfrontal contact and the transverse parietal contact: in CPC 2973, it is a right angle, while in ornithomimids it is obtuse (Currie, 1987). In CPC 2973 the olfactory tract is not well preserved, but the proximal portion to it is preserved (Currie, 1985). It is more

Table 1. Select neurocranium measurements (mm) for CPC 2973.

Dimension	CPC 2973
Length	92.3
Max. width	73
Max. height	56.3
Max. width cerebral hemisphere	53.3
Width from midline to postorbital process	41.8

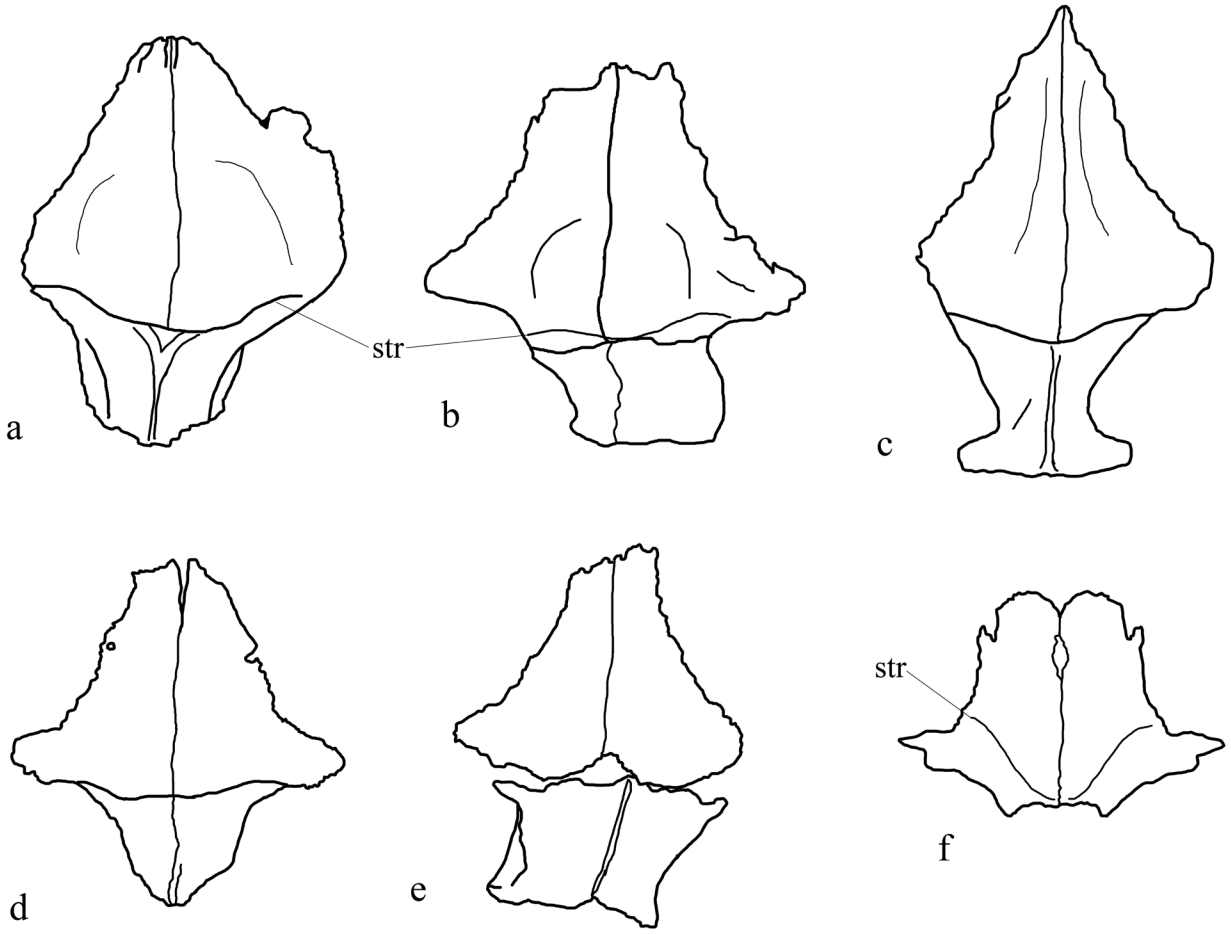

Figure 3. Comparative line drawings of a) CPC 2973; b) *Latenivenatrix mcmasterae* (TMP 1982.019.0023); c) *Saurornithoides mongoliensis* (AMNH 6516); d) *Stenonychosaurus inequalis* (UALVP 52611); e) *Gobivenator mongoliensis* (MPC-D 100/86); f) *Dromaeosaurus albertensis* (TMP 2009.003.0062). Abbreviations: str- supratemporal ridge. Not to scale.

elongated than those of dromaeosaurids, where the olfactory tract is short, *e.g. Saurornitholestes langstoni* and *Bambiraptor feinbergi* (Sues, 1978; Burnham, 2004). This condition is opposite in troodontids, where the olfactory bulbs and olfactory tract are longer.

The parietal shows a sagittal crest, although eroded, which is present in *Stenonychosaurus inequalis, Gobivenator mongoliensis*, and *Latenivenatrix mcmasterae* (Sternberg, 1932; Tsuihiji *et al.*, 2014; van der Reest and Currie, 2017).

The frontal has no diagnostic dromaeosaurid characters, but has several features of troodontids, such as the exclusion of the supratemporal fossa from the dorsal surface of the frontal (Fig. 3f). Because of the weathered condition of CPC 2973, it represents an indeterminate troodontid, matching in size and thickness with the range variation seen in troodontids.

When comparing CPC 2973 to more complete troodontid specimens such as *Saurornithoides mongoliensis, Gobivenator mongoliensis* and *Zanabazar junior*, the skull has a total length of 344 millimeters. This measurement, in turn, provides an estimate for a total body length of the animal, of about 2.6 meters.

5. Discussion

The discovery of troodontids in southern Laramidia represents a significant advance in our understanding of the biogeography and evolution of these theropod dinosaurs, for it provides new insights into their biogeography during the Late Cretaceous.

Latenivenatrix mcmasterae (van der Reest and Currie, 2017) and *Stenonychosaurus inequalis* (Sternberg, 1932) are from time-equivalent beds of the Dinosaur Park Formation of Alberta, as is *Stenonychosaurus inequalis* (Sternberg, 1932), and *Talos sampsoni* from the Kaiparowits Formation of Utah (Zanno *et al.*, 2011). The specimen CPC 2973 could belong to a different taxon with phylogenetic affinity with *Latenivenatrix mcmasterae* based on the morphology of the frontal.

The Coahuila specimen comes from rocks containing a large diversity of dinosaurs, crocodiles, and freshwater turtles (Brinkman *et al.*, 2016; Rivera-Sylva *et al.*, 2019). Furthermore, this is the first time that non-dental material of a troodontid from Mexico has been described.

Furthermore, the discovery of a new species of troodontid in southern Laramidia highlights the potential

for future discoveries in this region. As more fossil localities are discovered and studied, we may gain a more complete understanding of the evolution and biogeography of troodontids during the Late Cretaceous.

6. Conclusions

Dinosaur diversity from the Cerro del Pueblo Formation in southern Coahuila is predominantly limited to microvertebrate samples. Our increased understanding of the Cerro del Pueblo theropod fauna based on the new material, allows broad paleogeographical comparisons with other coeval Campanian formations in Laramidia, including the Dinosaur Park Formation in southern Alberta, Canada and the Kaiparowits Formation of southern Utah, USA.

To date the specimens recovered so far indicate that troodontids lived in this part of Mexico during the Campanian. Determination of the exact number of troodontid species in the Cerro del Pueblo Formation will presumably require the recovery of a much larger sample of well-preserved specimens. The occurrence of troodontids remains from the Cerro del Pueblo Formation extends the distribution of those theropods during the Cretaceous to the southernmost part of North America and supports the claim that Late Cretaceous dinosaur faunas were dominated by these highly specialized forms.

The potential of new discoveries of troodontids from Coahuila is very high, and it is likely that many more findings will become available as researchers concentrate on the already known localities.

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