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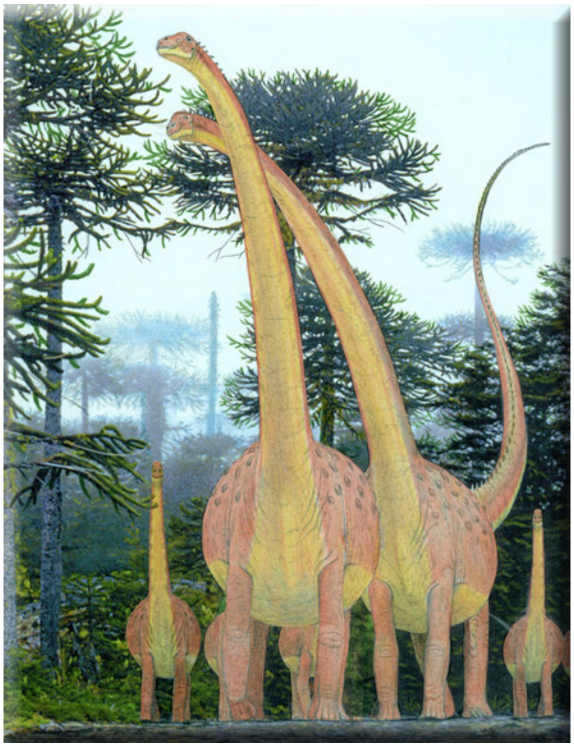
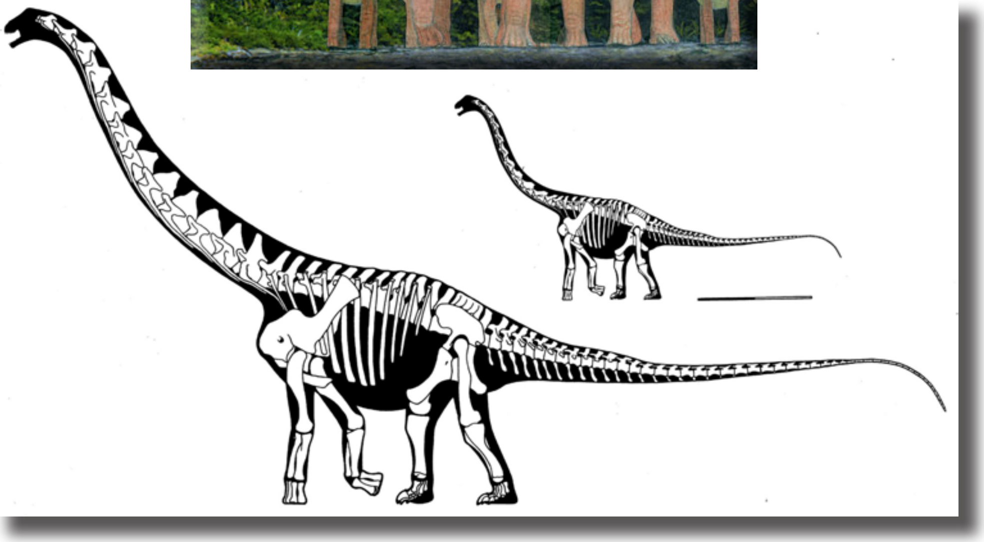
STRATIGRAPHIC AND ANATOMICAL EVIDENCE FOR MULTIPLE TITANOSAURID DINOSAUR TAXA IN THE LATE CRETACEOUS (CAMPANIAN-MAASTRICHTIAN) OF SOUTHWESTERN NORTH AMERICA

Gregory S. Paul





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Cover

The color rendering of *Utetitan zellaguymondeweyae* in its habitat. Same scale comparison of mature (scaled to USNM 15560) and juvenile (scaled to TMM 43621) skeletal restorations of generalized composite North American Maastrichtian titanosaurids. Scale bar equals 2 m. Illustrattions by Gregory S. Paul.

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Stratigraphic and Anatomical Evidence for Multiple Titanosaurid Dinosaur Taxa in the Late Cretaceous (Campanian-Maastrichtian) of Southwestern North America

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ABSTRACT

After the return of giant sauropod dinosaurs in the form of titanosaurids to North America in the Campanian of the Late Cretaceous, *Alamosaurus sanjuanensis* is generally considered to have been the sole taxon on the continent over a few million years. The possibility of one species existing that long is very low because sauropods often exhibit taxonomic diversity in the same habitat. The fossils from the southwestern states and northern Mexico are all incomplete, overlapping elements are often scarce, and sometimes differ in ontogenetic development. The fragmentary New Mexican *A. sanjuanensis* material from the early Maastrichtian lower Ojo Alamo Formation shows significant distinctions from the much later partial skeletons from the late Maastrichtian lower North Horn Formation of Utah. The latter is therefore made the holotype of *Utetitan zellaguymondeweyae*. Some late Maastrichtian Texas fossils can be assigned to *U. zellaguymondeweyae*, others cannot. Fossils from the middle Campanian cannot be assigned to either genus. Southwestern North America supported a diversity of titanosaurids, which may have formed a *Utetitan* miniclade as they evolved in semi-isolation from the global titanosaurid fauna. Past calculations that these titanosaurids were among the most massive in the group are not borne out by scaling of skeletal restorations.

INTRODUCTION

After an absence from the fossil record of North America over most of the Late Cretaceous, sauropod dinosaurs returned to the southwestern part of the continent in the Campanian in the form of the only sauropod clade extant by then, titanosaurids (D'Emic, 2010, see below). It has long been widely presumed to varying degrees of confidence that all fossil juvenile to adult titanosaurid specimens (Figure 1) from New Mexico, Utah, Texas, and Chihuahua (Figures 2 and 3), none of which preserved the majority of the individual, represent one species, *Alamosaurus sanjuanensis* (Gilmore, 1922, 1946; Lawson, 1972; Mateer 1976; Wolberg et al., 1986; Lucas and Hunt, 1989; Lehman and Coulson, 2002; Woodward, 2005; Lehman et al., 2006; Rivera-Sylva et al., 2006; D'Emic et al., 2010, 2011; Fowler and Sullivan, 2011; Jasinski et al., 2011; Wick and Lehman, 2014; Carrano and D'Emic, 2015; Curtice, 2016; Tykoski and Fiorillo, 2017)—or at least the one genus, the exact taxonomic intent is not always clear in these papers. The holotype of the taxon is an incomplete scapula, supported by a paratype pubis that probably does not belong to the same individual. A number of other fossil remains ranging from fragmentary to a major minority of a skeleton have been assigned to the other species. A rare expression of skepticism of the single taxon hypothesis has been Lucas and Sullivan (2000) whose analysis

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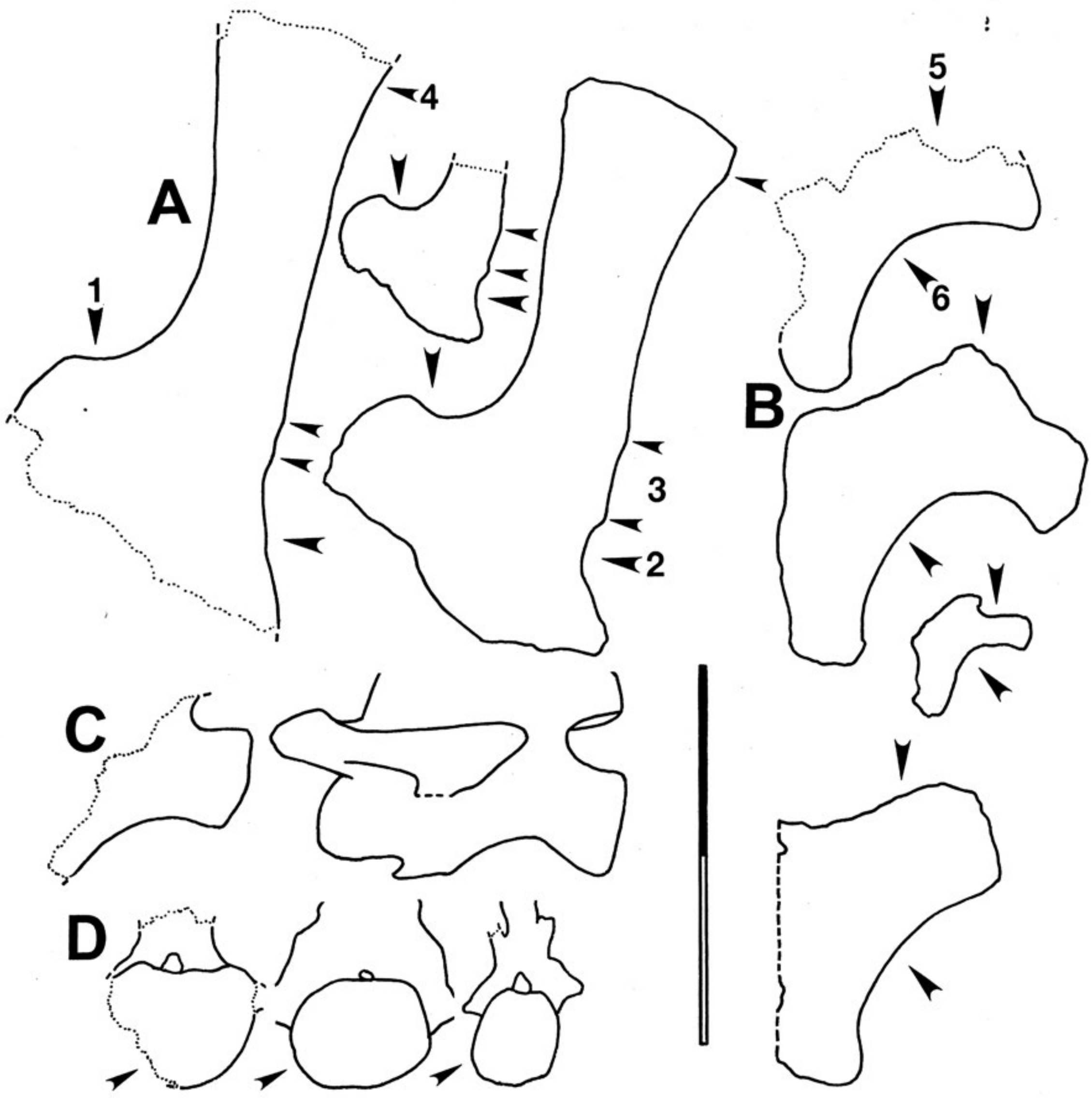

Figure 1. Same scale comparison of postcranial elements of Maastrichtian North American titanosaurids, entire bar equals 1 m (this figure is more accurate to a common scale than Figure 5 in D'Emic et al., 2011), appendicular elements are from the left side (reversed when necessary), dotted lines indicate missing bone, arrows point to taxonomic characters discussed in text and listed in diagnoses as numbered; traced from published images as indicated. (A) Scapulae in lateral view: left, early Maastrichtian *Alamosaurus sanjuanensis* holotype USNM 10846 (Plate 1 in Gilmore, 1922, Plate 10 in Gilmore, 1946; Figure 5C in D'Emic et al., 2011, bone is not as complete); middle, latest Maastrichtian *Utetitan zellaguymondeweyae* referred BIBE 45958 juvenile (Figure 12A in Tykoski and Fiorillo, 2017); right, late Maastrichtian *U. zellaguymondeweyae* holotype USNM 15560 (Figure 5D in D'Emic et al., 2011, contrast to Figure 6 in Gilmore, 1946). (B) Ischia in anterior view: top, *A. sanjuanensis* paratype USNM 10847 (Plate 2 in Gilmore 1922); middle left, late Maastrichtian titanosaurid incertae sedis TMM 41541-1 (Figure 11B in Tykoski and Fiorillo, 2017); middle right, late Maastrichtian titanosaurid incertae sedis TMM 43621-1 juvenile (Figure 9 in Lehman and Coulson, 2002); bottom, USNM 15560 (Figure 11 in Gilmore, 1946). (C) Mid cervicals in left lateral view left, *A. sanjuanensis* provisionally referred SMP VP-1850 (Figure 1A in Fowler and Sullivan, 2011); right, BIBE 45854 (Figure 3A in Tykoski and Fiorillo, 2017). (D) Anterior caudals in posterior view; left, *A. sanjuanensis* provisionally referred SMP VP-2104 (Figure 2B in Fowler and Sullivan, 2011); middle, TMM 41541-1 (Figure 10C in Tykoski and Fiorillo, 2017); right, USNM 15560 (Plate 8 in Gilmore, 1946).

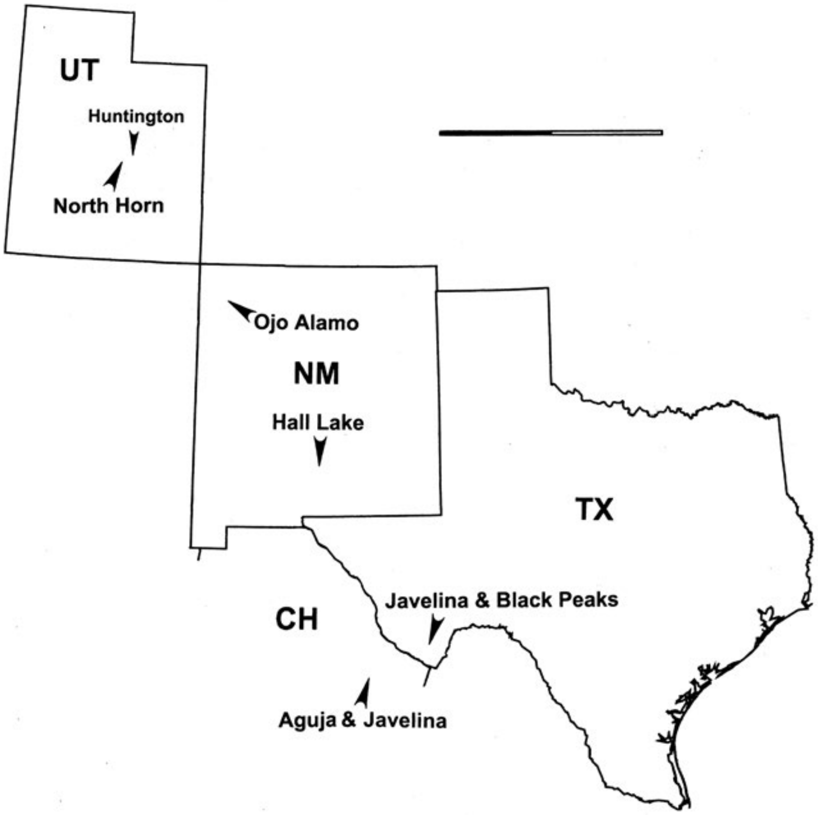

Figure 2. Map of the southwestern states and bordering Mexico showing the locations of formations containing Late Cretaceous titanosaurid fossils, and town of Huntington, Utah; entire scale bar equals 500 km; UT = Utah, NM = New Mexico, TX = Texas, and CH = Chihauhau State (Mexico).

indicated that *Alamosaurus sanjuanensis* had become a wastebasket taxon for the Late Cretaceous titanosaurids from the region. Fronimos and Lehman (2014) and Lehman et al. (2018) declined to refer some Texas titanosaurid elements to *A. sanjuanensis* while doing so with others. Lozinsky et al. (1984) noted the common tendency to refer Late Cretaceous North American sauropods to *Alamosaurus* without justification, while doing it themselves.

Because of the taxonomically deficient nature of the fragmentary *A. sanjuanensis* holotype USNM 10486, and the lack of sufficient anatomical overlap between the limited titanosaurid fossils from the early Maastrichtian lower Ojo Alamo Formation in northwestern New Mexico, the species has largely been defined by the Utah specimen USNM 15560 partial skeleton, it being the best single specimen available. Diagnosing a species based on fossils from a different geographic and stratigraphic location is inherently problematic and must be considered provisional until the systematic unification is verified, or perhaps more probably refuted, on morphological and stratigraphic grounds. While preparing a new edition of a field guide (Paul, 2024), it became apparent that a solid verification has not been established regarding *Alamosaurus*, in part because the deep time evolutionary issues have not been adequately addressed in the literature. This brief study is largely limited to assessing whether the pertinent fossils can be confidently assigned to one species, or if they more probably belong to at least two taxa at the species and perhaps genus level. This is not a major examination of larger issues of titanosaurid systematics, phylogeny, or biogeography, the investigation being only that necessary to achieve the basic aims. Also examined is the issue of the maximum masses indicated by the larger fossils of these titanosaurids.

ABBREVIATIONS

AMNH – American Museum of Natural History, New York City, New York. BYU – Brigham Young University – Provo, Utah. BIBE – Big Bend National Park, Texas. NMMNH – New Mexico Museum of Natural History and Science, Albuquerque, New Mexico. PMNS – Perot Museum of Nature and Science, Dallas, Texas.

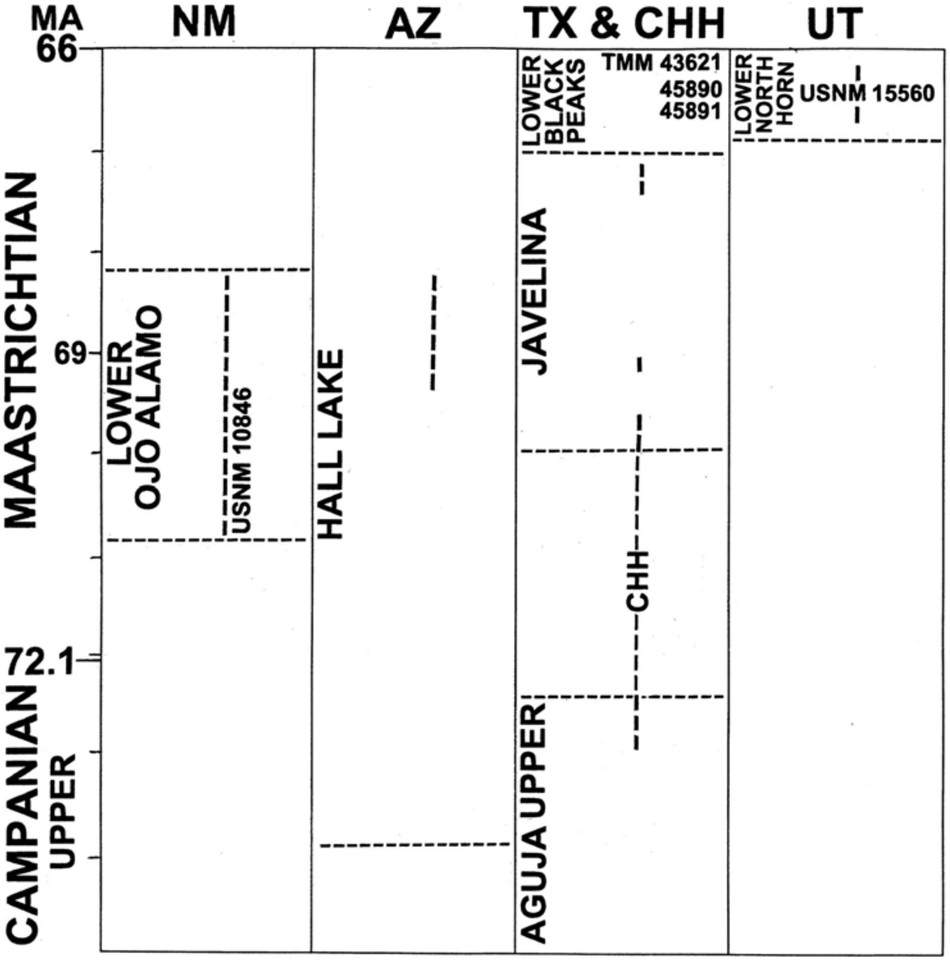

Figure 3. Stratigraphic chart for North American Late Cretaceous titanosaurids. Ages indicated by vertical dashed lines with placement of selected specimens also indicated—among the latter, those that are oriented vertically are less well dated than those that are oriented horizontally Based on references listed in the main text. All formation boundaries (horizontal dotted lines) and levels of most specimens are approximate to varying degrees, sometimes very much so, such as the CHH specimen that is from either the upper Aguja or lower Javelina Formations, which apparently have substantial missing sediments between them. The most precisely located fossils are TMM 43621, which is close to Cretaceous/Paleogene (K/Pg) boundary. A Javelina Formation, from which an uncollected femur (T.M. Lehman, Texas Tech University, written communication, 2025) has an isotopic (U/Pb) age of 69 ± Ma (Lehman et al., 2006). In some locations the top of the Javelina is close to the K/Pg boundary. In the lower Ojo Alamo, Hall Lake, Javelina, and North Horn Formations, the vertical dashed lines incorporate multiple specimens of uncertain exact level. Dalman et al. (2024) has obtain an isotopic age of 73 Ma (late Campanian) from the Hall Lake Formation.

PMU – Paleontological Museum, Uppsala University, Uppsala, Sweden. SMM – Science Museum of Minnesota, Saint Paul, Minnesota. SMP – State Museum of Pennsylvania, Harrisburg, Pennsylvania. TMM – Texas Memorial Museum, Austin, Texas. TTU – Museum of Texas Tech University, Lubbock, Texas. USNM – United States National Museum of Natural History, Washington, D.C. UTEP – Centennial Museum at the University of Texas at El Paso, Texas.

PREVIOUS WORK

The titanosaurid fossils from the New Mexico, Utah, Texas and the Chihuahua Provinces, Mexico, have been extensively described and illustrated including with photographs (Gilmore, 1922, 1946; Lawson, 1972; Mateer, 1976; Lucas and Hunt, 1989; Lucas and Sullivan, 2000; Lehman and Coulson, 2002; Rivera-Sylva et al., 2006; Williamson and Weil, 2008; D'Emic et al., 2011; Fowler and Sullivan, 2011; Jasinski et al., 2011; Fronimos and Lehman, 2014; Wick and Lehman, 2014; Tykoski and Fiorillo, 2017). The author has seen and examined much of the North American titanosaur material over the decades. Element illustrations (Figure 1) are traced at large scale directly from published photographs. Note that the illustrations of the USNM 15560 scapula in Gilmore (1946, Figure 6) differs from the actual fossil (Figure 5D in D'Emic et al., 2011). Two photographs of the scapulae are available, but I chose not to include them here because they are medial views of the bones showing their very poorly preserved inner surfaces that no one uses because they are very badly preserved on that side, and therefore useless. There is no point publishing these since high-quality photographs of the lateral surfaces are already in the literature, and there are no good resolution photographs in the files of the Smithsonian Institution's Museum of Natural History in Washington, D.C. Recent photographs of the USNM 10486 and USNM 15560 scapulae (Figures 5C and5D in D'Emic et al., 2011) show the bones have been somewhat degraded over the decades (compared to Plate 1 in Gilmore, 1922, and Figure 6 in Gilmore, 1946). The new illustrations are the most accurate images of the fossils yet produced.

Evidence has grown that herbivorous dinosaur species were prone to turning over rapidly, with species typically not lasting more than a few hundreds of thousands of years (Ryan and Evans, 2005; Paul, 2006, 2016, 2024, in press; Gates, 2012; Scannella et al., 2014; Tschopp et al., 2015; Mallon, 2017, 2019). The same studies also often found that a given herbivorous dinosaur family can exhibit diversity at the same level in a particular formation, including sauropods. Even taking possible over splitting of taxa into account, differing stratigraphic levels each feature an array of diplodocid, camarasaurid, and brachiosaurids, and the same is true of titanosaurids in the Adamantina, lower Allen, lower and upper Anacleto, lower Bajo Barreal, Huincul, Portezuelo and Rio Neuguen Formations of South America (Weishampel et al., 2004; Tschopp et al., 2015; Paul, 2016, 2024, in press). The possibility that just one titanosaur taxon inhabited the entirety of the North American southwest during most of the Maastrichtian is correspondingly quite low and nonparsimonious. A factor in the fast and diverse evolution of dinosaur taxa may have a genetic basis due to high chromosome numbers that remain operative in the many thousands of species of modern birds (O'Connor et al., 2018). The rapid, R-strategy reproduction of giant dinosaurs depositing large numbers of their small eggs may have also favored swift evolution and diversification compared to calf dropping K-strategy breeding big mammals. It is therefore presumed that if fossils are separated by more than a few hundred thousand years that they probably are different species, unless strong evidence indicates otherwise. The latter includes near identical morphology of overlapping elements as further discussed below. Nor can it be presumed that incomplete specimens found at the same stratigraphic level of a formation from a given family represent one species—unless found in very close association—rather than being from more than one taxon. Any conclusion one way or another on North American titanosaur diversity needs to be based on the preponderance of the data. Consisting of multiple species, genera can last over long stratigraphic periods. Yet gradistic anatomical differences may favor generic separation, even if the taxa are closely related to one another relative to other known fossil members of the taxonomic family. There is a good probability that gaps in the fossil record make two dinosaur species appear to be sibling taxa on a phylogenetic chart when they actually are separated by a number of intra subfamily species that created considerable gradistic space not readily accommodated in one genus. In order to provide more clarity regarding these issues and tighten up the taxonomic specifics, diagnoses based on a substantial number of specimens of the pertinent taxa are used to determine the species on a gradistic basis. This comparative anatomy approach is similar to work by Chure and Loewen (2022), Danison et al. (2024), and Paul (2025), who do not include statistical or phylogenetic analysis among fossils that are obviously closely related, but different enough to be divided at the genus and/or species levels.

An in-depth phylogenetic analysis of titanosaurids is far beyond the scope of this modest study. Nor would such likely to be productive because the differences between the Late Cretaceous North American specimens is of the modest degree expected within a subfamily that had been evolving with some degree of isolation from other titanosaurs in South America and/or Asia, probably forming a mini-clade. The North American specimens are too few and incomplete to produce phylogenetic results reliable enough to improve the taxonomy on the existing limited data base (as per the fossils examined in Danison et al., 2024). All specimens this researcher is aware of are listed and characterized in Systematics, with primary data and illustration sources noted.

Overcoming evidence for taxonomic distinction at the species level between members of a subfamily, despite a large separation in time, requires that the fossils be very similar in form in all details of the crania and postcrania, as is a norm within species at a given ontogenetic stage (Paul, 2025). An exception is strong sexual dimorphism, but that has not been observed among dinosaurs (Mallon, 2017). Determining this norm for sauropod scapulae is aided by a sample of a number of such elements, all little distorted, for adult *Camarasaurus supremus*, all found from the same quarry (Osborn and Mook, 1921; Figure 4); a badly distorted subadult scapula (Figure 76 in Osborn and Mook, 1921) is excluded. Aside from some possinle slight alterations due to minor distortion, none of the scapulae are markedly divergent in configuration. They share the same basic distinctive profile. This includes the prominence and shape of the large acromion process. And a prominent triangular glenoid process. If divergence in the North American titanosaur scapulae is greater than in *C. supremus*, especially from specimens from differing stratigraphic levels, then that is evidence they do not represent a united taxon.

Paul (1997, 2016, 2024, in press), Larramendi (2016), and Brassey (2017) detail the methods for restoring skeletons and body masses via volumetric models, with Paul (2019) focusing on the broad bellied titanosaurids, including specimens assigned to *Alamosaurus*. Larramendi et al. (2021) modified the results with higher specific gravity values of 0.96, except for the sauropod pneumatic neck at 0.85. Because the fossil remains are so incomplete, an approximate composite restoration of the collective Maastrichtian North American titanosaurids is all that can be prepared (Figure 5), which is then scaled to the most widely shared size class of large specimens, as well as a juvenile, with some modifications in each to represent their different growth stages based in part on age specific data from Lehman and Coulson (2002) and Tykoski and Fiorillo (2017). That the restorations are composites based on incomplete fossils renders the resulting mass estimates more approximate than those based on more completely known taxa. Their composite natures also mean that there is not mass to dimensions allometric scaling between growth stages that may have existed, other than the head of the juvenile is rendered a little larger in relation to the rest of the animal.

LATE CRETACEOUS NORTH AMERICAN TITANOSAURID STRATIGRAPHY

Although substantial uncertainties exist in some cases, there is broad consensus regarding the general ages of the beds containing Late Cretaceous North American titanosaurid fossils (Table 1, Figures 2 and 3). A fossil from the upper Aguja Formation or the lower Javenila Formation in the northeastern Chihuahua Province, Mexico, is late Campanian or early Maastrichtian (Woodward and Lehman, 2005; Rivera-Sylva et al., 2006; Rivera-Sylva and Carpenter, 2014; H.E. Rivera-Sylva, National Autonomous University of Mexico, written communication, 2024). Their boundaries apparently being a major nonconformity (Fowler, 2017), there appears to be a significant time gap between the top of Aguja and the base of the Javelina Formations. If the specimen is from the Javelina Formation, it may be the earliest known of the North American titanosaurs, dating from near the end of the Campanian. If so, its southerly location may reflect the migration of titanosaurs from the south. Probably deposited over a short period of time, the thin Naashoibito section of the lower Ojo Alamo Formation in northwestern New Mexico preserved the *A. sanjuanensis* types and numerous other specimens. The absence of lambeosaurine hadrosaur

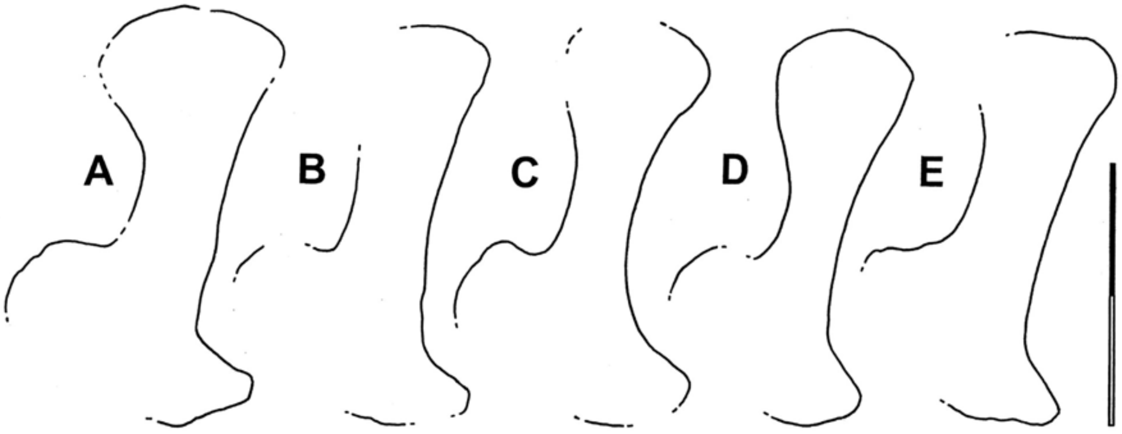

Figure 4. Same scale comparison of undistorted adult *Camarasaurus supremus* AMNH scapulae from the upper Morrison Formation (Late Jurassic) Cope quarry at Garden Park, Colorado; bar equals 1 m. Shown as lefts (reversed when necessary). Based on Figures 74, 75, 77, 79, and 80 in Osborn and Mook (1921) and personal observation. (A) 5760/3, (B) 5761/4, (C) 5761/5, (D) 5761/1, and (E) 5761/4.

fossils precludes a late Maastrichtian age as explained by Jasinski et al. (2011). Fowler (2017) provisionally places the sediments at 70 Ma based on a disputed radiometric result that is discussed.

Assertions that a 69-million-year age for Texas titanosaurid fossils assigned to *A. sanjuanensis* (as per Lehman et al., 2006) show that the Ojo Alamo types are about that age (as per Jasinski et al., 2011) but cannot be verified because the very fragmentary easterly material is not taxonomically determinate. For example, Lehman et al. (2006) assign nondiagnostic Texas titanosaurid material to *A. sanjuanensis* covering a taxonomically improbably long time span of 3 million years. Also not temporally informative is a large tyrannosaurid scapula-coracoid (Jasinki et al. 2011) because gigantic members of the group do not belong to the latest Maastrichtian species of *Tyrannosaurus* (Paul, 2025), which are known from the late Campanian (Stein and Triebold, 2013; Dalman et al., 2024).

The apparently middle Maastrichtian middle section of the Hall Lake Formation of southern New Mexico (Amato et al., 2017; Dalman et al., 2022, 2024) contains fragmentary fossil remains (Lozinsky et al. 1984; Wolberg et al. 1986; also see the Systematic Paleontology section in this article). The lower North Horn Formation of the Wasatch Plateau of central Utah produced USNM 15560 and a few other titanosaur elements. This part of the formation being shallower relative to the Cretaceous/Paleogene (K/Pg) boundary than it is elsewhere, the fossils are later late Maastrichtian, with the titanosaurid specimens not yet known from particularly close to the Cretaceous-Paleogene boundary (Figure 3 in Lawton et al., 1993; Cifelli et al., 1999; Difley and Ekdale, 1999; Sampson and Loewen, 2005; Difley, 2007; D'Emic et al., 2010; Jasinski et al., 2011; Curtice, 2016). The presence of a giant tyrannosaurid in the North Horn Formation in the same location at USNM 15560 is suggestive of such an age, but not entirely definitive as noted above. Also, the specimen of concern (Sampson and Loewen, 2005) consists of only two temporal cranial elements that are not sufficiently diagnostic at the genus level to be of stratigraphic value regarding taxonomic identification (Paul, 2025). Missing from the specimen is the taxonomically critical lacrimal. That bone does not bear a hornlet that is found only in *Tyrannosaurus* among American tyrannosaurids. Thus, lacking that element, the fossil cannot be shown to be a *Tyrannosaurus*. Being from significantly different levels of the Maastrichtian, specimens USNM 10846 and USNM 15560 are therefore separated by a few million years.

The southwestern Texas Big Bend and nearby Chihuahua region Javelina and lower Black Peaks Formations feature fairly abundant titanosaurids that range

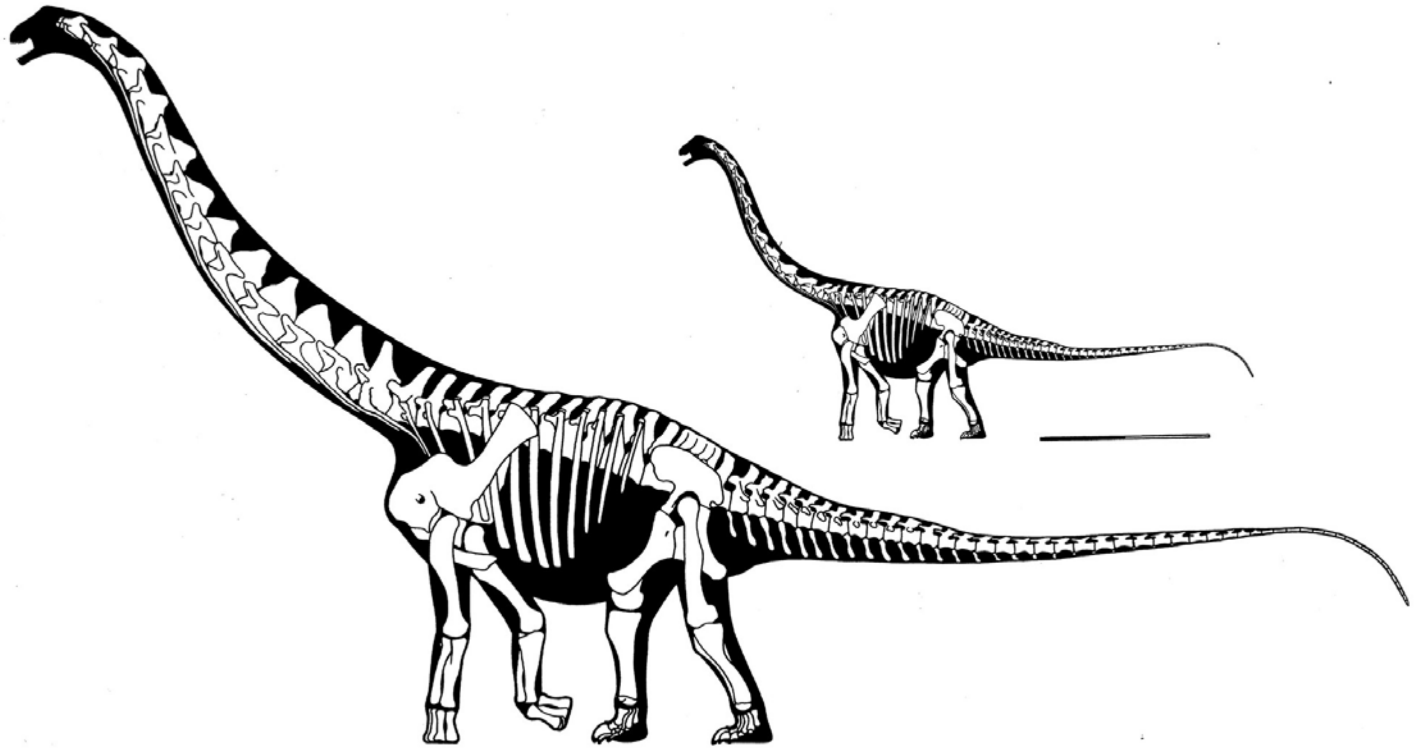

Figure 5. Same scale comparison of mature (scaled to USNM 15560) and juvenile (scaled to TMM 43621) skeletal restorations of generalized composite North American Maastrichtian titanosaurids; scale bar equals 2 m.

from perhaps the later early to late Maastrichtian, with some in the Black Peaks very close to the K/Pg boundary (Lehman and Coulson, 2002; Woodward, 2005; Lehman et al., 2006; Rivera-Sylva and Carpenter, 2014; Fowler, 2017). Part of the top of the Javelina is also very late Maastrichtian, although it does not necessarily reach the K/Pg boundary (Caitlin et al., 2018; Lehman et al., 2022).

Late Cretaceous titanosaurids were present in North America for 5 to perhaps 6 million years (Figure 3). That is abundant time for taxa to experience substantial evolution, especially at the species level. The possibility that one species lasted even half that long is hardly tenable—a million years for a species would be a bioevolutionary stretch. A genus being present for 5 million years is plausible but not necessarily probable. Because the upper Javelina and lower Black Peaks Formations that contain titanosaurids are late Maastrichtian (Lehman and Coulson, 2002; Tykoski and Fiorillo, 2017), they are good potential candidates for being the same taxon as specimen USNM 15560, but that still requires comparative osteological confirmation. Imprecise dating of the Ojo Alamo fossils especially and also of the North Horn Formation in Utah and some Texas and Mexican material (as per Wick and Lehman, 2013), leaves most of the information on the stratigraphic chart (Figure 3) approximate. However, exacting stratigraphic placement is not necessary regarding the issues at hand because the only two named taxa are based on type materials with 3 to 4 million years between them.

RESULTS AND DISCUSSION

That the New Mexican *A. sanjuanensis* holotype and paratypes USNM 10846 and USNM 10847 were found about 300 m from one another (Gilmore, 1922) disfavors

Table 1. North American titanosaur-bearing formations and their usually approximate stage ages and fossil contents; see Systematics for additional information.

Formation	Location	Age	Specimen
Lower Black Peaks	West Texas	latest Maastrichtian	BIBE 45854, 45958; TMM 43621-1
Lower North Horn	Central Utah	late Maastrichtian	USNM 15560 (*Utetitan* holotype), BYU 9087, 11392, 11393
Upper Javelina	West Texas	middle to late Maastrichtian	AMNH 21531; TMM 41541-1
Middle Javelina	West Texas	middle to late Maastrichtian	TMM 46052-1
Lower Javelina	West Texas, northeastern Chihuahua Province	middle to late Maastrichtian	TMM 40699, 41060, 41061, 41398-1-2, 41450-1-2; TTU 542, 546; UTEP P-25, uncataloged Chihuahua fossil remains
Javelina (stratigraphic position was not available)	West Texas	middle to late Maastrichtian	TMM 40597-5, 41063, 41396-1, 41541, 42495-7, 43090-2, 43598-1-6, 43599-1-3, 45601-1, 45602-1, 45854-1-8, 45855-1-4, 45856-1, 45857-1, 45859-1, 45861-1, 45862-1, 45863-1, 45864-1, 45865-1, 45888-1, 45890-1&2, 45891-1-17, 45864-1
Middle Hall Lake	southern New Mexico	middle Maastrichtian	TKM 007, 009
Lower Ojo Alamo	northwestern Chihuahua	early Maastrichtian	USNM 10846 (*Alamosaurus* holotype), 10847, 15658; NMMNH 22544, 25072, 25077, 25077, 27291, 28741, 29031, 29722, 29723, 29724, 29725, 29726, 29727, 29728, 49967; PMU 24305, 24893; SMP VP 1097, 1136, 1138, 1139, 1271, 1494, 1539, 1541, 1581, 1625, 1626, 1641, 1715, 1718, 1850, 1864, 1866, 1876, 2043, 2065, 2097, 2104, 2175, 2230, 2233, 2507, 2696, 3323, SSM 5428
Upper Aguja or lower Javelina	northeastern Chihuahua	late Campanian or early Maastrichtian	Uncataloged tibia

their being from the same individual. That the paratype ischium appears to be too small to belong to the same animal as the large scapula (Figures 1A and 1B) increases the probability that the two specimens, USNM 10846 and USNM 10847, are from two individuals. Because the scapula is missing some parts from the holotype (Figure 1A), the species is dangerously close to being a nomen dubium (doubtful name) (Lucas and Sullivan, 2000).

The standard titanosaurid form paratype ischium (Figure 1B), that may or may not be the same species, does little to improve the taxonomic understanding of lower Ojo Alamo Formation's titanosaurids. The same applies to additional fragmentary and usually badly damaged titanosaurid fossil remains from the same level of the Ojo Alamo Formation—the aft end of a cervical (Figure 1C), an anterior caudal (Figure 1D), a distal femur, a fairly complete pes, and numerous other elements (D'Emic et al., 2011; Fowler and Sullivan, 2011; Jasinski et al., 2011). It therefore is not known how many taxa are represented by these nonoverlapping fossils, contrary to Jasinski et al. (2011) who insist on a presumption of one taxon while not noting that multiple titanosaurid and other sauropod taxa often inhabit the same habitats.

Found on the eastern rim of Joe's Valley in Utah's Wasatch Plateau, USNM 15560 is the most complete North American latest Cretaceous titanosaurid specimen (Gilmore, 1946). Because its scapula is a little smaller than that of specimen USNM 10846 (Figure 1A), USNM 15560 was probably somewhat lesser sized in life. Specimen USNM 15560 ischium is about the same size as that of specimen USNM 10847, which indicates that those two dinosaurs were similar in overall dimensions (Figure 1B). Thus, it is not clear whether the Utah dinosaur was somewhat smaller in life than the New Mexico dinosaur or about the same size. Importantly, the USNM 15560 scapula is well preserved. Its acromion process point is markedly more prominent than that of *A. sanjuanensis* USNM 10846 (Figure 1A). D'Emic et al. (2011) seem to attribute the differences of the two specimens to distortion of USNM 15560, but the exact basis of this assertion is not documented. I have examined the specimens and did not observe any distortion after directly comparing the two bones. The latter has a markedly deeper indentation in the profile of the posterior edge immediately dorsal to the glenoid (Gilmore, 1946), resulting in a prominent triangular glenoid process similar to that of some *C. supremus* (Figure 2). These divergences on their own are not in good accord with taxonomic synonymy. The paired tubercles just above the posterior indentation cited as evidence for conspecifity by D'Emic et al. (2011) are widely separated and quite prominent on the Utah scapula despite its not being a larger animal. Their presence on USNM 10846 is at most marginal if they are true morphological features. They are not widely spaced, and such structures are present on some other titanosaurids from other regions and geologic ages (D'Emic et al., 2011). These structures are consequently not necessarily species specific diagnostic characters, contrary to D'Emic et al. (2011) and Tykoski and Fiorillo (2017). Instead, they are different enough to help define at least two species, if not genera. The same comments apply to the both similar but also different dorsal flaring of the scapula blades cited as taxonomically significant by D'Emic et al. (2011) and Tykoski and Fiorillo (2017), that of specimen USNM 15560 being greater than that of specimen USNM 10846. The cumulative differences between the two USNM scapulae are readily seen to markedly exceed that observed between the five camarasaur scapulae from one quarry (compare Figures 1A and 1B to Figures 4A through 4E). So much so that USNM 15560 looks somewhat like a camarasaur scapula; USNM 10846 is not close to having such a shape. Far from sharing the sufficient anatomical uniformity to surmount the stratigraphic differential, the morphological divergences are sufficient to indicate two different taxa even if the bones were found at the same level of the same formation. A badly damaged immature Ojo Alamo scapula (Jasinski et al., 2011) does not have a prominent acromion process, paired tubercles, or ventroposterior indentation in accordance with the *A. sanjuanensis* holotype. Of great interest is the juvenile ventral scapula BIBE 45958, which is a near perfect match in the relative strong prominence and form of the acromion process, the strong indentation just above the glenoid resulting in a substantial triangular glenoid process, and very similar development and placement of the two tubercles compared to the much larger USNM 15560. The two elements are so alike that specimen BIBE 45958 looks like the juvenile of the same specimen as USNM 15560 despite the geographic distance between them. Both are markedly different from specimen USNM 10846 found in New Mexico. Such a close similarity between these two late Maastrichtian specimens reinforces the probability that shared characteristics are genetically determined, and therefore of taxonomic significance. Thus, specimen BIBE 45958 can be confidently assigned to the same taxon as contemporary specimen USNM 15560, but not to the geologically earlier specimen USNM 10846.

The claims by D'Emic et al. (2011) and Tykoski and Fiorillo (2017) that four ischia are similar in form are not correct, they are all divergent from one another (Figure 1B). Specimens USNM 10847 and TMM 41541-1 have distinctly longer lateral processes relative to midline length than does specimen USNM 15560, and the first two have far deeper and more subcircular concave arcs to their postero-lateral edge profiles. Specimen TMM 41541-1 is more curved than specimen USNM 15560. There is, therefore, no reason to conclude these pelvic bones are indicative of just one or even just two taxa. The same applies to the North American titanosaur ilia and pubes. The elements of a large individual from the late Maastrichtian Black Peaks Formation are very different from those of a similar sized, much earlier fossil from the lower Javelina Formation (Figure 7 in Fronimos and Lehman, 2014). The younger example has a pubic peduncle about half the length of, yet more massive than, that of the other, and the shapes of the anterior and aft ilial plates are quite distinctive. The latter Maastrichtian pubis has a longer and more gracile ventral process than its older counterpart. These two specimens could easily represent different genera, with the earlier possibly being *Alamosaurus*, although not necessarily *A. sanjuanensis*.

Complicating matters is another Black Peaks Formation ilium (Figure 8 in Lehman and Coulson, 2002), which is different in all respects from the other two titanosaurids. Its anterior plate is shallower and the posterior plate deeper. Meanwhile the pubic peduncle is very long like the earlier potential *Alamosaurus*, and very divergent from the short process of the contemporary ilium. That means two terminal Maastrichtian regional titanosaurid taxa is possible. That the three ilia appear to share an indentation on the dorsal rim may indicate an alliance within a common titanosaurid subclade.

The relative proportions and shape of the Texas juvenile TMM 43621-1 ischium is more similar to that of the *A. sanjuanensis* paratype and specimen TMM 41541-1 than to specimen USNM 15560, but the juvenile status of the first obscures the systematic significance of this observation (Figure 1B). The anterior caudals of specimen USNM 15560 from Utah are not in close accord with those of either earlier New Mexico specimen SMP VP-2104, or similar Texas specimen TMM 41541-1. The latter two having a broader centrum relative to their own heights (Figure 1E). It is possible that the differences are due to ontogenetic changes, SMP VP-204 and TMM 41541-1 being larger than USNM 15560, but that is speculative.

Proximal ends of a humerus and femur from the North Horn Formation are close to USNM 15560, but do not belong to that specimen (Curtice, 2016). A titanosaurid femur and humerus are present in the correlative McRae Formation of southern New Mexico (Lozinsky et al., 1985; Wolberg et al., 1986), and a number of humeri and femora, many complete or close to it, from juvenile to adult are known from Texas (Lehman and Coulson, 2002; Fronimos and Lehman, 2014; Wick and Lehman, 2014). As those researchers have noted, these fossil elements are sufficiently similar enough to represent a single taxon, but they were not definitive at addressing whether the fossils are or not. That may be due to the fossil assemblage greatly differing in the sizes of the specimens due to ontogeny and, in some cases, the bones being incomplete and/or distorted.

Early Maastrichtian Ojo Alamo Formation femora are too incomplete (Lucas and Sullivan, 2000; Fowler and Sullivan, 2011) to compare to the late Maastrichtian Utah and Texas specimens, and a humerus from the first locale is not yet known. Wick and Lehman (2014) observe that two femora from the upper Javelina Formation are more robust, even though immature, than the three specimens found lower in the formation. That may be of taxonomic significance, although sexual and individual variation cannot be ruled out. The similar size of the Ojo Alamo and North Horn specimens cited by D'Emic et al. (2011) as suggestive of one species is not an important taxonomic item in many species being similar in size, which is all the more so because some of the Ojo Alamo material is markedly larger than anything from the North Horn to date (Figure 1D; Fowler and Sullivan, 2011). Sexual and individual variations may or may not justify taxonomic synonymy if the specimens were from the same stratigraphic level of the same formation, but in view of their being separated by millions of years the possibility of a monospecies is small. There is not sufficient reason to maintain the Ojo Alamo and North Horn Formations' titanosaurid fossils in the same species, or even genus, with the stratigraphic and morphological data at hand. Therefore, taxonomic division is strongly favored.

Because they lived at the same time or close to it (Figure 3), the late Maastrichtian Utah and Texas titanosaurid fossils are candidates for being the same taxon at least at the genus level, but such should not be automatically presumed to avoid the risk of oversimplifying the systematic situation at the end of the Cretaceous based on the very limited fossil data set. Whereas the similarities between the two Black Peaks ilia favor that they the same taxon perhaps at the species level, their differences with the North Horn Formation ilium indicate the former and the latter are not the same taxon, probably at the genus level. In contrast, the Utah and BIBE 45958 scapulae are so extremely alike that they are entirely compatible with the latter being a juvenile of the same species as USNM 15560. That the last two are so alike while being so different from earlier USNM 10846 reinforces the systematic separation of early from end Maastrichtian titanosaurids.

Concerning ontogeny, the small juvenile status of TMM 43621-1 (Lehman and Coulson, 2002) severely limits its taxonomic utility as a potential type specimen. Meanwhile, the great differences in cervical morphology between large (Tykoski and Fiorillo, 2017) and small (Lehman and Coulson 2002) may represent differential ontogeny, or systematics, or both. The dorsals of a large specimen (Fronimos and Lehman, 2018) and a juvenile (Lehman and Coulson 2002) appear fairly similar, but the size differences, and the disarticulation of the juvenile's neural spines from the centra, hinder needed anatomical comparisons. The lack of sufficient overlap between the large cervicals described by Tykoski and Fiorillo (2017) with other latest Cretaceous regional titanosaurids means their taxonomic value is currently nil. TMM 43621-1 and BIBE 45854 are therefore indeterminate specimens.

Because the TMM 41541-1 ischium and caudal are so distinct from specimen USNM 15560, they are not readily referable to the same taxon and may be a distinct form. Perhaps closer to *A. sanjuanensis* than USNM 15560, specimen TMM 41541-1 should be considered indeterminate titanosaurid fossils until more information becomes available. Two late Maastrichtian osteoderms found with Utah USNM 15560 (Carrano and D'Emic, 2015) and from Texas (Fronimos, 2021) are compatible with their being one taxon, but they do not establish such. Nor do they offer comparison to earlier *Alamosaurus* for which no armor is yet known. The suggestions by Fronimos and Lehman (2018) and Lehman et al. (2018) that latest Maastrichtian lower Blacks Peak Formation and earlier Javelina Formation titanosaurids are distinct taxa is sound, but their assignment of the former to the much older *A. sanjuanensis* is not well founded. Even if future information indicates that some of the Texas titanosaurids constitute a distinct taxon, none of the known specimens is of holotype quality.

The few vertebral, pectoral, and pelvic characters shared by the collective end Cretaceous specimens, their geographic isolation from non-North American titanosaurids, and considering genetic drift, suggest North American titanosaurids formed a small clade distinct from other titanosaurids that are diagnosed as a subfamily—a higher level titanosaur taxonomy is currently too unsettled to assign this little group to a larger family. But there is no strong evidence which are considered a subfamily . But there is no strong evidence that they all belong to one species in one genus, such would be probable only if all the southwestern titanosaurids were structurally very similar and came from one narrow stratigraphic level. However, that is far from the actual situation because there is too much time stratigraphic separation (Figure 3) and morphological variation (Figure 2) between the North American titanosaurids to place them in one species that lasted for millions of years during the Maastrichtian or even earlier up to the K/Pg crisis in natural selection stasis. Therefore, the dinosaurs that dwelled together experienced rapid and extensive Darwinian evolution, including the apparent loss of whole clades of North American albertosaurines, lambeosaurines, centrosaurines, and classic chasmosaurines in favor of over-sized tyrannosaurines, edmontosaurines and triceratopsines (Paul, 2016, 2024, 2025, in press). No other dinosaur species is currently projected to have lasted so long based on extensive fossil remains.

My interpretation is the Utah material can be readily differentiated from the New Mexico fossils, and at least two taxa need to be recognized, with the understanding that more, perhaps many more, taxa may have been present over that time on the continent. Diagnosing the relatively complete USNM 15560 as a holotype is more readily done than for any other North American titanosaurid. The failure to identify USNM 15560 as the basis of a taxon, and using it to help identify the far less adequately characterized *A. sanjuanensis,* is not well advised.

The more difficult question is whether the taxonomic separation is just specific or is also generic. Continuing to place the North Horn Formation specimen in *Alamosaurus* is problematic because the genus is founded on such poor material. The differences are substantial, and—very importantly—ongoing congeneric status, risks encouraging the continued use of the Ojo Alamo and North Horn material to define one dubious genus and tossing assorted specimens in a probable genus level taxonomic wastebasket (as per D'Emic et al., 2011; Tykoski and Fiorillo, 2017). So USNM 15560 is designated the holotype of a new genus and species. The generic name recognizes the original peoples of the region, and the specific title honors a centurion resident of the Wasatch Plateau area in which it was found. A few other incomplete titanosaurid fossil remains from the lower North Horn are referred on a tentative basis, but the characters they exhibit should not be used to diagnose the taxon until further comparisons are made.

Despite living at a similar time, most of the Texas specimens are not placed in the new taxon because, in part, they are not sufficiently identifiable at the genus and/or species level, and avoids potentially contaminating the taxon and its identification with dinosaurs from a different horizontal location. This also precludes future taxonomic inertia from leading researchers to presume synonymy as has been the past tendency, rather than more aggressively investigating the taxonomic situation. The new genus is not intended to be another wastebasket taxon for incomplete specimens across the late Maastrichtian of the North American southwest.

Because it is quite possible that more than one titanosaurid lived in the same place at the same time, *Alamosaurus sanjuanensis* is authoritatively identified on the one element that definitely belongs to the taxon, USNM 10846. The characteristics of the paratype ischium are highly tentative, the reference of the specimen to the species being suspect. The other lower Ojo Alamo Formation specimens are referred to *A. sanjuanensis* on a very provisional basis and need to be considered as potentially distinct taxa as they do not exhibit the diagnostic features and the age is inconclusive. The tibia from Chihuahua is a taxonomic floater. The differential identifications are intended to distinguish the North American titanosaur taxa from one another, not from foreign examples.

SYSTEMATIC PALEONTOLOGY

Dinosauria Owen 1842
Sauropoda Marsh 1878
Titanosauria Bonaparte and Coria 1993
Utetitaninae n. sf.

Provisional diagnosis: circumferential depression limited to ventral half of the anterior condyle of biconvex first caudal centrum, multiple large foramina pierce lateral surface of first caudal, paired tubercles dorsal to scapula glenoid, base of blade cross section asymmetrically concave with thinner anterior and thicker posterior margin, antero-dorsal blade edge nearly straight whereas postero-dorsal edge flares posteriorly. Small indentation on dorsal rim of ilium.

Alamosaurus Gilmore 1922
Type species *A. sanjuanensis*
Diagnosis: as for type species

Alamosaurus sanjuanensis Gilmore 1922
Holotype: USNM 10846 (nearly complete left scapula-coracoid, Gilmore, 1922; Figure 1A).

Paratype: USNM 10847 (nearly complete right ischium, Gilmore, 1922; Figure 1B).

Provisional referred specimens: NMMNH P-22544 (proximal and distal right tibia), 25072 (nearly complete left scapula), 25077 (fragmentary right femur) (Mateer, 1976), NMMNH 25077 (fragmentary right femur), 27291 (anterior caudal, NMMNH 28741 (partial mid caudal), 29031 (partial caudal), 29722 (partial mid caudal), NMMNH 29723 (partial anterior caudal), NMMNH 29724 (seven tooth fragments), NMMNH 29725 (tooth fragment), NMMNH 29726 (four tooth fragments), NMMNH 29727 (tooth fragment), NMMNH 29728 (tooth fragment), NMMNH 49967 (nearly complete right pes), (Lucas and Sullivan, 2000; D'Jasinski et al., 2011); PMU 24305 (fragmentary right ilium), PMU 24893 (last sacral and first caudal); SMP VP 1097 (partial tooth), SMP VP 1136 (posterior left ilium), SMP VP 1138 (partial left femur), SMP VP 1139 (partial right? pubis), SMP VP 1271 (tooth root), SMP VP 1494 (2 partial left caudals), SMP VP 1539 (partial scapula), SMP VP 1541 (skull fragments), SMP VP 1581 (distal caudal), SMP VP 1625 (distal left femur), SMP VP 1626 (nearly complete right fibula), SMP VP 1641 (fragmentary dorsal), SMP VP 1715 (coracoid and possible associated fragments), SMP VP 1718 (fragmentary femur), SMP VP 1850 (posterior cervical, Figure 1C), SMP VP 1864 (partial dorsal), SMP VP 1866 (partial dorsal), SMP VP 1876 (nearly complete dorsal), SMP VP 2043 (proximal tibia), SMP VP 2065 (partial tibia), 2097 (partial left ischium, right femur), SMP VP 2104 (partial anterior caudal, fragments, Figure 1D), SMP VP 2175 (distal right radius), SMP VP 2230 (nearly complete caudal), SMP VP 2232 (partial ribs), SMP VP 2233 (anterior right ilium), SMP VP 2507 (tooth), SMP VP 2696 (chevron, fragments), SMP VP 3323 (partial left pubis) (Lucas and Sullivan, 2000; Fowler and Sullivan, 2011; Jasinski et al. 2011); SSM 5428; USNM 15658 (distal caudal, Kues et al., 1980), TKM 007 (nearly complete right humerus), 009 (femur), (Lozinsky et al., 1984).

Location, horizon, age: northwestern New Mexico, lower (Naashoibito Member) Ojo Alamo Formation; southern New Mexico? lower Hall Lake? early Maastrichtian.

Diagnosis: acromion process not strongly prominent (1), posterior profile of scapula gently sinuous so a triangular glenoid process is absent (2), paired tubercles dorsal to glenoid very subtle and closely spaced (3), flare of postero-dorsal edge of blade subtle (4), lateral process of ischium long? (5), postero-lateral profile of ischium has a strong concave subcircular arc? (6).

Utetitan n.g
Etymology: after the original Ute peoples of central Utah upon whose ancient lands the fossil was found.
Type species *U. zellaguymondeweyae* n.s.
Diagnosis: as for type species.

Utetitan zellaguymondeweyae n.s.
Etymology: after the author's maternal grandmother Zella Guymon Dewey (1901–2002), born and raised in Huntington, Utah, 30 km northeast of the USNM 15560 quarry, who called the Wasatch Plateau "the hills of home." Shortly after the specimen was excavated her family moved from Salt Lake Valley to the wartime Washington, D.C. suburbs a few kilometers from the fossil's new Smithsonian location where I visited with her on occasion. She is buried in Arlington National Cemetery with her husband William E. Dewey (1899–1962).

Gilmore, 1922 *Alamosaurus sanjuanensis*
Holotype: USNM 15560 (partial dorsal ribs, caudals 1-30, 25 chevrons, both sternals, right scapula coracoid, humerus, radius, ulna, metacarpus, both ischia, osteoderm, Gilmore, 1946).

Referred specimens: BIBE 45958 (partial left scapula (Tykoski and Fiorillo, 2017); very probably BYU 9087 (proximal left humerus and femur, Curtice, 2016), BYU 11392 (anterior caudal), BYU 11393 (anterior caudal), (D'Emic et al., 2011).

Location, horizon, age: central Utah, lower North Horn Formation; West Texas, upper Javelina? and lower Black Peaks Formations; late Maastrichtian.

Diagnosis: acromion process strongly prominent (1), posterior profile of scapula strongly sinuous so a prominent triangular glenoid process is present (2), paired tubercles dorsal to glenoid fairly prominent and widely separated (3), flare of postero-dorsal edge of blade more prominent (4), lateral process of ischium modest in size (5), postero-lateral profile of ischium moderately concave arced (6), femur robust?

Middle/late Maastrichtian *Utetitan* or titanosaurid incertae sedis: AMNH 21531 (right femur, Wick and Lehman, 2014); BIBE 45854 (cervicals 6-14; Tykoski and Fiorillo 2017), TMM 40597-5 (pubis), TMM 40699 (mid caudal), 41060 (right ilium), TMM 41061 (right rib), TMM 41063 (left pubis), TMM 41396-1, TMM 41398-1-2 (cervical centrum, proximal left humerus), TMM 41450-1 and TMM 41450-2 (1st caudal, right ulna), TMM 41541 (partial posterior cervical, right ischium), TMM 41541-1 (anterior dorsal ribs, 1st caudal), TMM 42495-7 (pubis), TMM 43090-2 (partial femur), TMM 43598-1-6 (partial cervical, nearly complete anterior dorsal, partial dorsal centrum, partial anterior caudals, partial left femur, right metatarsal II), TMM 43599-1-3 (partial rib, anterior caudal), TMM

43600-2 (right humerus), TMM 43621-1 (7-8 partial cervicals, 6-7 partial dorsals, partial sacral and sacral rib, left coracoid, left humerus, left ulna, left ilium, left fibula, distal right tibia), TMM 45601-1 (right fibula), TMM 45602-1 (right tibia), TMM 45854-1-8 (rib material), TMM 45855-1-4 (left dorsal rib/s, proximal left scapula, proximal right metacarpal II?), TMM 45856-1 (left ulna), TMM 45857-1 (partial left humerus), TMM 45859-1 (right femur), TMM 45861-1 (nearly complete left fibula), TMM 45862—1 (partial left ischium), TMM 45863-1 (right humerus), TMM 45864-1 (partial mid caudal), TMM 45865-1 (distal caudal), TMM 45888-1 (osteoderm, Fronimos, 2021), TMM 45890-1 and TMM 45890-2 (nearly complete right tibia, nearly complete right ungual), TMM 45891-1-17 (5 complete and partial dorsals, sacral fragments, partial anterior caudal, transverse process, left and right nearly complete humeri, nearly complete left ilium, fragment of right ilium, nearly complete left pubis, nearly complete left ischium,), TMM 45864-1 (anterior mid-caudal), TMM 46052-1 (nearly complete left femur) (Lawson, 1972; Woodward and Lehman, 2009; Fronimos and Lehman, 2014; Wick and Lehman, 2014); TTU 542 (nearly complete right femur, Wick and Lehman, 2014), TTU 546 (proximal caudal, Lehman and Coulson, 2002), UTEP P-25 (nearly complete left femur, Wick and Lehman, 2014).

Late Campanian and/or early Maastrichtian *Alamosaurus* or titanosaurid incertae sedis: uncatalogued Chihuahua fossils (right tibia, minority of skeleton, Rivera-Sylva, 2006; Rivera-Sylva and Carpenter, 2014).

SKELETAL RESTORATIONS AND BODY MASS

The large (scaled to USNM 15560, close to USNM 10846, USNM 10847, and TMM 41541) and juvenile (scaled to TMM 43621-1) skeletals (Figure 5) are broadly similar to those produced by Lehman and Coulson (2002), with an improvement that the mature version is able to incorporate the adult cervicals subsequently described by Tykoski and Fiorillo (2017), and a juvenile partial scapula from the same reference. Reliably estimating the relative size of the neck in adults is currently not possible, the large cervical series not being accompanied by more posterior postcranial elements (Tykoski and Fiorillo, 2017) necessary for cross scaling. The length of the cervical series in the large skeletal is scaled to the same ratio relative to the dorso-sacrals of the juvenile, and that results in a large mature neck. But the quite large BIBE 45854 cervicals may favor the neck being a fifth or more longer relative to the body, or they may have been attached to a larger bodied individual. The volume greater than mass results for juvenile TMM 43621-1 is approximately 1.3 mt, the somewhat larger BIBE 45958 is approximately 3 mt. The similar sized TMM 46052-1 (femur 1510 mm), USNM 10487, and USNM 15560 are approximately 16 to 17 mt. The larger USNM 10846 is in the range of 20 mt, and still heftier UTEP P-25 (femur 1675 mm) and TMM 41541 (femur 1730 mm) is 22 to 24 mt. The TMM 41541 mass value is about three quarters the estimate for the specimen based on bone strength factors (Lehman and Coulson, 2002), which is in fair agreement; although long bone circumferences have a much greater mass estimate error range than do scientifically proportioned volumetric models (Paul, 1997, 2019; Larramendi, 2016; Brassey, 2017; Larramendi et al., 2021). A middle cervical, anterior caudal, and femur from the Ojo Alamo Formation have been offered as evidence of much larger putative *Alamosaurus* individuals (Fowler and Sullivan, 2011). The incomplete nature of all these bones prevents rigorous quantitative comparisons. The cervical is quite large, but the true dimensions of the very fragmentary vertebra (Figure 1D) are correspondingly very unclear—the short distance from the posterior rim of the centrum to the postero-lateral end of the wing of the parapophysis suggests the total length was much less than that of the mid cervicals of *Puertasaurus* (Figure 1A2 versus 1B2 in Fowler and Sullivan [2011] sans speculative outlines), which reached 60 to 70 mt as do some other South American titanosaurids (Paul, 2019; Larramendi et al., 2021; Paul and Larramendi, 2023). The cervical appears to be similar in size to the more ordinary sized Black Peaks Formation cervical series (Figure 1D) in which that big individual may have been in the range of 30 or somewhat more tonnes. The caudal centrum is markedly larger than those of USNM 15560 (Figure 1E) and is similar in size to that of *Futalognkosaurus* (Figures 2B and 2C in Fowler and Sullivan, 2011), which was approximately 30 mt (Paul 2019; Larramendi et al., 2021). The large femur also suggests a 30-mt individual, as does the large pes described by D'Emic et al. (2011), and the tibia from Chihuahua (Rivera-Sylva et al., 2006). The largest known Ojo Alamo titanosaurids were 30 mt or little more, which is in general agreement with Paul (2019) and Larramendi et al. (2021), although higher estimates cannot be ruled out on the limited data on hand. At this time, it appears that neither *Alamosaurus* nor *Utetitan* matched the enormous bulk of South American or Indian super titanosaurids and other sauropods of 50 to possibly well over 100 mt (Paul, 2019; Larramendi et al., 2021; Paul and Larramendi, 2023). Nor can these end Mesozoic sauropods said to be the largest known North American sauropods, those being nontitanosaurids known from the Late Jurassic and Early Cretaceous (Paul, 2019, 2024, in press). But the small North American fossil titanosaurid sample allows for much larger examples having existed. With all the elements used to produce the PMNS composite display mount originating from the late Maastrichtian the fossil is not *Alamosaurus*. Because part of fossil is modeled after USNM 15560 it can be tagged *Utetitan*, although there is a possibility the fossil is at least a species and perhaps generic chimera. It is possible that *Utetitan* did not have as wide a hindlimb gauge as most titanosaurids (Wick and Lehman, 2014).

CONCLUSION

The possibility that all the titanosaurids of the late Campanian and Maastrichtian stages of the North American southwest over the 5 or more million years of the return of sauropods to the continent were just one taxon, especially species—the universal *Alamosaurus sanjuanensis* thesis—is not a systematically viable hypothesis. A closer look at the specimens from the region shows sufficient anatomical diversity to demonstrate that more than one taxon, probably including two known genera, were present over the stratigraphic stage as is to be expected among dinosaurs that are prone to exhibit rapid evolution and diversification starting in the Campanian.

Sauropods in the latter stage were probably one or more distinct indeterminate taxa whose detailed characteristics are not yet known. *Alamosaurus sanjuanensis* was very probably restricted to the early Maastrichtian lower Ojo Alamo Formation of New Mexico and any lateral regional formations. Even then, multiple taxa may have been extant at that time and preserved among the known fossils. Additional fossil remains discovered over time may resolve this question. Later stage sauropods probably went extinct later in the Maastrichtian, possibly after having spawned related taxa via cladogenesis and/or anagenesis.

The late Maastrichtian lower North Horn Formation in Utah was home to the distinct *Utetitan zellaguymondeweyae* that probably went extinct at the end of the Mesozoic. Titanosaurids from contemporary lateral formations such as the Black Peaks Formation in Texas may be the same species, but more than one titanosaurid taxon was present in the North Horn and/or Black Peaks habitats at that time is at least plausible, if not probable. Again, there is a need for additional fossil remains.

I suggest that incomplete North American titanosaurid elements not be assigned to a specific taxon unless there are strong anatomical and stratigraphic reasons to do so, if not they should be tagged as enigmatic taxa. With the titanosaurid fossils in *Alamosaurus* spanning millions of years, their biostratigraphic utility is limited to showing that the sediments containing them were latter Campanian and Maastrichtian. Under the new scheme fossil remains that can be assigned to *A. sanjuanensis* are indicative of early Maastrichtian age, those to *U. zellaguyondemeya* to late in the stage. Neither *Alamosaurus* nor *Utetitan* or any close relatives appear to have been much over 20 to 30 mt, which is far short of observed titanosaurid maximums, although higher masses cannot be eliminated.

Being classic titanosaurids, *Alamosaurus* and *Utetitan* could not have directly descended from much earlier North American sauropods (D'Emic et al., 2010). This analysis does not provide any compelling evidence regarding the Asian versus South American origin of North American Maastrichtian titanosaurids; however, Lucas and Sullivan (2000) and Tykoski and Fiorillo (2017) suggest that an improved understanding of the low level taxonomy of the beasts may eventually be productive. The absence of fossil sauropod fossils in Alaskan dinosaur-bearing beds (Chiarenza et al. 2022)—although there are substantial stratigraphic gaps in the Bering Land Bridge dinosaur fossil record—may be due to the severe climate restricting the food base for the land giants (Paul, 2024). Additionally, the very large, attenuated necks and tails of sauropods could have precluded the heat retention needed in polar winters. If so, then a South American origin is favored. That once back in North America titanosaurids were just one static taxon for millions of years is not evolutionarily logical.

The combination of shared vertebral and pectoral characters of *A. sanjuanensis, U. zellaguymondeweyae*, and other Maastrichtian North American titanosaurids on one hand, along with significant differences between them on the other, indicate that utetitans formed their own small local clade, presumably because of their restricted geographic isolation and experienced Darwinian selection that caused them to become anatomically distinct from their foreign ancestors. Individuals investigating titanosaurid phylogeny should use the North American fossils with caution, the collective partial fossils represent multiple genera and species that risk complicating cladistic results if they are assumed to represent just one taxon. *Alamosaurus sanjuanensis* was not the last known North American titanosaurid, that was *Utetitan zellaguymondeweyae*, and possibly another taxon or more.

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