

Late Cretaceous vertebrate paleoecology of Big Bend National Park, Texas

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Abstract

Big Bend National Park, Texas, has some of the southernmost terrestrial vertebrates of the Western Interior of North America, and its faunal assemblage was part of the "*Kritosaurus*" southern dinosaur biogeographic province. Compared to Dinosaur Provincial Park in Alberta, Big Bend was relatively more distant from uplands and characterized by slower sedimentation rates. The Late Cretaceous climate in Big Bend was warmer and drier than Dinosaur Provincial Park, with periodic droughts and fires, which resulted in important paleoecological differences. However, less is known about southern vertebrate fauna of Big Bend compared to that of the northern province. Twenty microsites were collected from the upper shale member of the Aguja Formation at two areas in the Park, Talley Mountain and Rattlesnake Mountain. Deposits become more terrestrial upsection, from coastal floodplain to inland floodplain facies, and span from the late Campanian to the mid-Maastrichtian. Collection of microsites in Big Bend has yielded thousands of bones and teeth of vertebrates (fish, amphibians, lizards, crocodylians, turtles, dinosaurs, and mammals), providing a more detailed picture of the paleocommunity. Recent discoveries of numerous dinosaur eggshell fragments and teeth from juvenile hadrosaur, ankylosaur, tyrannosaurid, cf. *Sauromitholestes*, *Richardoestesia isosceles*, and other small theropods document for the first time that these dinosaurs nested in the area. Discoveries of burned wood and many horizons with nodules of paleocaliche indicate that Big Bend had periodic droughts and fires.

Introduction

Southern biogeographic province

Within the Western Interior of North America (Fig. 1), Big Bend was part of a southern dinosaur biogeographic province, the "*Kritosaurus*" fauna (Lehman, 1997). The southern province, south of southern Colorado, was characterized by the *Normapolles* palynoflora, and had a warm, dry, non-seasonal climate, and open-canopy woodlands (Wheeler and Lehman, 2000; Lehman and Wheeler, 2001). In contrast the northern province, north of southern Colorado, was characterized by the *Aquilapollenites* palynoflora and had a temperate and more humid climate, with a more closed-canopy forest (Nichols and Sweet, 1993). Rainfall and temperature differences were the main factors that produced these north-south biogeographic patterns (Baghai, 1996; Lehman, 1997; for a differing opinion on Late Cretaceous provinces, see Sullivan and Lucas, 2003). Big Bend in the late Campanian to mid-Maastrichtian was at ~35 degrees N paleo-latitude (Robinson-Roberts and Kirschbaum, 1995), and the Western Interior Seaway was at least 100 km away (Lehman, 2001). However, considerably less is known about the vertebrate faunas from the southern biogeographic province than the long-studied northern areas. Big Bend is critical in improving our understanding of the southern

province because it contains some of the southernmost Late Cretaceous vertebrate fossils in North America.

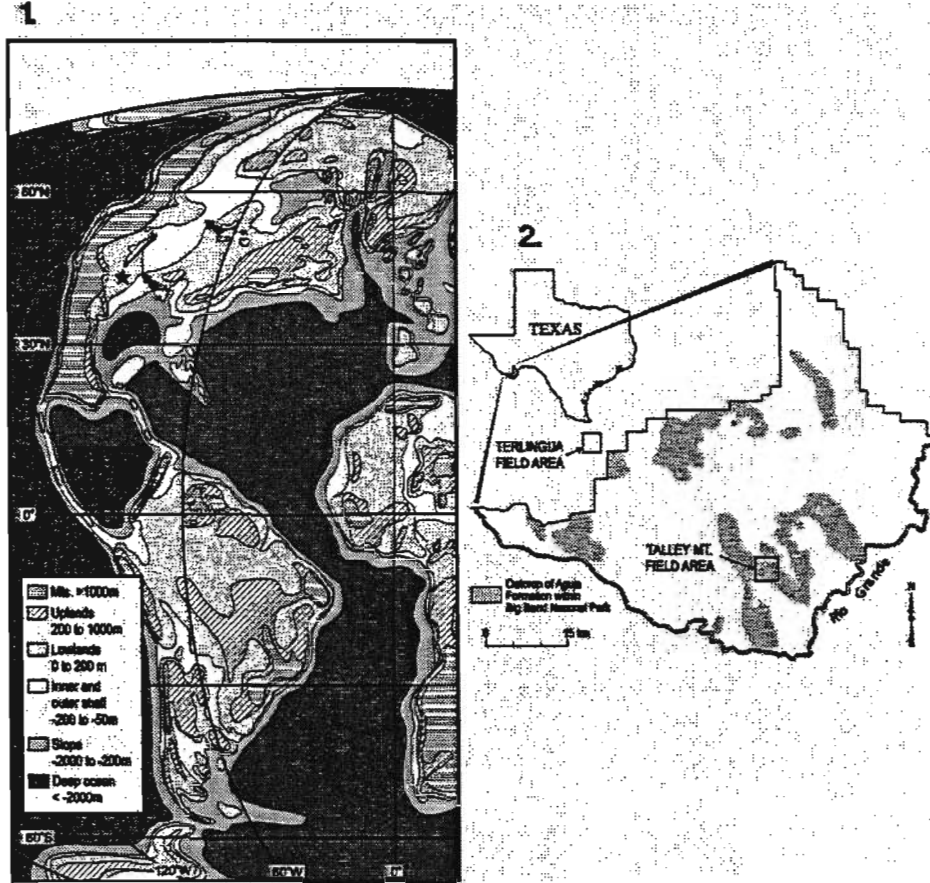


Figure 1. Late Cretaceous paleogeography. 1) Maastrichtian paleogeographic reconstruction of North America (redrawn from Ziegler and Rowley, 1998). 2) Big Bend National Park, west Texas, with Aguja Formation outcrops stippled. Talley Mountain and Terlingua fossil sites are shown by arrows.

Aguja Formation

The Aguja Formation is a widespread sedimentary unit in Big Bend. It is an eastward-thinning succession composed of 135 to 285 meters of interbedded sandstones, shales, and lignite (Fig. 2). Environments of deposition vary from marine, paralic, to inland floodplain (Lehman, 1985). The upper shale member of the Aguja Formation represents the last phase of the pre-Laramide tectonic sedimentation in the area (Lehman, 1991) and records the final marine regression of the Western Interior Sea from west Texas (Regression 8 of Kauffman, 1977). The lower part of this member contains carbonaceous mudstones, thin beds of lignite, and large siderite ironstone concretions representing distributary channels, levees, crevasse splays, and poorly-drained interdistributary marshes and bays. The upper part of this member, with variegated mudstones and sandstones containing conglomeratic lags of paleo-caliche nodules, represents fluvial environments within a deltaic coastal plain and inland floodplain. Typical large vertebrates from the upper Aguja Formation are the giant crocodylian *Deinosuchus riograndensis*, the horned dinosaur *Chasmosaurus mariscalensis*, and the hadrosaur *Kritosaurus* sp. (Lehman, 1985), which are known from associated skeletons. The age of the microsites from the Talley Mt. area (see Methods) was constrained by paleomagnetic analysis of the fine-grained sedimentary rocks. Magnetostratigraphic correlations to the base of chronozone 32 (Fig. 2) constrain the microsites to approximately 71 to 75 Ma (late Campanian

to early Maastrichtian) (Sankey, 1998; Sankey and Gose, 2001). Similar work constrains the upper Aguja Formation to the mid-Maastrichtian (Lehman, 1985, 1989, 1990; Standhardt, 1986).

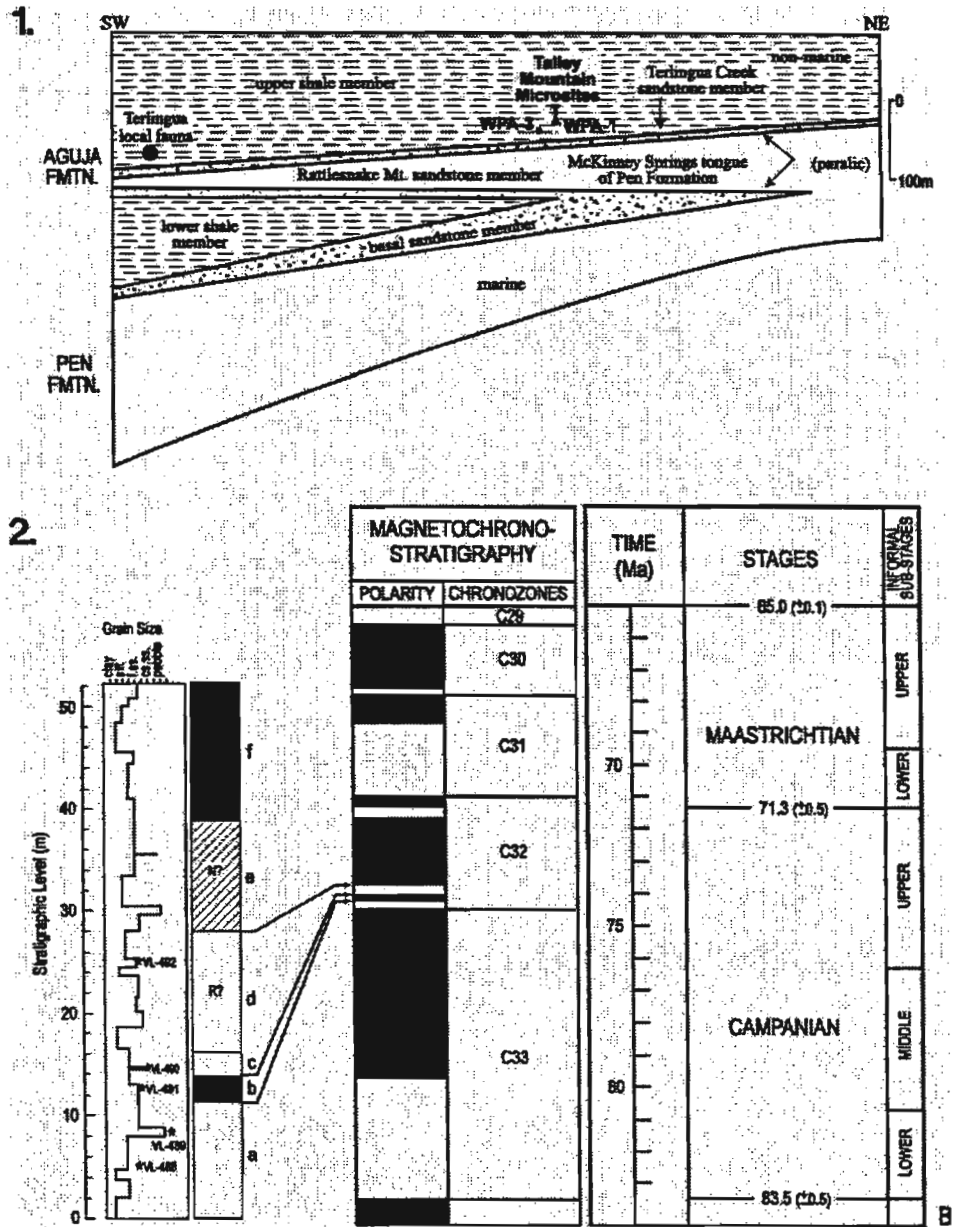


Figure 2. Stratigraphy of the Aguja Formation, Big Bend National Park, Texas. 1) Lithostratigraphy of the Aguja Formation modified from Rowe et al. (1992), showing positions of the Talley Mt. (Sankey 1998) and Terlingua (Rowe et al., 1992) sites. Stratigraphic position of the Talley Mt. microsites and WPA dinosaur quarries 1 and 2 (Work Progress Administration) from Lehman (1985; Plate III and written comm., 1998). Formal members of the Aguja Formation are capitalized; informal members are not. 2) Magnetostratigraphic correlations of upper Aguja Formation from Talley Mt. area (from Sankey and Gose, 2001).

Methods

From the Talley Mountain Area, fossils were collected from five horizons of carbonate-cemented sandstone containing numerous clasts of clay, pedogenic nodules, small bones and teeth, and large fragments of wood and bones. Collected rocks (1753 kg) were disaggregated by soaking in a 10-25% solution of acetic acid and screened through fine-mesh screens with 1

mm maximum openings (methods described in Sankey, 1998). Matrix was inspected with a dissecting microscope, and all identifiable fossils, even small fragments of teeth, were counted

Table 1. Taxa present at Talley Mountain microsites.

Taxa	492	490	491	489/140	488
<i>Onchopristis</i>	0	3	10	37	0
<i>Squatirhina</i>	1	1	10	34	0
<i>Ptychotrygon</i>	1	0	3	9	0
<i>Ischyrhiza</i>	0	0	1	3	0
Dasyatidae	0	4	16	6	1
<i>Lissodus selachos</i>	1	1	21	197	12
<i>Hybodus</i>	0	0	0	1	1
<i>Scapanorhynchus texanus</i>	0	0	0	3	1
Chondrichthyes-indet.	3	0	12	46	21
Lepisostidae	28	6	126	319	331
Phyllodontid teeth	0	0	0	2	5
Fish-indet.	23	0	186	1216	28
<i>Albanerpeton</i>	0	0	1	3	27
Amphibian-indet.	0	0	0	37	1
Glyptosauridae	0	0	0	1	0
Teidae Sp. "B"	0	0	0	2	0
Teidae: <i>Chamops</i>	0	0	0	1	0
<i>Peneteius</i> sp. nov.	1	0	0	0	0
Scincomorph	0	0	0	1	0
Lizard-indet.	1	0	0	23	1
Croc indet. B	0	3	29	105	13
Croc indet. A	0	0	8	11	4
<i>Brachychampsa</i>	7	0	28	50	23
Goniopholidae	0	0	0	4	1
Crocodylian-indet.	18	2	10	46	10
Hadrosauridae	1	0	1	6	0
Ornithischian-indet.	2	0	0	4	1
Tyrannosauridae	0	0	4	2	0
<i>R. isosceles</i>	1	0	0	6	2
<i>R. gilmorei</i>	0	0	0	1	0
Pachycephalosauridae	0	0	0	1	0
cf. <i>Richardoestesia</i>	0	0	0	2	0
<i>Sauromitholestes</i> -indet.	0	0	0	2	1
<i>S. langstoni</i>	1	0	9	5	0
Theropod indet.	0	8	5	10	16
Dino. frags.	3	0	0	6	0
cf. Aves	0	0	0	4	0
<i>Alphadon</i> cf. <i>A. halleyi</i>	1	0	0	1	0
Marsupialia-indet.	1	0	2	8	1
<i>Cimolomys</i> sp. nov.	0	0	0	1	0
<i>Paracimexomys magnus</i>	0	0	0	1	0
cf. <i>Cimexomys</i>	0	0	1	1	0
<i>Mesodma</i>	0	0	1	0	0
Multituberculata-indet.	0	0	0	5	2
Mammals indet.	3	0	1	9	5
Total Specimens	97	28	485	2232	507

(Table 1). Microsites from the Rattlesnake Mountain area were surface collected and one was screened. Fossils are curated in the Louisiana State University (LSU), Museum of Natural Science Vertebrate Paleontology Collections. VL refers to vertebrate locality and V to specimen number. Specimen and locality information is available to qualified researchers by written request to the curator of Vertebrate Paleontology at LSUMNS.

Results

Talley Mountain microsites: coastal floodplain

The five sampled microsites, spanning 20 m of section, yielded 3,349 identifiable specimens from 38 taxa. Based on counts of identifiable specimens, occurrence percentages of each group are: fish (68%), sharks and rays (14%), crocodylomorphs (11%), dinosaurs (3%), amphibians (2%), turtles (not counted), squamates (1%), and mammals (1%) (Fig. 3, Table 1). The depositional environments of sampled microsites become more terrestrial upsection; the stratigraphically lowest site is within the interdistributary marsh facies and the stratigraphically highest site is within the coastal floodplain facies. Aquatic vertebrates (fish, sharks, and rays) decrease in abundance upsection, while terrestrial vertebrates (dinosaurs and mammals) increase. The lowest microsite is adjacent to the AMNH (American Museum of Natural History) locality that yielded the type specimen of *Deinosuchus riograndensis* (Colbert and Bird, 1954) and to the WPA (Work Progress Administration) localities from which the horned dinosaur *Chasmosaurus mariscalensis* and the hadrosaur *Kritosaurus* sp. were collected. (Lehman, 1982).

Mammal fossils are rare (1 to 5% of the specimens; Fig. 3 #59-64, Table 1), include teeth from the multituberculates *Cimolomys* sp., *Mesodma* sp., cf. *Cimexomys*, cf. *Paracimexomys*, and the marsupial *Alphadon* cf. *A. halleyi*, and are assigned to the Judithian Land Mammal Age (Sankey, 1998; Sankey and Gose, 2001). Small dinosaur teeth make up 2 to 8% of the specimens, and include hadrosaurs, ceratopsians, pachycephalosaurs, tyrannosaurids, *Sauromitholestes* cf. *S. langstoni*, *Richardoestesia isosceles*, and two undetermined theropod taxa. Many of the dinosaur teeth are small and represent hatchlings or young individuals, evidence that many of these taxa nested in the area (Sankey, 2001).

Rattlesnake Mountain microsites: inland floodplain

Microsites were collected in the Rattlesnake Mt. area from the base to the top of the upper shale member, representing the inland floodplain facies. The deposits represent more terrestrial environments upsection and span the late Campanian to the mid-Maastrichtian.

Vertebrates found at these localities include fish (rare), salamanders, lizards, turtles, crocodylians (*Brachychampsia*, *Deinosuchus*), and dinosaurs. A particularly rich microsite area has yielded numerous (300+) eggshell fragments referred to dinosauroid spherulitic, dinosauroid prismatic, and aves (Welsh, 2004). Additionally, numerous teeth of dinosaur hatchlings or juveniles from hadrosaurs and theropods (tyrannosaurids and cf. *Sauromitholestes*), demonstrate that these dinosaurs nested in this area. Less abundant teeth have been found from hatchling or juvenile ankylosaurs, cf. *Richardoestesia*, and other small theropods. Although no nesting site has been found in Big Bend, the discovered microfossils are the first well-documented evidence that dinosaurs and birds nested in the area.

Discussion

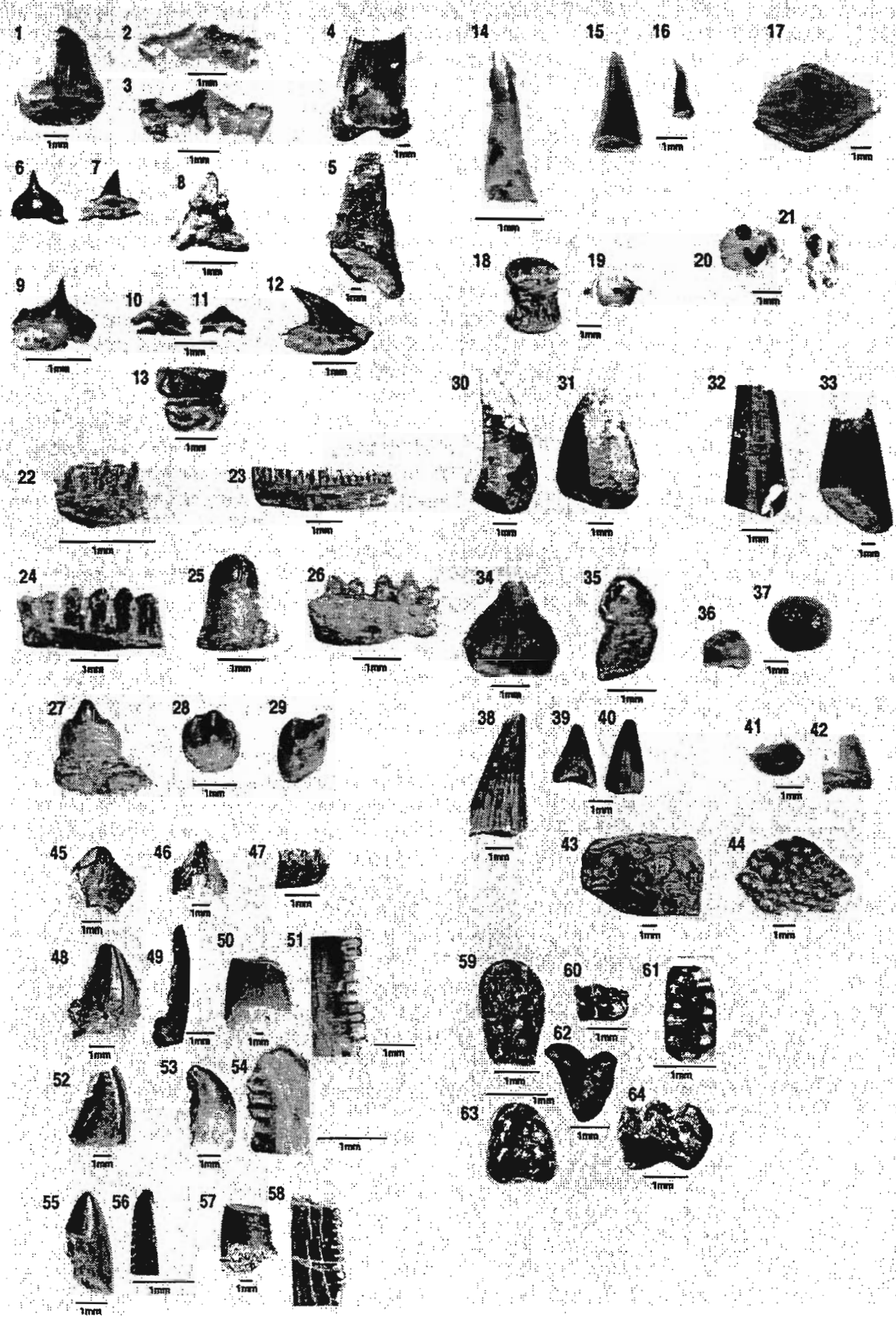
Big Bend is unique in several important ways. First, because Big Bend was relatively distant from uplands, the area had slower sedimentation rates compared to northern areas, resulting in condensed stratigraphic and faunal records (Lehman, 1991). Second, increased aridity, due to the retreat of the Western Interior Seaway and uplift of western mountains, occurred in Big Bend earlier than in the north and had an important influence on its paleocommunities. Evidence for aridity in the upper Aguja Formation of Big Bend include: 1) dinosaur bonebeds

that accumulated during periodic droughts severe enough to cause marshes to dry up (Davies and Lehman, 1989); and, 2) abundant channel lag deposits with carbonate-cemented and pedogenic nodule-rich conglomerates (Sankey, 1998; Schiebout et al., 1997) and burned wood (Sankey, 2005). In contrast, during the late Campanian in Alberta, the Dinosaur Park Formation was deposited within an extensive mesic coastal lowland (Eberth and Hamblin, 1993) and Alberta did not experience aridity until the late Maastrichtian (Brinkman, 2003).

Late Cretaceous vertebrate paleoecology in Big Bend has not been as thoroughly documented as in northern areas. However, the collection of numerous microfossil sites from the upper Aguja Formation is providing a more detailed picture of the vertebrate paleoecology during the late Campanian to mid-Maastrichtian. Many vertebrates that are common in Big Bend but rare or absent from contemporaneous northern assemblages probably reflect particular paleoclimatic and paleoenvironmental constraints. One example is the giant crocodylian, *Deinosuchus riograndensis*, which was common during the late Campanian in Big Bend, but was rare or absent in the north; this is striking in comparison with the abundance of small alligatoroids further north. Additionally, preliminary results indicate that dinosaurs in Big Bend were different from those found in the north, and may have been less diverse. Interestingly, the late Campanian Big Bend dinosaur assemblage was more similar to the Alberta dinosaur assemblage during the late Maastrichtian (Scollard Formation) in the following ways: *Richardoestesia isosceles* was more abundant than *R. gilmorei*; *Troodon* and *Dromaeosaurus* were absent or rare; and pachycephalosaurids were present (Sankey, 2001; Sankey et al., 2005).

Beginning in the late Campanian (~74 Ma), a cooling trend and corresponding drop in sea level caused changes in paleoenvironments and paleocommunities in the Western Interior of

Figure 3 (next page). Vertebrate taxa from the Talley Mt. sites. 1, *Hybodus* sp. (LSUMG 489:5627). 2-3, *Lissodus selachos*; 2, LSUMG 491:5965; 3, LSUMG 489:5692. 4-5, *Scapanorhynchus texanus*; 4, LSUMG 489:5626; 5, LSUMG 489:5666. 6-7, *Onchopristis dunklei* (LSUMG 489:5667). 8, *Ischyrbiza avoncola* (LSUMG 491:5977). 9, *Squatirhina americana* (LSUMG 489:5689). 10-11, *Ptychotrygon* sp. (LSUMG 489:5670). 12, Chondrichthyan dermal denticle (LSUMG 140:6163). 13, Dasyatidae (LSUMG 489:5648). 14, *Lepisosteus* complete tooth (LSUMG 488:5521). 15-16, *Lepisosteus* tooth caps; 15, LSUMG 140:6127; 16, LSUMG 140:6128. 17, Lepisosteidae scale (LSUMG 489:5732). 18-19, Indeterminate fish vertebrae (LSUMG 140:6144). 20-21, Phyllodontid tooth plates (LSUMG 489:5577). 22, *Albanerpeton* sp. maxilla, lingual view (LSUMG 491:5958). 23, *Scapberpeton* sp. dentary, lingual view (LSUMG 489:5694). 24, Glyptosaurinae indet., maxilla, lingual view (LSUMG 140:6106). 25, Teiidae-"Species B" (Miller, 1997), tooth (LSUMG 489:5656). 26, *Chamops* sp. mandible, labial view (LSUMG 140:6104). 27-29, *Peneteis* sp. nov., tooth, lateral and occlusal views (LSUMG 492:6253). 30-31, *Deinosuchus riograndensis* teeth; 30, LSUMG 489:5672; 31, LSUMG, 488:5484. 32-33, Goniopholid indet. Teeth; 32, LSUMG 489:5673; 33, LSUMG 489:5608. 34-37, cf. *Brachychampsia* sp. Teeth; 34, LSUMG 491:5621; 35, LSUMG 140:6125; 36-37, LSUMG 489:5658. 38-40, Crocodylian indeterminate type B teeth; 38, LSUMG 140:5564; 39-40, 489:5697. 41-42, Crocodylian indet. type A teeth; 41-42, LSUMG 488:5496. 43-44, Crocodylian indet. Scutes; 43, LSUMG 489:5582; 44, LSUMG 140:6136. 45, Hadrosaurid tooth, hatchling or juvenile (LSUMG 489:5538, occlusal view). 46, Ceratopsian tooth fragment (LSUMG 488:6230, occlusal view). 47, Tyrannosaurid tooth fragment, close-up of denticles (LSUMG 489:5580). 48-49, Pachycephalosauridae, lateral view and close-up (LSUMG 140:6117). 50-51, Undetermined family and genus, lateral view and close-up of denticles (LSUMG 488:5483); 52, *Saurornitholestes* cf. *S. langstoni*, lateral view (LSUMG 140:6139); 53-54, *Saurornitholestes* cf. *S. langstoni* unshed tooth, lateral view and close-up of denticles (LSUMG 489:5659); 55-56, *Richardoestesia isosceles* n. sp., lateral view and close-up of denticles (LSUMG 489:6238). 57-58, Undetermined family and genus, lateral view and close-up of denticles (LSUMG 489:6239). 59, *Cimolomys* sp. LM1 (LSUMG 489:5681). 60, *Mesodma* sp. anterior fragment, Lm1 (LSUMG 491:5779). 61, cf. *Cimexomyys* rm1 (LSUMG 140:6121). 62, cf. *Paracimexomyys* RM2 (LSUMG 491:5778). 63, cf. *Paracimexomyys* anterior fragment, PM3 (LSUMG 489:5684). 64, *Alphadon* cf. *A. halleyi* LM3 (LSUMG 492:6252).



North America (Barrera and Savage, 1999). During the Maastrichtian, two short greenhouse events occurred, corresponding to minor extinctions before the final K/T mass extinction (Nordt et al., 2003). What were the effects of these climatic changes on the vertebrate paleocommunities in Big Bend? Can climatically sensitive vertebrate groups be used, for example turtles and crocodylians, to track these changes? Future work in Big Bend will track paleocommunity changes corresponding with climatic and environmental changes through the section by making further collections from microsites and by analyzing associated paleosol carbonates. By studying the Big Bend area, relationships between vertebrates and climate may be identified that can be used to interpret climate in other areas.

Acknowledgments

Thanks to J. Schiebout and D. Brinkman. Financial support is appreciated from LSU; Dinosaur Society; Jurassic Foundation; U.S.-Canada Fulbright Program; South Dakota School of Mines and Technology; and California State University, Stanislaus. Fossils were collected under research permits, and the assistance of D. Corrick and V. Davilla of Big Bend National Park is appreciated. Thanks to students who assisted in the field and lab work. M. Eggart and L. Pond (LSU) made the figures.

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