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OCCASIONAL PAPERS OF THE
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LATE CRETACEOUS MAMMALS AND
MAGNETOSTRATIGRAPHY,
BIG BEND, TEXAS

By Julia T. Sankey¹

and

Wulf Gose²

The Aguja Formation, west Texas, contains some of the southernmost Late Cretaceous (late Campanian to early Maastrichtian) terrestrial vertebrates in North America (Lehman, 1982-1991; Miller, 1997; Rowe *et al.*, 1992; Standhardt, 1986; Sankey, 1998, 2001; Weil, 1992, 1999). Less is known about southern Late Cretaceous vertebrates, so new fossil faunas in this area are important, especially to determine differences with contemporaneous northern assemblages (Cifelli, 1995; Rowe *et al.*, 1992; Weil, 1992; 1999).

Mammals reported here are from the upper Aguja Formation near Talley Mountain (Mt.), Big Bend National Park, Texas. They include the multituberculates *Cimolomys* sp., *Mesodma* sp., cf. *Cimexomys*, cf. *Paracimexomys* and the marsupial *Alphadon* cf. *A. halleyi* and were associated with small bones and teeth from fishes, amphibians, turtles, lizards, crocodylians, and dinosaurs. Associated with the Talley

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Mt. fossil sites is a paleomagnetic section through the upper Aguja Formation. The section is tentatively correlated to Chron 32 (late Campanian to earliest Maastrichtian).

The Aguja Formation outcrops in and around Big Bend National Park, west Texas (Fig. 1). It contains 135 to 285 m of paralic and marine sandstones interbedded with shale and lignite, and it thins to the east (Fig. 2; Lehman, 1985). The upper shale member of the Aguja Formation represents the last 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 consists of carbonaceous mudstones, representing distributary channels, levees, crevasse splays, and poorly drained interdistributary marshes and bays. The upper part contains variegated mudstones and sandstones, representing fluvial environments in a deltaic coastal plain and inland floodplain (Lehman, 1985).

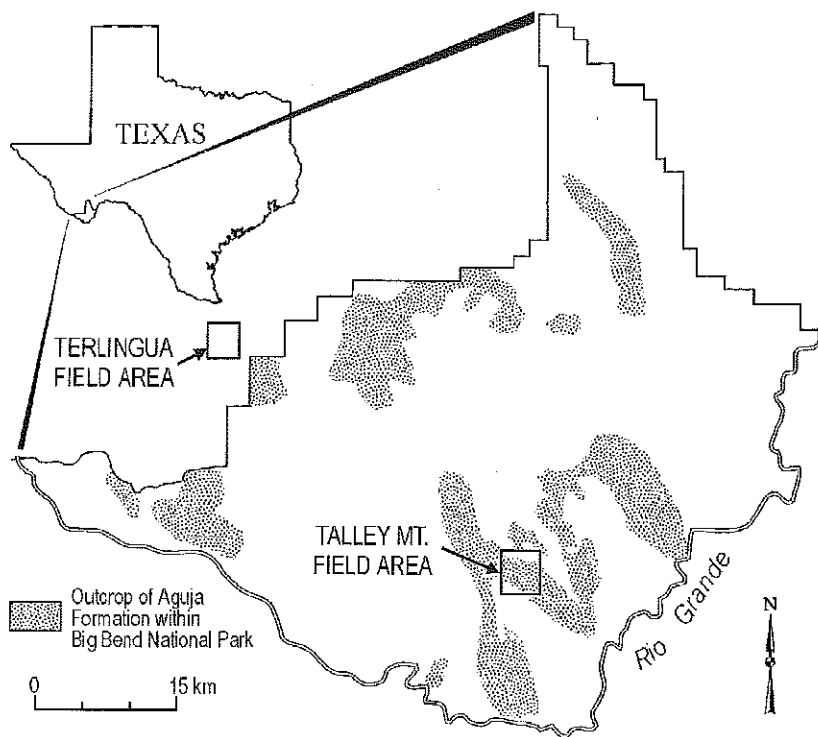


Figure 1. Map of Big Bend National Park, west Texas with Aguja Formation outcrops stippled. Talley Mountain and Terlingua fossil localities are shown by arrows.

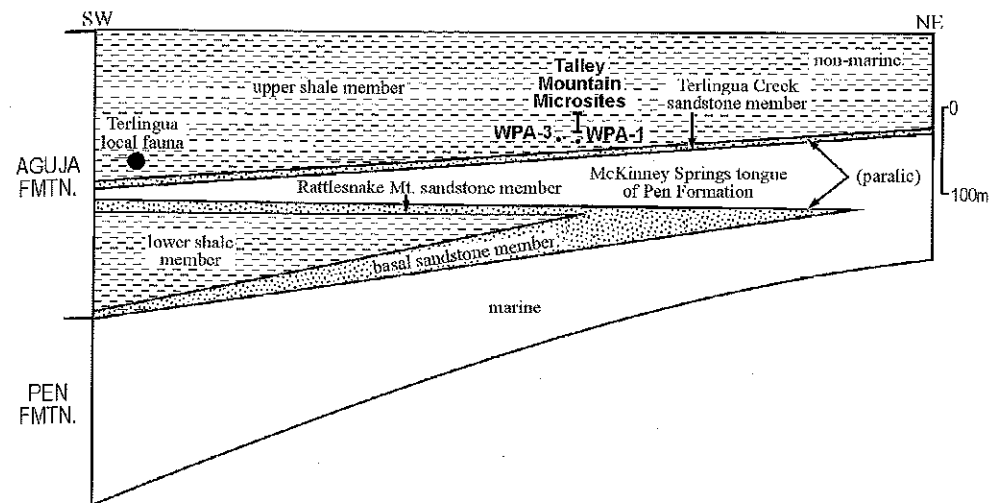


Figure 2. Aguja Formation stratigraphy modified from Rowe *et al.* (1992), showing positions of the Talley Mt. (Sankey, 1998) and Terlingua (Rowe *et al.*, 1992) microsities. Stratigraphic position of the Talley Mt. microsities and WPA quarries 1 and 2 (Work Progress Administration) from Lehman (1985; Plate III and written comm., 1998). Formal members of the Aguja Formation are capitalized; informal members are not.

In the Talley Mt. Area, outcrops of the upper shale member of the Aguja Formation produced the type specimen of the giant crocodylian *Deinosuchus riograndensis* (Colbert and Bird, 1954) and bonebeds of the horned dinosaur *Chasmosaurus mariscalensis* and the hadrosaur *Kritosaurus* sp, collected by crews from the WPA (Work Progress Administration). Deposits become more terrestrial upsection, from interdistributary marsh-bay facies at the base to inland floodplain facies at the top (Davies and Lehman, 1989; Lehman 1982, 1985).

This paper reports on the mammals from the Talley Mt. microvertebrate assemblage, an assemblage that has significantly increased the number of vertebrate taxa known from the Aguja deposits in this area.

Fossils were collected above the level of the WPA quarries, from five microvertebrate horizons spanning 20 m. Sampled horizons are carbonate-cemented, pedogenic-nodule, sandstone conglomerates containing numerous clasts of clay, pedogenic nodules, small vertebrate bones and teeth, and large fragments of wood and vertebrate bones and teeth. These are lag deposits from the base of fluvial channels that were deposited within a marshy floodplain. Large samples were collected (1753 kg) and broken down in a 25 percent solution of acetic acid. The resulting residue was washed through fine-meshed screens (USA Standard Screen, 30-mesh, with 1 mm

wide openings). The concentrate was picked for small fossils with the use of microscopes. Thirty eight taxa of fishes, amphibians, turtles, squamates, crocodylians, dinosaurs, and mammals were identified from small teeth and bones (Sankey, 1998; 2001). All fossils have been catalogued within the LSUMNS (Louisiana State University Museum of Natural Science), and detailed locality descriptions are on file there.

Abbreviations cited are: LSUMG, Louisiana State University Museum of Geoscience (a division of the LSU Museum of Natural Science), Baton Rouge, Louisiana; VL, vertebrate locality and V, vertebrate fossil specimen. A complete LSUMG catalog number for a vertebrate fossil includes both of these numbers, separated by a colon; for example, 488:5566. Often only the second number is used. UALVP, University of Alberta Lab for Vertebrate Paleontology. All measurements are given in millimeters (mm): AP, anteroposterior length and W, greatest width.

PALEOMAGNETICS

Oriented samples for paleomagnetic analyses were collected from the fine-grained sedimentary rocks along a 52-meter measured section through the lower portion of the upper shale member of the Aguja Formation in the Talley Mt. area. One to three samples (87 samples total) were collected at one meter intervals. Samples were progressively thermally demagnetized (nine steps, 150°C to 600°C), and measured in a cryogenic magnetometer at the Paleomagnetic Laboratory of the University of Texas at Austin.

Figure 3 shows examples of vector component diagrams for samples of normal polarity (Fig. 3A) and reversed polarity (Fig. 3B). All samples contain a component of magnetization which demagnetizes after heating to only 150°C. This magnetization is carried by goethite and is loosely aligned with the present geomagnetic field. This component is particularly apparent in the reversely magnetized samples (Fig. 3B). The characteristic direction of magnetization was typically revealed over the temperature range from 300°C to 550°C. Upon exceeding the magnetite Curie point of 580°C, the samples lost virtually all the remanence, implying that magnetite is the dominant magnetic mineral. This lends support to the interpretation that the characteristic magnetization is a primary detrital remanence.

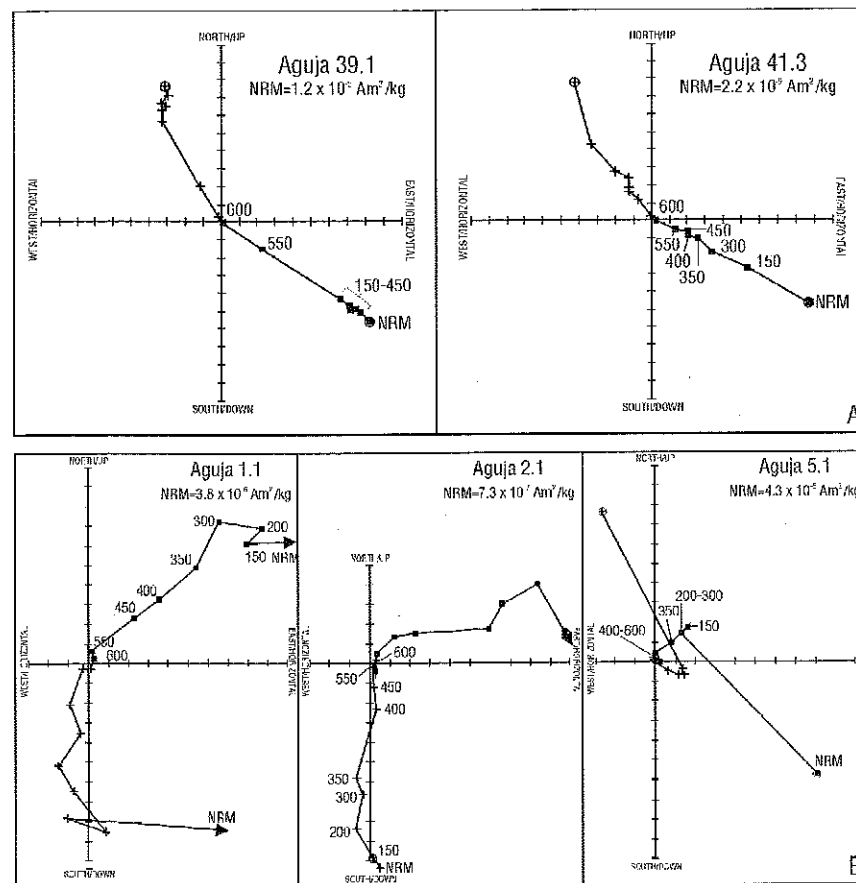


FIGURE 3. As-Zijderveldt diagrams for two samples of normal polarity. Crosses are the projection of the magnetic vector onto the North-East-South-West plane and solid circles are the projection onto the Up-Down-Horizontal plane. The scale is given below the sample number. The demagnetization steps are indicated in degrees C. B. As-Zijderveldt diagrams for three samples of reversed polarity.

The data were analyzed by the principal component method (Kirschvink, 1980). Most samples gave good results with MAD values (mean angular deviation) of typically less than 10°. However, the directions of samples of the same stratigraphic level often differed by tens of degrees and in a few cases up to 90°. The results of multiple samples at a given stratigraphic level were combined into site means and are plotted against their stratigraphic position in figure 4A.

Assigning polarity zones is straightforward in some parts of the section (the top and bottom) but speculative in others (the middle part of the section). Correlation of this reversal sequence with the geomagnetic polarity time scale is not possible

based on the magnetic data alone. Besides ambiguities in the polarity assignment, the section is too short to yield an identifiable signature. However, the fossil record constrains the age of the section sufficiently well that we feel a tentative correlation is possible (Fig. 4B).

Time constraints from the fossil record are:

1) The marine Terlingua Creek sandstone member of the Aguja Formation, which underlies the upper shale member, is middle Campanian in age (Lehman, 1985; Rowe *et al.*, 1992). Of particular importance is the presence within this unit of *Baculites maclearni* (Rowe *et al.*, 1992), a zonal index fossil for the middle Campanian, with a duration of approximately 79.6 to 80.2 Ma (Obradovich, 1993).

2) Western-most outcrops of the lower portion of the upper shale member of the Aguja Formation are middle Campanian based on mammals from Terlingua (Cifelli, 1995; Rowe *et al.*, 1992; Weil, 1992, 1999). Although the Talley Mt. microsites produced few mammals, one (V-6252; fig. 5F) is tentatively referred to *Alphadon cf. A. halleyi*, a cosmopolitan marsupial characteristic of Judithian (North American Land Mammal 'Age') faunas (Lillegraven and McKenna, 1986), and also found from Terlingua (Rowe *et al.*, 1992). The known range of the Judithian is approximately 5 million years, from ~75 to 78 (Goodwin and Deino, 1989) or ~74 to 79 Ma (Lillegraven and McKenna, 1986).

3) The uppermost part of the upper shale member is early Maastrichtian, based on vertebrates, especially mammals and limited magnetostratigraphy (Lehman, 1985, 1989, 1990; Standhardt, 1986).

These three points constrain the magnetostratigraphic correlation from late Campanian to early Maastrichtian. Based on the two reversed zones, correlation to Chron 32 is the most likely, making the microvertebrate sites approximately 71 to 75 Ma.

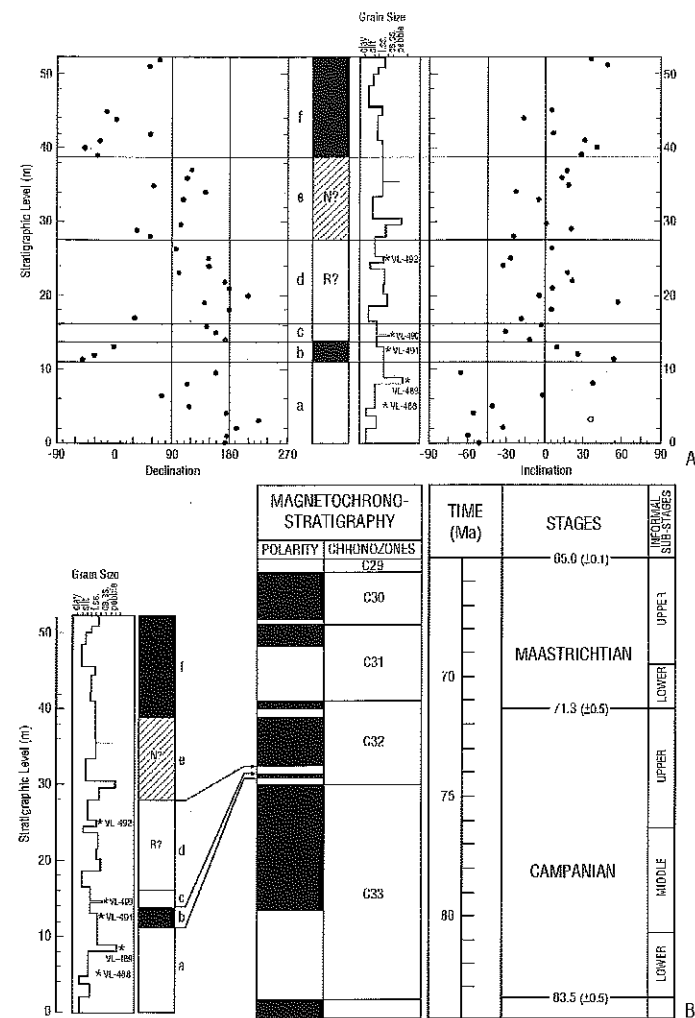


Figure 4. A. 52-meter Talley Mt. magnetic polarity sequence from the lower part of the upper shale member of the Aguja Formation. Site averages of declination and inclination (based on the high temperature component characteristic direction) were calculated using Fisher statistics. These data were plotted (dots) against elevation and the polarities were interpreted (center column). Polarity zones are labeled, a-f, and are shown in black, normal polarity; white, reversed polarity; R?, probable reversed polarity; and N?, probable normal polarity. Lithologic section with position of conglomeratic samples (VL-488 to 492) is also shown. B. Tentative correlation of the Talley Mt. magnetic polarity sequence to the geomagnetic polarity time scale (Gradstein *et al.*, 1995). The two reversed polarity zones in the Talley Mt. section are tentatively correlated to the base of C32.

Mammalian Paleontology
Order MULTITUBERCULATA

Family Neoplagiulacidae

MESODMA Jepsen, 1940

MESODMA sp.

Figure 5B

Referred Specimen.--LSUMG 491:5779.

Description.--V-5779 is a Lm1 (anterior fragment). W, 0.70 mm. Cusps well separated, crescentic-pyramidal, and robust; square-shaped cusp bases; third cusp on lingual side slightly recurved posteriorly; first external cusp is the smallest; and a small pocket is present at the base of anterior-most cusp on the labial side.

Discussion.--Isolated mls of *Mesodma primaeva* and *Cimolomys clarki* have similar cusp numbers and tooth lengths, and were considered indistinguishable (Sahni, 1972; Montellano, 1992). However, cusps in *M. primaeva* are more crescentic-conical in shape and the postermost internal row cusps are more blade-like (Eaton, 1987). V-5779 fits this description, and is referred to *Mesodma*. Rowe *et al.* (1992) also mention that tiny molars from Terlingua may be from *Mesodma*.

Family CIMOLOMYIDAE

CIMOLOMYS Marsh, 1889

CIMOLOMYS sp.

Figure 5A

Referred Specimen.--LSUMG 489:5681.

Description.--V-5681 is a worn LM1 with a 5:6:4 cusp count. AP (anteroposterior length), 2.15 mm; W (greatest width), 1.45 mm. Cusps are square in outline; striations present at base of cusps in medial cusp row; long third cusp row, extending halfway past fourth cusp of medial row.

Discussion.--V-5681 resembles specimens of *Cimolomys clarki* from Terlingua (Weil, 1992; fig. 5A): strong striations at base of cusps; external cusp row extends to fourth cusp of medial row; and cusps well separated from each other. However, V-5681 is half their size.

Family, *incertae sedis*

CIMEXOMYS Sloan and Van Valen, 1965

CIMEXOMYS sp.

Figure 5C

Referred Specimen.--LSUMG 140:6121.

Description.--V-6121 is a right lower first molar. AP, 1.51 mm; W, 0.81 mm. Cusp count is 4:3. There is a large U-shaped valley between the two cusp rows; internal row cusps are higher than external row cusps; transverse valley deepest between second and third cusps on internal cusp row; and tooth is not waisted.

Discussion.--V-6121 is referred to *Cimexomys* because it is small, is not waisted, cusps are more erect than crescentic, and it has a deep transverse valley. It is similar to teeth from Terlingua that were referred to *Paracimexomys* (Weil, 1992: fig. 7A), but now referred to *Cimexomys* (A. Weil, pers. comm., 1998). V-6121 is similar to *C. antiquus* from the Milk River Formation, Alberta (UALVP 5396), but V-6121 is smaller, has fewer cusps, and has a more U-shaped valley.

Family, *incertae sedis*

PARACIMEXOMYS Archibald, 1982

cf. *PARACIMEXOMYS*

Figure 5D and E

Referred Specimens.--LSUMG 489:5684; 491:5778.

Description.--V-5778 is a worn right M2. AP, 1.22 mm; W, 0.93 mm. It has a low cusp count (1:2:3), strong diagonal valley, two central cusps, and an internal row containing three cusps with third cusp offset from others. Tooth is waisted at base of third cusp on internal row and between the two cusps on the median row. Cusps are pyramidal and subcrescentic and pointed slightly anteriorly. V-5684 is a worn PM3 (anterior fragment) with L shaped cusp rows.

Discussion.--Both teeth are tentatively referred to *Paracimexomys* because they are waisted.

Order MARSUPIALIA

New taxon A Johanson, 1996

ALPHADON s.s. Simpson, 1927

ALPHADON sp.

Referred Specimens.--LSUMG 492:6252; 489:5679.

Description.--V-6252 is a left M3. AP, 1.80 mm; W, 1.86 mm. V-5679 is a M2 (anterior fragment).

Discussion.--V-6252 is similar to *Alphadon halleyi* (Sahni, 1972) from Terlingua (OMNH 22726; fig. 5A, Cifelli, 1995), and is considerably smaller than *A. russelli* (Fox, 1979) and *A. praesagus* (Russell, 1952) (UALVP collections). V-5679 is too fragmentary for further identification.

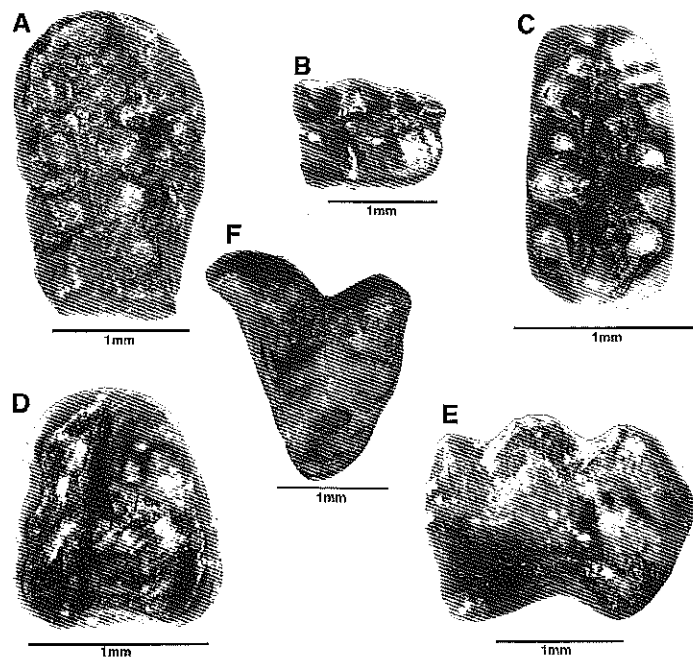


Figure 5. Mammal teeth from the Talley Mt. microsities (occlusal views). Multituberculates (A-E): A. *Cimolomys* sp. LM1 (LSUMG 489:5681); B. *Mesodma* sp. anterior fragment, Lm1 (LSUMG 491:5779); C. cf. *Cimexomys* rm1 (LSUMG 140:6121); D. cf. *Paracimexomys* RM2 (LSUMG 491:5778); E. cf. *Paracimexomys* anterior fragment, PM3 (LSUMG 489:5684); Marsupial: F. *Alphadon* cf. *A. halleyi* LM3 (LSUMG 492:6252).

DISCUSSION

The Terlingua is an extremely rich microvertebrate site from the Aguja Formation. It was deposited in an estuarine setting (Weil, 1992), and has produced more specimens and numbers of taxa than any other microsite in the Aguja (Cifelli, 1995; Miller, 1997; Rowe *et al.*, 1992; Weil, 1992).

The Talley Mt. microvertebrate assemblage has produced fewer specimens and numbers of taxa, and is from fluvial channels within a marshy floodplain. Taxo-

the Talley Mt. assemblage, which contains fewer fish and other specimens of aquatic taxa than the Terlingua fauna, was probably a slightly more inland assemblage. Despite the different depositional environments for the Terlingua and Talley Mt. microsities, their assemblages are similar, confirming the uniqueness of the Aguja fauna.

Southern areas like Big Bend may have had seasonally severe dry conditions in the Late Cretaceous, with more sporadic river flow making burial of fossils a rarer phenomenon in this area. For example, Davies and Lehman (1989) suggested that the Aguja Formation dinosaur bonebeds in the Talley Mt. area may have resulted from periodic droughts, severe enough to cause the marshes to dry up. Such seasonally extreme dry conditions, when paleocaliche could form in soils, would explain the presence of numerous carbonate-cemented and pedogenic nodule rich conglomeratic channel lag deposits in the Aguja, such as those collected in the Talley Mt. area. These conglomeratic deposits may have formed during heavy rainstorms when soil and vertebrate bones were transported and deposited in streams, possibly even in flash flood-like conditions (Sankey, 1998).

This paleoenvironmental and paleoecological picture for the Aguja differs from that of more northern areas, such as the Judith River Group of Alberta and Montana, which is approximately contemporaneous. For example, the late Campanian Dinosaur Park Formation (upper Judith River Group), an extremely fossil-rich unit, has produced approximately 300 species of plant and animal fossils including many articulated or associated dinosaurs (Eberth, 1996). The Dinosaur Park Formation was deposited by a high-sinuosity fluvial system in the extensive coastal lowland adjacent to the Cretaceous Western Interior Seaway (Eberth and Hamblin, 1993). Considerably higher sedimentation rates and rates of fossil burial in this area now yield richer fossil assemblages compared to southern areas.

The Talley Mt. and Terlingua assemblages are both from the lower part of the upper shale member of the Aguja, and both are probably late Campanian to early Maastrichtian. Determining which assemblage is older or younger is not possible with the information available. However, both assemblages are probably Judithian in age because *Alphadon halleyi*, a cosmopolitan marsupial characteristic of the Judithian (Lillegraven and McKenna, 1986) has been recorded from the Terlingua and tentatively recorded from the Talley Mt. assemblages.

The type Judithian NALMA fauna is from the Judith River Formation of Montana (Sahni, 1972), but Judithian faunas are also known from the Oldman Formation, Alberta; Judith River Formation, Montana; and 'Mesaverde' Formation, Wyoming (Lillegraven and Ostresh, 1990). The known range of the Judithian is approximately five million years. In Judithian faunas, multituberculates dominated (cimolodontans, Cimolomyidae, Neoplagiaulacidae, *Paracimexomys*, and *Cimexomys*); metatherians were less abundant; and eutherians were rare (Lillegraven

Late Cretaceous NALMAs are based on faunas from the northern and central Western Interior (Lillegraven and McKenna, 1986), and their utility is limited outside of these areas (Weil, 1999). Difficulty in correlations is due to paleoenvironmental differences among Late Cretaceous faunas, for example coastal vs. inland (Sankey *et al.*, 1999) and north vs. south (Weil, 1999). Late Cretaceous bioprovinciality has also been documented for dinosaurs (Lehman, 1987; 1997; Sankey, 2001).

Because southern Late Cretaceous mammalian faunas are distinct and correlations to NALMAs are difficult (Weil, 1999), better independent age control for southern faunas is particularly important. The mammals and magnetostratigraphy reported here provide additional paleontologic and chronologic information for the Aguja Formation. However, additional efforts need to be made in Big Bend, especially to recover and date larger samples of mammals and other vertebrates.

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