THE STRATIGRAPHIC POSITION OF FOSSIL VERTEBRATES FROM THE POJOAQUE MEMBER OF THE TESUQUE FORMATION (MIDDLE MIOCENE, LATE BARSTOVIAN) NEAR ESPAÑOLA, NEW MEXICO

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THE STRATIGRAPHIC POSITION OF FOSSIL VERTEBRATES FROM THE POJOAQUE MEMBER OF THE TESUQUE FORMATION (MIDDLE MIocene, LATE BARSTOVIAN) NEAR ESPAÑOLA, NEW MEXICO

By

GARRETT ROSS WILLIAMSON, B.S.

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Stephen F. Austin State University

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THE STRATIGRAPHIC POSITION OF FOSSIL VERTEBRATES FROM THE POJOAQUE MEMBER OF THE TESUQUE FORMATION (MIDDLE MIOCENE, LATE BARSTOVIAN)
NEAR ESPAÑOLA, NEW MEXICO

By:

Garrett Ross Williamson, B.S.

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ABSTRACT

The stratigraphy of the Pojoaque Member of the Tesuque Formation near Española, NM is not well understood. This region, during the Middle Miocene, represented a dynamic alluvial fan-fluvial-lacustrine environment within the Española Basin while the Rio Grande Rift was active. Cavazza (1986) identified two paleodrainage systems (lithosome A, basin-margin facies and B, basin-floor facies) by means of sandstone and conglomerate petrology, paleocurrent, and sedimentary facies analyses. After x-ray diffraction analyses of claystones within lithosome B, mordenite was discovered, which is a zeolite mineral commonly found within volcanic rocks. This is significant because the presence of mordenite confirms Cavazza’s (1986) conclusion that lithosome B was sourced by the Taos Plateau–Latir volcanic fields.

The objective of this study was to identify the stratigraphic position of vertebrate fauna of the Pojoaque Member of the Tesuque Formation using known fossil locality data, newly discovered fossil locality data, and measured sections of the Pojoaque Member. A faunal list was compiled that incorporates all vertebrates that have been taxonomically described from the Pojoaque Member, as well as first appearance datum. Two new vertebrate species were also described.
Fossils discovered within the Pojoaque Member are almost exclusively found within relatively thin (0.5–3 m) maroon-red and pale green claystone to fine-grained siltstone beds of lithosome B which were concluded to likely be small lacustrine deposits.

Unfortunately, it was not common practice for early paleontologists to record specific geographic locations of fossils. Therefore, this study was restricted to relatively recently published paleontological data, fossils discovered during this study, and coarse stratigraphic ranges of common fossil collecting localities to identify the stratigraphic positions of the fossil specimens. Many previous explorations recorded fossils singly from the Santa Cruz Red bed; in reality, there are multiple red horizons. Seven stratigraphic transects were measured across eight sections in the Española Basin. Examinations of the stratigraphic distribution of these fossiliferous beds have led to the conclusion that the Santa Cruz localities span the entire member. It was also concluded that making lithostratigraphic correlations within the Pojoaque Member across the Española Basin would be difficult, if not impossible, on account of the variability of the lithology.
I would first like to thank my thesis advisor Dr. LaRell Nielson of the Geology Department at Stephen F. Austin State University. He consistently allowed this thesis project to be my own work and allowed me to research any topics I so desired.

Besides my advisor, I would like to thank the rest of my thesis committee: Dr. Kevin Stafford, Dr. Timothy Walsh, and Dr. Stephen Mullin, for their insightful comments and encouragement. They always greeted any questions or problems that I had with my research.

I would also like to thank Phil Gensler from the Bureau of Land Management (BLM) for assisting me in acquiring a permit to collect vertebrate fossils on BLM lands. Phil introduced me to Gary Morgan (paleontologist: New Mexico Museum of Natural History and Science) who aided in fossil identifications. Both Phil and Gary showed me around the study area, recommended good spots to camp, and took me to their fossil collecting localities. Without their guidance and input, much more time would have had to be dedicated to finding a way onto the land, locating fossil bearing strata, and identifying fossils.
I thank my friends within the geology department for the simulating discussions, for their support and reassurances, and for all the fun we have had in the last two years.

Lastly, I would like to thank Dr. Tim Walsh of the Geology Department at Wayland Baptist University. Along with volunteering to spend three weeks me in the field and providing outstanding feedback on my thesis edits, he agreed to serve as a committee member on my thesis. Without his constant guidance and passion, I would not be the geologist that I am today.
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INTRODUCTION

In 1874 and 1875, Professor of Anatomy at the University of Pennsylvania Edward D. Cope, a pioneer of American vertebrate biology, first documented the vertebrate paleontology of the Española Basin (Cope, 1874; Cope, 1875b) (Fig. 1). Later, Falkenbach and Simpson's exploration produced a complete skeleton of the “bear-dog” *Hemicyon* (Frick, 1926a) among various other fossil vertebrates. As a result, new explorations within the Española Basin transpired yearly over the following 40 years funded by Childs Frick, heir to part of the Carnegie steel industry. The Frick Laboratory funded these expeditions to enhance the research collections of the American Museum of Natural History (AMNH). This institution holds at least 20,000 “major skeletal elements” from the Española Basin (Aby et al., 2011). This collection includes mostly isolated bones or

Figure 1. The extent of the Española Basin. The red box outlines the study area (modified from Sawyer, 2004).
skeletons, but there were more than a dozen dense concentrations of several
distinct animals that were discovered and quarried (Kues et al., 1979). In 1935 and
1936, the largest of these dense concentrations was discovered on the south side of
the town of Round Mountain, NM (Fig. 2).

The individuals who continued research on New Mexican vertebrates
were Childs Frick, his personal assistant Beryl Taylor who focused
his research on camels, carnivores, mastodons and ruminants, Charles
Falkenbach who focused his research on oreodonts, Morris Skinner who
focused his research on horses and rhinos and Theodore Galusha who
focused on the geology (Tedford et al., 1997). The death of Frick in 1965 led
to the conclusion of the AMNH explorations into the Española Basin
and in 1968 his collections, which

Figure 2. Location of the exposures (dashed line) and the area where most of the fossils have been discovered within the Española Basin. Red box outlines study area (adapted from Kues et al., 1979).
included over 20,000 fossil mammals, were donated to the museum. It was 13 years after the conclusion of the AMNH explorations when, in the summer of 1978, a University of New Mexico survey was conducted of areas around Española that revealed there were still skeletal remains surfacing (Kues et al., 1978). In recent years, the New Mexico Museum of Natural History and Science has conducted numerous paleontological expeditions to the Española Basin collecting hundreds of vertebrate fossils.

Although the fauna of the Española Basin have been known for more than a century, only recently (since the 1980s) have the importance and diversity of these faunal assemblages been appreciated, and their placement in absolute geologic time been attempted. The basin-fill sediments of the Española Basin are classified as the Santa Fe Group. In the study area, these sediments have been subdivided to consist of the Tesuque Formation which includes six members (Nambé, Skull Ridge, Pojoaque, Chama-el Rito, Ojo Caliente, and Cejita; Fig. 3). This study attempts to derive the stratigraphic position of vertebrate fauna within the highly fossiliferous Pojoaque Member.
Research Area

Permission was authorized for this study by the United States Department of the Interior Bureau of Land Management, allowing surface collection of paleontological resources from 30 June 2015 to 31 December 2016. The location of authorized paleontological fieldwork included the Santa Fe Group deposits in the Española Basin within the BLM Taos field office administrative area, including the Sombrillo ACEC (Area of Critical of Environmental Concern; Fig. 4). The study area lies within the Española Basin, which is a segment of the Rio Grande Rift that is
bound by the Jemez Mountain volcanic field to the west and the Sangre de Cristo Mountains to the east (Fig. 1).

During field work, vertebrate fossils were collected from Arroyo del Llano or First Wash, Arroyo de Quarteles or Second Wash and Arroyo de la Morada or Third Wash. Within older publications, such as Galush and Blick (1971), arroyos are referred to as washes. This study surveyed and collected fossils within the sections to the east and southeast of the Ohkay Owingeh Pueblo (formerly known as San Juan Pueblo) land grant. These sections include: sections 27, 28, 29, 30 (part), 31 (part), 32, and 33; T21N, R9E (Fig. 5). The closest town is Española, NM, which has a semi-arid high desert (~1713 m) climate with temperatures ranging from 10–32°C in the summer months. According to the National Centers for Environmental Information (NOAA), the study area receives an average of 4.3 cm of rainfall during July, the time field work was conducted, and an average annual rainfall of 28.98 cm. Elevations that exist over the study area range from approximately 1798 m above mean sea level in section 31, which is found within the southwestern portion of the study area, to approximately 1921 m above mean sea level in section 28 in the northeastern part of the study area.
Figure 4. The permitted area includes all of the Santa Fe Group deposits in the Española Basin within the Bureau of Land Management (BLM) Taos Field Office administrative area, including the Sombrillo Areas of Critical Environmental Concern (ACEC).
Figure 5. Study area (outlined in black) within section 27, 28, 29, 30 (part), 31 (part), 32, 33, and 34 (part); T21N, R9E.
PURPOSE OF STUDY

Much of the precise location data for the Española Basin fossils held by the AMNH was either not collected, been lost, or has not been retrieved from the archived field notes of the early collectors (only ~30% of the specimens from that site have been formally catalogued; Kues et al, 1979; Aby et al., 2011. Unfortunately, it was not customary in the past to specifically designate fossil localities or to put the fossils in the proper stratigraphic framework. Although the early paleontologists were able to taxonomically identify many Miocene mammals, their “harvesting” of the fossils cannot be put into a biostratigraphic framework. Further paleontological explorations into the Española Basin must be conducted in order for future paleontologists to extend our knowledge of the population structure and intraspecific variability of the diverse and abundant organisms that lived in the Española Basin during the Miocene Epoch.

Galusha and Blick (1971) emphasizes the importance of active and sustained field work in old and new localities by referencing the discovery of the first Hemicyon, by Simpson and Falkenbach, ever documented in the Santa Fe area (Frick, 1926b). “For only by the continued collection of the remains of the life of the past, as brought to the surface through the seasonal erosion of ancient accumulations of sand and clay, data available today and gone forever tomorrow, may we learn the
history of nature’s course in the production of existing forms, of those that were in the broad sense ancestral to the faunas of today, and of those strange and unthought of forms that predominated in and vanished with the faunas of the past” (Galusha and Blick, 1971: 24).

Several problems exist with current understanding of the stratigraphy found in the Pojoaque Member: (1) as a result of the large size of this member, previous authors, such as Koning and Manley (2003), lump the many different lithologies into lithosome A, lithosome B and a mixed zone of lithosome A and B, which makes it difficult to pinpoint the exact stratigraphic position of the fauna; (2) there are numerous mudrock deposits that are not laterally extensive, rendering previous measured sections, including the type section of this member, undependable. The fossils from the New Mexico Museum of Natural History and Science in Albuquerque have location data and lithology data with almost all of their fossil specimens, but there are many of the same lithologies that are repeated in this member requiring a stratigraphic study of this member to determine the stratigraphic position of the fossils.

Sections 19 (part), 20, 29 and 30 (part) were targeted for this study because they are in danger of being involved in a land trade between the state of New Mexico and the Ohkay Owingeh Pueblo (Fig. 5). Access to the fossils that are eroding out of
the rock within these areas may be lost to scientific scrutiny and be left to be destroyed by the elements if the trade occurs.
METHODS

Field Methods

A literature search was conducted before heading into the field to determine the different properties of the Pojoaque Member as well as the contacts between the underlying Skull Ridge Member and the overlying Cejita Member. The majority of the time in the field was spent collecting fossil specimens and measuring stratigraphic sections of the Pojoaque Member to be able to better understand the stratigraphy as well as place the fossil specimens in a stratigraphic column. The Jacobs Staff was set to a height of 150 cm and the dip of the strata was acquired by using a Brunton compass. Once the beginning of a measured section was chosen, geospatial coordinates were taken (Trimble Nomad handheld computer; ±3 m; GSP datum = NAD83) at that location and it was also notated on a topographic map. As the thickness of each stratum was being measured, the lithology, color, and any noticeable features were described.

The remaining time was spent prospecting for fossils where microsites and single excavation sites were found. A special permit would have been needed if a site was found that required quarrying, but no such site was discovered. Once a site was found, traditional excavation and transportation methods were used. When a microsite was discovered, the noticeable fossils were collected off of the surface first
followed by recovery of sediment from the microsite for screen-washing. When a single excavation site was discovered, a jacket was created in order to stabilize the specimen for transport back to the lab for preparations (Fig. 6). The jacketing process has several steps which include: (1) trenching – a trench must be dug in order to define the boundaries for the jacket; (2) pedestalling – once the trench is dug around the area of the fossil, the base of the rock must be thinned in order to flip and remove the jacket; (3) applying a separator – this step includes applying

Figure 6. GRW2015-12 being excavated. This picture represents the specimen being trenched around and pedestaled before being jacketed. A separator has been applied in the form of toilet paper and aluminum foil.
damp toilet paper or paper towel as well as aluminum foil to protect the fossil from becoming attached to the jacket; (4) jacketing – this step strengthens and protects the fossil for transport. Depending of the size of the jacket, duct tape or plaster of paris may be used to stabilize the fossil. Usually smaller fossils only require duct tape and larger fossils require a stronger method such as plastering. When applying a plaster jacket, burlap is cut into strips and placed into wet plaster. The plaster soaked burlap strip is then applied to the separator as tightly as possible. Many layers may be needed depending on the size of the jacket; (5) burnishing – to prevent sharp edges, additional layers of wet plaster must be applied to the jacket to smooth out those edges; (6) flipping – once the top of the jacket is dry, then the jacket can be flipped, which, depending on the size of the jacket, can be very difficult and require a variety of tools such as rock hammers, picks, shives, wooden poles and bare hands. After the jacket has been flipped over, the underside that is now exposed must then be jacketed; (7) transport – once the jacket is completely dry, it must now be carried to a vehicle to be transported back to the lab for preparations.

Laboratory Preparations

Many of the fossils collected were not complete and had been broken up into numerous pieces. Once pieces of the fossil have been identified to fit each other and the matrix, if any, has been removed from the surface, the pieces of the specimen
were glued together using Vinac resin as recommended by the New Mexico Museum of Natural History and Science. If matrix is present on a specimen, it was removed using various sized and angled picks.

Fossil Locality Data

The New Mexico Museum of Natural History and Science provided four excel spreadsheets with fossil locality data along with a description of the lithology that the fossil was found within, whether or not the fossil was found in situ or as float, the general location and any other notes describing what was found. The fossils that were collected were cataloged using Microsoft Excel along with the appropriate data associated with each fossil specimen. The New Mexico Museum of Natural History and Science used a variety of GPS units that were all set to NAD83 with horizontal accuracies within several meters when collecting fossil locations. The points collected during field studies were acquired using a Trimble Nomad handheld computer in latitude and longitude values DMS (degrees, minutes, seconds). All of the coordinates were converted to the Universal Transverse Mercator (UTM) North American Datum of 1983 (NAD83) coordinate system.

Geographic Information System (GIS)
The aforementioned spreadsheet generated with spatial and attribute data, which are the two components of geographically referenced information, were transferred into ArcGIS 10.3 to graphically ascertain the exact original location of each fossil specimen that was collected. These localities, which are vector points, were overlaid onto geologic and topographic maps of the study area. The geologic maps (Koning 2003; Koning et al., 2003) and topographic maps were already been digitized and georeferenced. This map that was generated is not included in this thesis because specific fossil localities on public lands cannot be released. The New Mexico Museum of Natural History and Science will receive all of the fossil locality data.

**Stratigraphic Identification of Fossils**

The bulk of the fossils from the Pojoaque Member were collected before the 1960s, at which time it was not common practice to identify the location of fossils collected stratigraphically. A large number of fossil locations described fossils as coming from the Santa Cruz Red Bed. During field studies, numerous fossiliferous red beds were found throughout the Pojoaque Member, so it was impossible to discern the exact stratigraphic location of the fossils from the older collections. Figure 57 was modified from Barghoorn (1985: Fig. 26) to depict the stratigraphic equivalencies of commonly used collecting localities. Figure 57 had to be modified.
to include the Cejita Member as well as include five subdivided units of the Pojoaque Member from Aby et al. (2011). Appendix 3 includes this figure as well as a list of fossil collecting localities and what specimens were collected from those localities. Stratigraphic locations of fossils collected within this study are found within the stratigraphic columns of Appendix 1.

**X-ray Powder Diffraction Analysis**

To be able to identify the depositional environment of the fossiliferous maroon-red and pale green strata, as well as the unfossiliferous reddish brown beds of lithosome B, 3 samples of each bed were collected for X-ray powder diffraction analyses (XRD). The samples were prepared for testing by pulverizing using a porcelain mortar and pestle (Fig. 7-A). Once the sample was pulverized, the sediment was run through a 35 mesh (500 micron) sieve (Fig. 7-B) and approximately 2 grams were collected for analysis (Fig. 7-C). The samples named FMR-01, FMR-02, and FMR-03 originated from the fossiliferous maroon-red beds; samples FG-01, FG-02, and FG-03 originated from the fossiliferous green beds; and samples UFR-01, UFR-02, and UFR-03 originated from the unfossiliferous red beds. These 9 samples were sent to the department of chemistry and biochemistry at Texas Tech University for XRD analyses.
A total of 29 fossil samples, many containing multiple different vertebrates, were collected during the summer of 2015 (Table 1). Part of this study includes the taxonomic identification of select bones that are taxonomically significant. Six fossils within the 29 samples were taxonomically identified which include: a horn core within GRW2015-02; a horn core within GRW2015-13; the forelobe of a
plastron of “black turtle” within GRW2015-14; both right and left horn cores within GRW2015-19; the distal portion of a humerus within GRW2015-23; and the left mandible absent teeth within GRW2015-24.

The three individuals (GRW2015-02, GRW2015-13, and GRW2015-19) were identified based on morphological characteristics of the antilocaprids found within the Pojoaque Member such as, where, if present, the burr is located on the shaft or how high on the shaft do the points start to split. Frick’s (1937) study provided systematic descriptions of antilocaprids which was used to taxonomically identify these specimens. Once the specimens were identified based on Frick’s (1937) systematic paleontological descriptions, Davis (2007) re-evaluated the genera updated taxonomic identifications. Because the points of all three horn cores were absent, the specimens were classified to genus.
<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Date</th>
<th>In Place?</th>
<th>General Area</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRW2015-01</td>
<td>7/1/2015</td>
<td>Surface</td>
<td>Second Wash</td>
<td>Juvenile Merycodus? Jaw fragment, frog bones, misc. small mammal bones</td>
</tr>
<tr>
<td>GRW2015-02</td>
<td>7/1/2015</td>
<td>Surface</td>
<td>Second Wash</td>
<td>Horn core (Cosoryx) with skull fragment attached and a tooth fragment. Bone have red mud on them.</td>
</tr>
<tr>
<td>GRW2015-03</td>
<td>7/1/2015</td>
<td>Surface</td>
<td>First Wash</td>
<td>Rabbit p3 and astragales</td>
</tr>
<tr>
<td>GRW2015-04</td>
<td>7/1/2015</td>
<td>Surface</td>
<td>Second Wash</td>
<td>Horse tooth fragments, metatarsal (toe bone) and jaw fragments</td>
</tr>
<tr>
<td>GRW2015-05</td>
<td>7/2/2015</td>
<td>Surface</td>
<td>Second Wash</td>
<td>Camel? Jaw. Lots of fragments found in this area</td>
</tr>
<tr>
<td>GRW2015-06</td>
<td>7/3/2015</td>
<td>Surface</td>
<td>Second Wash</td>
<td>Turtle shell and oreodont? toe bone</td>
</tr>
<tr>
<td>GRW2015-07</td>
<td>7/3/2015</td>
<td>Surface</td>
<td>Second Wash?</td>
<td>Jaw fragment and end pieces of limbs</td>
</tr>
<tr>
<td>GRW2015-08</td>
<td>7/7/2015</td>
<td>Surface</td>
<td>First Wash</td>
<td>End piece of limb and shards</td>
</tr>
<tr>
<td>GRW2015-09</td>
<td>7/9/2015</td>
<td>Surface</td>
<td>Third Wash</td>
<td>Tooth fragment, jaw fragment and vertebrae</td>
</tr>
<tr>
<td>GRW2015-10</td>
<td>7/9/2015</td>
<td>Surface &amp; in place</td>
<td>Third Wash</td>
<td>Small mud turtle with vertebrae and limb bones</td>
</tr>
<tr>
<td>GRW2015-11</td>
<td>7/9/2015</td>
<td>Surface</td>
<td>Third Wash</td>
<td>End piece of limb, toe bone, rib fragments and vertebrae</td>
</tr>
<tr>
<td>GRW2015-12</td>
<td>7/10/2015</td>
<td>Surface &amp; in place</td>
<td>First Wash</td>
<td>Jaw (camel? pronghorn?) there is a pie with this bag. Many limbs (at least 6)</td>
</tr>
<tr>
<td>GRW2015-13</td>
<td>7/10/2015</td>
<td>Surface</td>
<td>First Wash</td>
<td>Horn core of Merycodus</td>
</tr>
<tr>
<td>GRW2015-14</td>
<td>7/12/2015</td>
<td>Surface &amp; in place</td>
<td>Spider Hole</td>
<td>&quot;Black turtle&quot; Glyptemys valentinensis</td>
</tr>
<tr>
<td>GRW2015-15</td>
<td>7/12/2015</td>
<td>Surface</td>
<td>Spider Hole</td>
<td>Turtle fragments</td>
</tr>
<tr>
<td>GRW2015-16</td>
<td>7/12/2015</td>
<td>Surface &amp; in place</td>
<td>Spider Hole</td>
<td>Large bones including teeth and jaw fragments (probably more than one animal in the bag)</td>
</tr>
<tr>
<td>GRW2015-17</td>
<td>7/12/2015</td>
<td>Surface</td>
<td>Spider Hole</td>
<td>Beaver jaw, vertebrae and other bone fragments found near the jaw</td>
</tr>
<tr>
<td>GRW2015-18</td>
<td>7/12/2015</td>
<td>Surface</td>
<td>Spider Hole</td>
<td>Beaver jaw (unrelated to GRW2015-17)</td>
</tr>
<tr>
<td>GRW2015-19</td>
<td>7/12/2015</td>
<td>Surface</td>
<td>Spider Hole</td>
<td>Horn cores (left and right) of Ramoceros</td>
</tr>
<tr>
<td>GRW2015-20</td>
<td>7/12/2015</td>
<td>Surface</td>
<td>Spider Hole</td>
<td>Camel? jaw fragment (canine tooth on jaw)</td>
</tr>
<tr>
<td>GRW2015-21</td>
<td>7/12/2015</td>
<td>Surface</td>
<td>Spider Hole</td>
<td>Large vertebrae</td>
</tr>
<tr>
<td>GRW2015-22</td>
<td>7/12/2015</td>
<td>Surface</td>
<td>Spider Hole</td>
<td>Tooth found near camel? jaw (GRW2015-20) unrelated</td>
</tr>
<tr>
<td>GRW2015-23</td>
<td>7/12/2015</td>
<td>Surface</td>
<td>Spider Hole</td>
<td>Small limbs and teeth (bird, rodent, and bat - Vespertilionidae-Antrozoinae)</td>
</tr>
<tr>
<td>GRW2015-24</td>
<td>7/13/2015</td>
<td>Surface</td>
<td>Third Wash</td>
<td>&quot;Toothless&quot; jaw fragment of Carpocyon webbi</td>
</tr>
<tr>
<td>GRW2015-25</td>
<td>7/13/2015</td>
<td>Surface &amp; in place</td>
<td>Third Wash</td>
<td>Sharp pointy teeth locality with pie. Lots of bone/jaw fragments</td>
</tr>
<tr>
<td>GRW2015-26</td>
<td>7/15/2015</td>
<td>In place</td>
<td>Third Wash</td>
<td>Whole limb bone broken in 2 pieces. There are 3 pieces and the middle pieces is splintered</td>
</tr>
<tr>
<td>GRW2015-27</td>
<td>7/13/2015</td>
<td>Surface</td>
<td>Third Wash</td>
<td>End of limb piece fragments</td>
</tr>
<tr>
<td>GRW2015-28</td>
<td>7/13/2015</td>
<td>Surface</td>
<td>Third Wash</td>
<td>Small pelvis fragment</td>
</tr>
<tr>
<td>GRW2015-29</td>
<td>7/12/2015</td>
<td>Surface</td>
<td>Spider Hole</td>
<td>Large limb bones and vertebrae</td>
</tr>
</tbody>
</table>

Table 1. This table lists the 29 fossil samples collected during the summer of 2015. It includes the sample number, date collected, whether the specimen was found in place or on the surface, the general area where the sample was collected, and a brief description of the contents of each sample.
GRW2015-14 included the plastral forelobe of a turtle among other shell fragments and was discovered within the Spider Hole Site. An outline of the forelobe was created by uploading pictures of the ventral and dorsal views of the specimen, and then the bone and scute patterns were digitized. This specimen was taxonomically identified based on morphological characteristics of the bone and scute patterns as well as the overall shape of the forelobe. The morphologic comparisons were based on descriptions of emydine turtles from Holman and Fritz (2001) and Holman (2002).

GRW2015-23 containd several small limb bones of a bird, rodent and bat and was found within the Spider Hole Site. The bat fossil is the distal portion of a humerus and is a diagnostic bone for bats. This fossil was identified based on the morphological characteristics of the distal portion of the humerus. At the moment, this fossil is only identified to subfamily (personal communications, G. Morgan [New Mexico Museum of Natural History and Science], Nicholas Czaplewski [Oklahoma Museum of Natural History].

The sinistral side of a toothless canine mandible was recovered from GRW2015-24. This specimen was described using both morphologic features and tooth measurements. All measurements were made with a dial caliper (±0.5 mm). This study adapts the definitions of dental measurements (Fig. 8) following Wang et al. (1999):
p1–p4 lengths (e.g., Lp1)–Maximum anteroposterior diameter on the major axis of each tooth.

p4 width (Wp4)–Maximum transverse diameter of p4.

m1 length (Lm1)–Maximum anteroposterior diameter of each tooth.

m1 trigonid width (Wm1tr)–Maximum transvers diameter of the carnassial notch.

m1 talonid width (Wm1tl)–Maximum transverse diameter of the talonid at hypoconid.

m2 length (Lm2)–Maximum anteroposterior diameter on the main axis of the tooth from the paraconid to the posterior cingulum or hypoconulid.

m2 width (Wm2)–Maximum transverse diameter.

Figure 8. Definition of dental measurements for p4–m2 (modified Wang et al., 1999).
GEOLOGIC SETTING

Stratigraphy

Lee (1907) was one of the first to recognize the strata of the pre-Santa Fe Group that was later named by Bryan (1938). Bryan stated that the Santa Fe marls of Hayden (1869) and Cope (1875a) had become generally known as the Santa Fe Formation and then added that the chief body of sedimentary deposits of the Rio Grande depression, from the north end of the San Luis Valley to and beyond El Paso, is considered to be of the Santa Fe Formation. The type section of the Santa Fe Formation was designated by Denny (1940), and was placed within the region between the Sangre de Cristo and Jemez Mountains, north of Santa Fe, New Mexico (Fig. 1). Spiegel and Baldwin (1963) disregarded Denny's (1940) observations and proposed that the Santa Fe Formation be raised to group status, and that all the basin fill, whether Tertiary or Quaternary, be included in the Santa Fe Group. This also included the sedimentary and volcanic rocks related to the Rio Grande Trough.

In 1971, the first comprehensive stratigraphic study of the Española Basin was conducted by Galusha and Blick (1971). They proposed to restrict the term Santa Fe Group to those deposits that crop out in the classic type area of the Santa Fe marls (Galusha et al., 1971). Their benchmark study described two formations; the Tesuque Formation and the unconformably overlying Chamita Formation. The
Chamita Formation, which crops out west of the study area, was first described by Galusha and Blick (1971).

**Tesuque Formation**

The Tesuque Formation was formally proposed by Spiegel and Baldwin (1963) and split into 2 provinces or lithosomes by Cavazza (1986 and 1989) and figure 9 depicts their interfingering relationship. Galusha and Blick (1971) redefined the formation into 5 members, from oldest to youngest: (1) the Nambé Member, (2) the Skull Ridge Member, (3) the Pojoaque Member, (4) the Chama-El Rito Member, and (5) the Ojo Caliente Sandstone (Fig. 10). The Nambé, Skull Ridge and Pojoaque Members crop out on the east side of the basin; the Chama-El Rito and Ojo Caliente Sandstone Members crop out on the west side of the basin (Fig. 11). In the northern Española Basin, Steinpress (1980 and 1981) added the Dixon Member, Manley (1976, 1977) added the Cejita Member and Leininger (1982) Figure 9. Schematic diagram illustrating the interfingering stratigraphic relations of lithosomes A and B of the Nambé, Skull Ridge and Pojoaque Members of the Tesuque Formation. Stratigraphic positions of synchronous ash-bed markers and retrogradational and progradational sequences of lithosome A are also depicted (adapted from Koning et al., 2005).
Figure 10. Composite stratigraphic section of the Santa Fe Group with some of the main ash beds and important stratigraphic horizons (modified from Galusha et al., 1971).
Figure 11. Northwest-southeast cross-section through the study area (adapted from Koning et
added the Cieneguilla Member to the Tesuque Formation but it was generally disregarded in the literature. The Chama-el Rito and Ojo Caliente Sandstone Members crop out west of the study area and have been subjected to numerous sedimentologic and stratigraphic studies (May, 1980 and 1984; Ekas et al., 1984; Dethier et al., 1984; Dethier et al., 1985; Koning, 2004; and Koning et al., 2004b). Since Galusha and Blick's (1971) study, the Cejita and the Cuarteles members are the only newly recognized members that were added of the Tesuque Formation. The latest member added to the Tesuque Formation was the Cuarteles Member by Koning et al. (2005). The Cuarteles and Cejita members overly the Pojoaque Member in some localities, but Quaternary gravels can also be found to unconformably overly the Pojoaque Member. Westward, the Cuarteles Member is classified as part of the Chamita Formation along with the Cejita Member.

The Tesuque Formation is the most widely exposed formation of the Santa Fe Group and is known for its production of well-preserved Miocene-aged vertebrate mammals. The beds are more than 1,128 m thick in the Española Basin. There are seven different members that have been identified and described of the Tesuque Formation, as follows from oldest to youngest: (1) Nambé Member, (2) Skull Ridge Member, (3) Pojoaque Member, (4) Ojo Caliente Member, (5) Chama el Rito, (6) Cejita Member, and (7) Cuarteles Member (Fig. 12). The Tesuque Formation in the
Figure 12. Schematic diagram illustrating age relations of middle to upper Miocene lithostratigraphic units of the eastern portion of the Española Basin (modified from Koning et al., 2007).
eastern part of the Española Basin ranges from late-early Miocene (~17 Ma) to late Miocene (~6.4 Ma). The entire formation ranges from late Hemingfordian North American Land Mammal Age (NALMA) to late Hemphillian NALMA (Fig. 13).

Pojoaque Member, Tesuque Formation. The Pojoaque Member is composed of pink to buff, or tan to gray, soft sandstones of granitic origin that disconformably overlies the Skull Ridge Member (Galusha et al., 1971). The contact between the Pojoaque and Skull Ridge Members can be found within 3rd wash and has been interpreted as a disconformity based on magnetostratigraphy studies by Barghoorn (1981) and Tedford and Barghoorn (1993). Following the study by Cavazza (1986), the Pojoaque/Cejita and Skull Ridge Members were subdivided into two distinct lithologic units called lithosome A and lithosome B (Koning, 2002, 2003; Koning, et al., 2001, 2002, 2003).

Lithosomes A and B are differentiated based on their composition, bedding characteristics and paleoflow directions. These two lithosomes represent two
distinct paleodrainage systems that were depositing sediment from the eastern and northeastern margins of the Española Basin (Fig. 14) during the major rifting of the Rio Grande Rift in the late Cenozoic. Lithosome B displays consistent south-southwest-directed paleocurrents and is characterized by a substantial quantity of volcaniclastic and sedimentaclastic detritus likely derived from the Taos Plateau–Latir volcanic fields to the northeast (Cavazza, 1986).

Lithosome A, Pojoaque Member. Lithosome A is characterized by westward paleocurrents and by a predominantly plutoniclastic and metamorphiclastic composition derived from the Precambrian Santa Fe block of the Sangre de Cristo Mountains (Cavazza, 1986). In the study area, lithosome A consists of light pink to pale brown or tan, fine siltstone to very fine- to medium-grained sandstone beds with minor channel fills of fine- to coarse-grained, arkosic sandstone (Fig. 15) and ash beds are found throughout the strata. The channels also have general westward flow directions supporting the overall definition of lithosome A (Koning, 2003).
Lithosome B, Pojoaque Member. The focus of this study was on lithosome B lithologies because beds from lithosome A are known to be virtually barren of fossils. Within lithosome B, thin maroon-red mudrock strata (both laterally continuous and localized; Fig. 16-A) and thin pale green silty mudrock strata (generally localized beds; Fig. 16-B) produce virtually all of the vertebrate fossils that have been recovered from the Pojoaque Member. The bulk of lithosome B is comprised of mostly unfossiliferous light to dark reddish brown, brown, or tan mudrock representing the majority of the floodplain. The channel sandstones
Figure 16. (A) Between the dashed lines represents one of the many fossiliferous maroon-red beds; (B) the black arrow is pointing to one of the many fossiliferous pale green beds. Note hammer for scale in lower image.
scattered throughout lithosome B sediments are relatively thin gray coarse-grained trough-crossbedded sandstones (Fig. 17). Thin limestone beds are found within lithosome B sediments which have been interpreted as ephemeral-lake deposits (Cavazza, 1986).

Figure 17. Gray coarse-grained, crossbedded channel sandstone.

*Salmon-Colored Unit, Pojoaque Member.* The upper unit of the Pojoaque Member, named the salmon-colored unit, is a distinctive pink to reddish yellow to orange-brown, silty mudrock to sandstone. This unit is intercalated with sparse, pebbly medium- to very coarse-grained sandstone channel fills. The sandstone is
arkosic and gravel is dominated by granite with subordinate quartzite and is considered as part of lithosome A (Koning, et al., 2005). The salmon-colored unit is interbedded with the lowermost Cejita Member to the west and is sharply overlain by this member to the east (Fig. 18).

Figure 18. The interfingering contact of the Salmon-Colored Unit (SCU) and Cejita Member.

Structural Setting

The Española Basin lies between the Jemez and Sangre de Cristo Mountains in north-central New Mexico. The approximately 1 km thick basin fill strata within
the central and eastern parts of the basin have a predominant westward tilt (Kelley, 1978), which indicates that the basin here is a west-tilted half-graben (Koning et al., 2005). The probable master faults for the half-graben are the Pajarito and Santa Clara faults (Fig. 19; Golombek, 1983; Harrington et al., 1984). Near the eastern margin of the Abiquiu Embayment, which is a structurally shallower part of the Española Basin, the strata consistently dip to the east-southeast (Koning et al., 2004a, 2005). The western side of the Abiquiu Embayment is bound by an approximately 17 km wide zone of east-down faults (Baldridge et al., 1994).
The structural features that are of highest import around the study area includes the Santa Clara Fault to the north-west and numerous northwest- and northeast-trending normal faults that have both west- and east-down separation (Koning et al., 2003, 2005). There were small faults with minuscule amount of displacement (Fig. 20) as well as a large normal fault observed within third wash (Fig. 21). Beds east of Española dip northwest at magnitudes ranging from 9° to roughly horizontal. The dip directions of beds to the west of Española are more variable but have magnitudes ranging from 4° to 12° (Koning et al., 2005).
Figure 21. Large fault found within third wash. The upper picture shows the fault breccia of the normal fault and the lower picture shows where the upper picture was taken and the displacement. Note rock hammer for scale in upper image.
Geomorphology

During the medial Miocene, most of the Española Basin was being filled with influxes of alluvial-slope (lithosome A) and fluvial (lithosome B) basin fill deposits with numerous coarse-grained channel sandstones and thin limestone beds (Cavazza 1986 & 1989). Over time, the boundary between the alluvial-slope and fluvial basin floor deposits would migrate back and forth across the study area. Apart from climate, the influences of base-level and floodplain sediment accumulation rates are difficult to determine because both are results of similar sedimentary successions.

The limestone beds are lake deposits and exist within perennial fluvial floodplain deposits which is what Cavazza (1986) interpreted lithosome B to be. Such lake deposits require a minimum siliciclastic input to contemporaneously exist (Truchan, 2009). Meandering and braided river systems do not have areas shielded from siliciclastic bedload during floods, whereas, anastomosing river systems have flood basin areas surrounded by levees that protect the basins, protecting them from siliciclastic input and depositing mostly suspended and dissolved load during floods (Truchan, 2009). Smith (1983, 1986) suggests that anastomosis is the prime cause of rapid base-level rise and high floodplain sedimentation rates based on modern analogues from western Canada and Colombia. The term ‘anastomosis’ has been used as a synonym for braiding, but Schumm (1968; 1580) stated why they
should not be synonymous: “The terms braiding and anastomosing have been used synonymously for braided river channels in this country, but elsewhere, particularly in Australia, anastomosing is a common term applied to multiple-channel systems.

Figure 22. Alluvial river types base on channel pattern and floodplain geomorphology. Anastomosing rivers (lower) are classified as a composite form of which the individual channel belts may have braided, meandering or straight channels (upper) (adapted from Makaske, 2001).
on alluvial plains.” It is difficult to define anastomosing rivers solely based on the channel platform; therefore, Makaske (2001: 149) proposed an amended definition that combines channel pattern and floodplain geomorphology: “an anastomosing river is composed of two or more interconnected channels that enclose floodbasins” (Fig. 22).

Makaske (2001) described channel deposits of anastomosing river systems to be 1-3 m thick and can be up to 1 km wide. The width/thickness ratios of these channels are given by Makaske (2001) ranging from 5-100 m. The bulk of these examples were limited to the range from 5-50 m. Figure 23 depicts a relatively thin channel deposit from the Pojoaque Member.

![Channel Sandstone](image)

Figure 23. An example of a thin gray crossbedded channel sandstone bed.
A comparable modern analogue to the lithosome B depositional environment would be small-scale rivers in western Canada. These rivers include the Alexandra, North Saskatchewan, Mistaya, Upper Columbia and Lower Saskatchewan Rivers. These rivers show average floodplain sedimentation rates between 0.6 and 1.8 mm/year (Makaske, 2001), whereas, the sedimentation rates of the Pojoaque Member were as high as 0.7 mm/year (Koning, 2005).

Climate change is a factor that leads to anastomosis (Makaske, 2001) and a change in climate did occur during the deposition of lithosome B sediments (Koning et al., 2005), but tectonic or isostatic movements were also potential causes of anastomosis within the Española Basin during the Middle Miocene Epoch. The local uplift of the riverbed could have reduced the river gradient upstream of the uplift, thereby inducing anastomoses (Schumm, 1983; Ouchi, 1985). Figure 24-a represents the degree of tilt over millions of years during the deposition of the Pojoaque Member sediments, providing evidence for uplift of the riverbed, and figure 24-c illustrates the monoclonal folding downstream of the study area. Because of the high floodplain sedimentation rates of the Pojoaque Member (Fig. 24-b), the downstream uplift (Cerrillos Uplift) reducing river gradients upstream, rapidly subsiding basins being considered ideal setting for anastomosing river systems as outlined by Smith and Putnam (1980), Smith (1986). McCarthy (1993) describing that half grabens are also important settings for extensive anastomosing
Early-Middle Miocene

Explanation

- Generalized strike and dip of bedding. Bolder font = higher tilt rates.
- Form lines depicting monocline folding. Amount of bending is approximately proportional to rate of tilting.
- Area of active subsidence. Darker shades indicate more subsidence (deeper basin).
- Active fault. Hachures on downthrown side; length of hachures approximately proportional to relative throw rates. Arrows indicate direction of lateral slip, if any. Queried where fault’s existence uncertain.
Figure 24. a) Box and whisker plot and stratal dips from bedding attitudes measured within the Cuarteles and Martinez stratigraphic sections (from maps of Koning, 2003, and Koning and Manley, 2003). The small filled square represents the mean, the horizontal line in the larger rectangle is the median, the length of the larger rectangle represents the upper and lower quartile (25% above and below the median), the brackets represent the 95% range, and the circles are outliers. At the bottom is the number of data in each interval; average rate of dip change between the intervals is illustrated by length of shaded bars. Abbreviations: PWAZ = Pojoaque White Ash Zone, CWAZ = Coarse White Ash Zone, ETZ = Española Tuffaceous Zone, ATZ = Alcalde Tuffaceous Zone. b) Range of stratal accumulation rates (adapted from Koning, 2005). c) Simplified drawing illustrating interpretations of tectonic activity for the Early-Middle Miocene. Abbreviations: BM = Barrancos faulted monocline, BMF = Black Mesa Fault, CAG = Cañada Ancha Graben, CCF-LBF = combined Cochiti Cone and La Bajada Faults, LA = Los Alamos, LAG = Los Alamos Graben, LMF = La Mesita Fault, MPF = Main Pajarito Fault, NPF = North Pajarito Fault, PuF = Puyé Fault, RdTF = Rio de Truchas Fault, SCF = Santa Clara Fault, SCG = Santa Clara graben, VF = Velarde Fault, VG = Velarde graben (adapted from Koning et al., 2013).
	her systems. Another mechanism that Makaske (2001) mentioned for a cause of anastomosis is the formation of dune fields that block the course of a river. The development of the Ojo Caliente Sandstone dune field at ~13 Ma roughly coincides with the increase in gravel size of the upper most lithosome B unit of the Pojoaque Member and in the lower Cejita Member (Koning et al., 2005). This increased stream power could have been the result of stream competition or an increase in snow melt from the mountains. During this time (13-14 Ma), the climate started cooling (Fig. 25).

Differentiating basin subsidence and climatic influences on sediment distribution is challenging because both can result in comparable sedimentary successions (Koning et al., 2005). Investigators such as Garner (1959, 1967) and Baker (1978) suggest that anastomosis as an expression of instability induced by climatic changes. Axelrod and Bailey (1976) reported a palm stump fossil found in the underlying Skull Ridge Member, which was used by Aby et al. (2011) to infer
frost-free conditions. Aby et al. (2011) inferred that the Pojoaque Member underwent a climate change from a frost-free environment in the Skull Ridge Member to possibly subalpine conditions during the deposition of the Pojoaque Member based on the discovery of bristlecone pine fossils. During the Miocene, studies indicate a major decline in sea level as a result of major glaciations in the Antarctic (Zachos et al., 2001).
The depositional environment of the maroon-red and pale green strata has not been intensively studied and this portion of the study will give possible interpretations of the depositional environment. Alternating red and green beds are often seen in the rock record and many interpretations have been formulated to show what causes these colorations. Frequently, river-transported red soils containing hematite in addition to hydrated iron oxide and other stable minerals such as quartz and clay accumulate as fluvial deposits in semi-arid and arid lowlands, or they can be swept into lakes (Einsele, 2000).

(1) When red soils are swept into lakes they may alternate with carbonates and playa evaporates. If the soils contain sufficient organic matter, hematite and ferric iron hydroxides are reduced, resulting in the beds slowly becoming greenish in color (Einsele, 2000). Ancient lake deposits have been observed to have alternating red and green beds which may cause minor differences in primary organic matter content (Einsele, 2000). This results in red silts or carbonate-rich muds that originally contained little hematite and ferric iron hydroxides to require less organic matter for decoloration to drab gray to greenish colors (Fig. 26; Einsele, 2000). This image depicts one of the pale green beds underlying a thin limestone bed supporting this possibility.
Figure 26. Picture of a thin limestone bed (middle of picture) above a pale green bed that has surficial red staining.

(2) These fossiliferous maroon-red and pale green beds could be interpreted as different stages in a lake’s life. When a lake has filled enough for the profundal zone to have low circulation causing anoxia, this could be the cause of the greenish coloration of the beds. This also explains why the beds are not laterally continuous. When the lake is too shallow to produce an anoxic zone, the waters become oxic causing hypoxia which could be the cause of the maroon-red coloration of the beds. A problem with this interpretation is that, in lacustrine depositional environments the grain size of the littoral zone has courser grains than the profundal zone which has
finer clay or silt grains (Petticrew et al., 1991); the opposite is the case for the maroon-red and pale green beds.

(3) Another interpretation for the depositional environment of these beds is that the pale green beds are backswamp deposits causing the anoxia. Backswamp environments, which hold stagnant water year-round, may have led to faster burial of the bones, enhancing the preservation potential. The problem with a backswamp environment being the depositional environment of the green beds is that coal beds were not seen and have not been documented within the study area (Fig. 27).

![Figure 27. Allochthonous red beds formed by eroded, redeposited lateritic soils. The swamp environment depicts a repeat of red and green beds with peat beds found as well. The playa lake environment depicts repeating red and green beds with evaporites. The semiarid fluvial plain also depicts the repeat of red and green beds around channel sandstone deposits (modified from Einsele, 2000).](image)

(4) It was observed that fossils found within the maroon-red beds were not eroding out of the rock throughout the strata; rather, the fossils were
concentrated at the base of the beds. This could be the result of bones being deposited during a flooding event, such as a crevasse splay, in which the bones settled at the base of the splay during deposition. A flooding event could also account for why the fossils in these beds are mostly broken up.

Figure 28. Textural facies diagram depicting a snapshot of the Middle Miocene within the Española Basin. This diagram illustrates an anastomosing river system with an alluvial fan (lithosome A) depositing onto the floodplain from the Sangre de Cristo Mountains, lakes that would be depositing thin limestone beds, and a crevasse splay possible depositing the sediments of the maroon-red beds.

Figure 28 represents this author’s current interpretation of what the deposition of the Pojoaque Member may have looked like during the Middle Miocene. The Sangre de Cristo Mountains are represented to the right of the
illustration with an alluvial-fan depositing sediment onto the floodplain. There were small and large lakes representing the very localized green beds and ones that are laterally continuous. Crevasse-splays were also common at this time creating new paths for the channel to flow or just depositing a large amount of sediment onto the floodplain in a short period of time.
PALEONTOLOGY OF THE POJOAQUE MEMBER

During the middle Miocene (late Barstovian; North American Land Mammal Age), the local fauna lived in an area with two primary depositional environments. These two environments included an undissected alluvial-slope (lithosome A) and a fluvial basin floor (lithosome B; Aby et al., 2011). The vast majority of the fossils found in the Pojoaque Member have been from lithosome B sediments.

The study area is historically one of the most fossiliferous areas in the entire Española Basin for Miocene vertebrates (Galusha et al., 1971; Tedford 1981; and Aby et al., 2011). A faunal list of the mammals that have been identified to come from the Pojoaque Member of the Tesuque Formation is provided in appendix 1. A large number of previously discovered fossils, as well as fossils in this study, were recovered from Arroyo del Llano (First Wash of the Frick Laboratory), Arroyo de Quarteles (Second Wash of the Frick Laboratory) and the west side of Arroyo de la Morada (Third Wash of the Frick Laboratory; Aby et al., 2011).

Taphonomy

During field studies, it became apparent that fossils were only being produced from relatively thin maroon-red claystone beds and pale-green siltstone to claystone beds within lithosome B. The pale green beds, although fossiliferous,
do not produce the quantities of material that the maroon-red beds do. The pale green coloration represents reduced oxygen conditions which promoted the fossilization of skeletal hard parts (Foote et al., 2007). Bones are better preserved in environments with a high pH causing the inhibition of bacterial activity (Lyman, 1994; Baxter, 2004). The lithosome B sediments within the Pojoaque Member are typically limey, whereas, lithosome A sediments are not typically limey and are unfossiliferous. Therefore, the groundwater moving through lithosome B sediments shortly after burial would have had a high pH. Referring back to Lyman (1994), this could be a reason why fossils are exceedingly abundant within these sediments, but this does not answer why fossils are almost exclusively found within the maroon-red and pale-green beds of lithosome B sediments. This topic is discussed within the Geomorphology section of the Geologic Setting chapter.

The fossils found within these beds were all broken-up and/or splintered. Three ideas are presented regarding why the fossils are not found at the surface intact. First, the break-up of the fossils could be attributed to the repeating freeze-thaw and/or the shrinking and swelling of the claystones based on the observed high moisture content. Second, the fossils could have been broken-up during deposition. Third, some of the limb bones were observed to have quartz growing within the bone. Once the quartz grows too large, it will begin the fracturing of the surrounding bone.
Taxonomic Analyses

The main objective of this study was to provide a comprehensive biostratigraphic column of the Pojoaque Member. The main objective of the field work was to analyze the stratigraphy by collecting measured sections of the Pojoaque Member. While conducting this survey, 15 new fossil locations were discovered and 29 samples were collected (some sample bags contain more than one individual; table 1). The most prolific of these localities is the Spider Hole Site (Fig. 29) where 11 samples were collected. Although many of the fossils collected have not been taxonomically designated, several are described and classified in the following section that include the families Antilocapridae (3), Canidae (1), Emydidae (1), and Vespertilionidae (1).

The Spider Hole Site (Fig. 29) produced the most notable discoveries of this survey which include a forelobe of the plastron of a turtle identified as part of the Family Emydidae (GRW2015-14) and a partial bat humerus identified as part of the Family Vespertilionidae (GRW2015-23). These are important discoveries because they have never been taxonomically described from the Pojoaque Member. Appendix 1 provides a complete faunal list with accompanying sources of the known vertebrates identified from the Pojoaque Member (middle Miocene; late Barstovian) of the Tesuque Formation within the Española Basin with these two new specimen included.
Figure 29. Photograph of the Spider Hole Site of the Pojoaque Member. This location consists of numerous fossiliferous maroon-red and pale green beds. It is located within the interfingering strata between the Pojoaque and the overlying Cejita Members.

**Qualitative and Quantitative Analyses**

- **Order** – Artiodactyla
- **Suborder** – Ruminantia
- **Superfamily** – Giraffoidea
- **Family** – Antilocapridæ

The Family Antilocapridae, evolving in North American, was a successful and diverse group of Artiodactyls during the Miocene. Frick (1937) identified a plethora of new genera and species focusing mainly on horn core morphology. Many of the new species identified were based on geographic distributions and not on
morphological differences (Frick, 1937). Currently, positive taxonomic identification often cannot be made without a horn core, and dental or postcranial apomorphies are not frequently used for taxonomic identifications because of the clear intergradation between dental characters (Frick, 1937; Davis, 2007). Davis (2007) provides the systematic paleontology for the Antilocapridæ Family simply by conducting a thorough review of the current literature. This section will focus on the identification of GRW2015-02, -13, and -19 which are all horn cores and thus horn core diagnostics will only be represented.

The three specimens are characterized as Antilocapridæ based on the branching, permanent supraorbital horns that diagnose the Antilocapridæ Family, as well as the round shaft of the horn in cross section with the possibility of one or more burrs at or near the base. There are five genera that have been recognized from the late Barstovian (Fig. 30; Ba2, Pojoaque Member) based on the cladogram of Janis et al. (1998). These genera include Cosoryx, Merycodus, Paracosoryx, Plioceros, and Ramoceros (Fig. 31).
Figure 30. Schematic illustrations of horns from the type species of the individual genera. The underlined genera are the genera compared. The scale bar equals 10 cm (modified from Davis, 2007).
Figure 31. Phylogeny of Antilocapridae based on North American Land Mammal Age (NALMA) divisions (adapted from Davis, 2007).
Genus – *Cosoryx*

The specimen GRW2015-02 is comprised of the main shaft, which is circular in cross section, on a cranial fragment (Fig. 32). The shaft is fractured just above a burr, which is positioned low on the shaft, and the tines are absent. Using the systematics from Frick (1937), GRW2015-02 is classified as the genus *Cosoryx* based on the following reasons:

1. Tall slender shaft with a circular cross section (Frick, 1937).
2. The shaft tends to be differentiated from the basal pedicle, tilted slightly forward and outward (Frick, 1937).
3. Burr, if existing, is positioned low on the shaft (Frick, 1937; Davis, 2007).

Figure 32. Lateral view of GRW2015-02 discovered in within a green mudrock layer within the Pojoaque Member of the Tesuque Formation (middle Miocene; late Barstovian). GRW2015-02 is the right horn on cranial fragment and is classified as *Cosoryx*.
Frick (1937) has identified 3 subgenera of *Cosoryx* which include *C.* (*Subcosoryx*), *C.* (*Paracosoryx*), and *C.* (*Subparacosoryx*), but Tedford et al. (2004) elevated the subgenus *Paracosoryx* to genus level based on the diastema being short and the premolars are larger; burrs are set high and the shaft is elongated. If Frick (1937) is followed using geographic distribution, then this specimen would be classified as *C.* (*Subcosoryx*). That being said, taxonomic identification cannot be distinguished solely on geography. Frick (1937) distinguishes the two remaining subgenera based on the following:

1. *C.* (*Subcosoryx*) – premolars are greatly reduced.
2. *C.* (*Subparacosoryx*) - the diastema is short and the premolars are large; burrs are set high and the shaft is short.

Because a jaw was not found with the horn core, a subgenus classification is not possible.


The specimen GRW2015-13 is comprised of the main shaft, which is short and compressed and wedge-shaped, on a cranial fragment (Fig. 33). The tines are absent but the branching of the tines is observed. Using the systematics from Davis (2007), GRW 2015-13 will be classified as the genus *Merycodus* based on the following reasons:

1. The shaft is compressed and wedge-shaped (Frick, 1937).
(2) The shaft is less tall and exhibits a wide branching of the tines (Frick, 1937).

Figure 33. Lateral view of GRW2015-13 discovered within a green mudrock layer within the Pojoaque Member of the Tesuque Formation (middle Miocene; late Barstovian). GRW2015-13 is the left horn on cranial fragment and is classified as *Merycodus*.

Davis (2007) demotes the genus *Meryceros* by Frick (1937) to the subgenus level within *Merycodus* based on the narrowness and robustness of the horns not seeming enough to warrant a generic distinction. *M. (Submeryceros)* remains a subgenus but within *Merycodus* (Davis, 2007). The main distinction between *M. (Meryceros)* and *M. (Submeryceros)* is that the burrs are found, if present, around the main shaft of *M. (Meryceros)* (Fig. 34), whereas, the burrs are found around the
Figure 34. Lateral views of *Meryceros crucensis* (Diminutive: F:A.M.31491, 31492, and 31494; Moderately large-sized: F:A.M.31478, 31477, 31485, 31455, 31484, and 31454) from Santa Cruz red beds and *Cosoryx* (*Subparacoryx*) savaronis (A.M.22746) from Sioux County, Nebraska for comparison of horns from Nebraska and New Mexico. F:A.M.31491 (with burr), F:A.M.31492 (with burr), and F:A.M.31494 (without burr) is the right horn on cranial fragment; F:A.M.31478 is the right horn on cranial fragment with a very heavy burr; F:A.M.31477 is the right horn with a burr; F:A.M.31485 is the right horn without a burr; F:A.M.31455 is the left horn on cranial fragment without a burr; F:A.M.31484 is the right horn on cranial fragment without a burr and with a narrow waist (modified from Frick, 1937).
basal portion of the tines of *M. (Submeryceros)* (Fig. 35). Because GRW2015-13 does not possess a bur around the shaft and the tines have been broken before the split of the shaft, the specimen cannot be classified beyond genus level. This is because figure 34 depicts several *M. (Meryceros)* species without a burr.

Figure 35. Lateral views of F:A.M.31495, 31496 and 31497, *Meryceros (Submeryceros) crucianus* from Santa Cruz, New Mexico. F:A.M.31495 and 31496 is the left horn with a separate burr on the base of each prong of the fork. F:A.M.31497 is the right horn on cranial fragment and does not have a separate burr on the base of each tine of the fork (modified from Frick, 1937).

**Genus - *Ramoceros***

The specimen GRW2015-19 is comprised of the left and right main shafts, which is long and cylindrical, on a cranial fragment (left is fractured; Fig. 36). The tines are absent on both and it does not show any branching of the tines. The specimen will be classified as the genus *Ramoceros* based on the following reasons:

(1) The main shaft of the horn is directed outwardly and posteriorly (Frick, 1937; Fig. 37).
(2) There is not a burr present which the location of the burr on the shaft is a major trait of *Paracosoryx* and *Cosoryx* (Frick, 1937; Davis, 2007).

(3) There is no observed split of tines low on the shaft.

Figure 36. Lateral view of GRW2015-19 discovered at the Spider Hole Site within the Pojoaque Member of the Tesuque Formation (middle Miocene; late Barstovian). GRW2015-19 consists of the left (fragmented) and right horn core on cranial fragment and is classified as *Ramoceros*.

Because the tines are not present, the taxonomic classification to subgenus and species levels is not possible. The subgenera are diagnosed based on the length of the secondary shaft, which is the posterior branch that splits to form the novel third tine (Davis, 2007). Species are also diagnosed based on the positioning of the tines.
GRW2015-24 represents the sinistral side of the mandible. When discovered, the jaw was fractured into four pieces and all of the teeth have been lost. After assembly, the specimen was diagnosed as part of the Family Canidae, Subfamily Borophaginae based on the lack of separation by diastemata between the
premolars (Wang et al., 1999; Tedford et al., 2009; Fig. 38). There are many other
diagnostic features differentiating the subfamilies based on their tooth
morphologies, but these will not be included because the teeth are absent on this
specimen.

Even though GRW2015-24’s teeth are absent the sockets are present
representing a near full dentition (canine 1, c1; premolars 1 through 4, p1-p4; and
molars 1 and 2, m1-m2; Fig. 39). Figure 39 also depicts the presence of a
symphyseal flange on the ramus, as well as a more prominent subangular process.

At the m1 point of the jaw, the labial side starts to angle obliquely.

Figure 38. A–C represents the ramus and tooth positioning of *Leptocyon vulpinus*, part of the Caninae
Subfamily. D represents the ramus of *Aelurodon taxoides*, part of the Borophaginae Subfamily. Note
the difference in diastema (modified from Wang et al., 1999; Tedford et al., 2009).
Figure 39. Sinistral (upper) and top (bottom) views of the mandible represented by GRW2015-24 discovered within the Pojoaque Member of the Tesuque Formation (middle Miocene; late Barstovian). The ramus did not retain the teeth leaving the tooth sockets of p1-m2. Abbreviations; p1-p4 = premolars 1-4; m1-m2 = molars 1-2; sf = symphyseal flange; sp = subangular process.

Of the Borophaginae that have been documented from the Pojoaque Member (Appendix 2), *Carpocyon webbi* has been found to be the most similar based on jaw structures (Fig. 40) and tooth measurements (Table 2). The diagnostic features of the jaw implying that GRW2015-24 is a *Carpocyon webbi* are as follows:

1. *Aelurodon ferox, A. stirtoni, Carpocyon webbi, and Tomarctus hippophaga* has a relatively horizontal ramus (Wang et al., 1999).
2. *Aelurodon ferox, A. stirtoni, Carpocyon webbi, and Tomarctus hippophaga* has a symphyseal flange on the ramus (Wang et al., 1999).
3. *Carpocyon webbi* has a more prominent subangular process, which is uncharacteristic of the Subfamily Borophaginae (Wang et al., 1999).
(4) The ramus angles are oblique to the labial side at m1 of *Aelurodon. Stirtoni* and *Carpocyon webbi* (Wang et al., 1999).

Table 2 denotes the tooth measurements of species with similar jaw characteristics which include *Aelurodon ferox, A. stirtoni, Carpocyon webbi*, and *Tomarctus hippophaga*. *Aelurodon ferox, A. stirtoni* are noticeably larger than GRW2015-24, whereas, *Carpocyon webbi* is only slightly larger and *Tomarctus hippophaga* falls within range of every measurement. Because the *Tomarctus hippophaga* specimen does not have a prominent subangular process, and the ramus does not angle obliquely to the labial side at m1, GRW2015-24 likely represents a small *Carpocyon webbi*.

Figure 40. *Carpocyon webbi*; A, lower teeth; B, ramus; A-B from the June Quarry within the Burge Member, Valentine Formation, Nebraska; C, lower teeth; D, ramus; C-D from the Santa Cruz, Pojoaque Member, Tesuque Formation, New Mexico (modified from Wang et al., 1999).
<table>
<thead>
<tr>
<th>Genus/Species</th>
<th>Body Size</th>
<th>BL</th>
<th>Lp1</th>
<th>Lp2</th>
<th>Lp3</th>
<th>Lp4</th>
<th>Wp4</th>
<th>Lm1</th>
<th>Wm1tr</th>
<th>Wm1t1</th>
<th>Lm2</th>
<th>Wm2</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Aelurodon ferox</em></td>
<td>Large</td>
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<tr>
<td>Standard Deviation</td>
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<td>1.19</td>
<td>1.00</td>
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Table 2. This table represents the tooth measurements of select Borophaginae with similar jaw structures. See methods for the definition of dental measurements. All measurements are in millimeters (modified Wang et al., 1999).
Order – Chiroptera  
Suborder – Microchiroptera  
Family – Vespertilionidae  
Subfamily – Antrozoinae

GRW2015-23 (Fig. 41) was discovered among an assortment of similar sized rodent and bird limb bones from the Spider Hole Site. This specimen represents the distal portion of the right humerus of a bat, which is the first known recorded bat fossil from the Pojoaque Member. On this distal portion of the humerus, the spinous process of the medial epicondyle does not extend beyond the distal articular surface of the trochlea. The blunt spinous process is not separated from the trochlea, the shaft curves slightly anteriorly, and the posterior tubercle on the shaft is absent (Fig. 42).

Figure 41. Distal fragment of right humerus (GRW2015-23) from the Spider Hole Site within the Pojoaque Member of the Tesuque Formation (middle Miocene; late Barstovian). The left picture represents the anterior view and the right represents the posterior view. Abbreviation; c = capitulum; lrc = lateral ridge of capitulum; me = epitrochlea or medial epicondyle; mrc = medial ridge of capitulum; of = olecranon fossa; rf = radial fossa; sp = spinous process of epitrochlea; tr = trochlea.
Using characters from this humerus, GRW2015-23 is identified to be part of the Family Vespertilionidae, Subfamily Antrozoinae based on the following characteristics (Fig. 43):

(1) The medial epicondyle has a distally projecting process, and lacks a medial projection which is seen in some Vespertilionidae, all Molossidae and Mormoopidae, but not in Phyllostomidae.

(2) Molossids usually have a wider capitulum than vespertilionids.

Vespertilionids capitulum width/condyle width ratio ranges from 0.30 to 0.41, whereas, molossids ratio range from 0.41 to 0.46 (Thewissen et al., 1987). GRW2015-23 has a ratio of 1.36mm/3.99mm which equals 0.34 falling within range of the vespertilionids.

(3) There is an olecranon fossa present which is found in some vespertilionids, but not in molossids (Thewissen et al., 1987).
Figure 43. Proximal and distal portions of the right humerus of a bat *Karstala silva* (Miocene, Florida) part of the Vespertilionidae Family (modified from Czaplewski et al., 2008).

(4) The distal spinous process on the humerus of Mormoopid bats extrude well beyond the trochlea (Simmons et al., 2001).

(5) GRW2015-23 is similar to the Subfamily Antrozoinae based on the absence of a posterior tubercle on the distal humerus near the olecranon fossa seen in figure 43 and the presence of a deep groove between the trochlea and the spinous process. Gary Morgan from the New Mexico Museum of Natural
History and Science and Nicholas Czaplewski from the Oklahoma Museum of Natural History claim that this specimen is most likely a representative of a new species of a new genus the two are currently describing (personal communication, January 7, 2016).

Order – Testudines  
Family – Emydidae  
Subfamily – Emydinae  
Genus – *Glyptemys*  
Species – *G. valentinensis*

Specimen GRW2015-14 has been identified to be part of the Family Emydidae. The specimen consists of the bone elements anterior to the hyo-hypoplastral suture (forelobe; Fig. 44), as well as elements of the carapace. This specimen is the first known documented Emydidae of the Pojoaque Member (middle Miocene; late Barstovian, NALMA). This section will discuss the diagnostic characteristics of this portion of the plastron to taxonomically classify GRW2015-14. 

The Family Emydidae is represented by two subfamilies, eleven genera and forty-one species of aquatic and terrestrial turtles in North America (Holman, 2002; Franklin, 2007). Turtles classified among the Family Emydidae are moderately sized turtles ranging from 11 centimeters to 15 centimeters. The two subfamilies (Emydinae and Deirochelyinae) are generally subdivided by the possession of a plastral hinge and the crossing of the humeral-pectoral sulcus onto the entoplastron; semiterrestrial Emydinae (*Clemmys, Emydoidea, Emys, Glyptemys*, *
Terrapene) possesses a plastral hinge and the humeral-pectoral sulcus crosses the Graptemys, Malaclemys, Pseudemys, Trachemys) possesses no such hinge and the humeral-pectoral sulcus does not cross the entoplastron (Ernst, 1994; Holman et al., 2001; Franklin, 2007).

The fossil specimen GRW2015-14 will be referred to the Subfamily Emydinae based on the following reasons:

(1) The humeral-pectoral sulcus crosses the entoplastron (in Deirochelyinae, the humeral-pectoral sulcus is excluded from the entoplastron; Gaffney et al., 1988).

(2) The plastron is rigid and has a well-developed bony bridge (Holman et al., 2001).
### Table 3. Skeletal characteristics of GRW2015-14 compared to other species of the subfamily Emydinae. Abbreviations: ✓ = present, X = absent, V = very prominent, M = moderately prominent, W = very weakly prominent, * = deep acromial excavation on epiplastron, A = autapomorphic, D = derived, P = primitive, gut = guttata, mar = marmorata, bla = blandingii, hutc = hutchisoni, orb = orbicularis, inscu = insculpta, muh = muhlenbergii, va = valentinensis, car = carolina, coa = coahuila, orn = ornata. The diagnostic features were acquired from Holman et al. (2001), Holman (2002), and Angielczyk et al. (2010)

<table>
<thead>
<tr>
<th>Characters</th>
<th>Clemmys: gut</th>
<th>Emydidae: mar</th>
<th>Emys: orb</th>
<th>Glyptemys: inscu</th>
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<tbody>
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<td>X ✓ X ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ X X</td>
<td></td>
</tr>
<tr>
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<tr>
<td>pronounced epiplastral tubercle</td>
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<tr>
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<td>✓ ✓ ✓ ✓ ✓</td>
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<td></td>
</tr>
<tr>
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<td>✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓</td>
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<tr>
<td>bell shaped entoplastron</td>
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Plastral feature of taxa within the subfamily Emydinae were compared with GRW2015-14. The most prominent plastral features include an ovoid shape of the plastron and the humeral-pectoral sulcus (HPS) that crosses the posterior end of the entoplastron. The specimen also exhibit pronounced epiplastral tubercles (ET), oval...
acromial excavations (AC) on the epiplastra, an overlap of the pectoral scute onto the hyoplastron dorsally, a bell shaped entoplastron, and an akinetic plastron.

Based on the qualitative comparisons from table 3, GRW2015-14 likely belongs to either *Glyptemys* or *Emydoidea*. The genera *Terrapene* and *Emys* were ruled out based on the plastron not being akinetic. *Clemmys* was not considered because these are small turtles with a shell length up to 12.5 cm (Holman et al., 2001).

When comparing the forelobes of select emydine turtles to GRW2015-14 (Fig. 45; E), there are noticeable similarities and differences. The general roundness of the plastron is an obvious feature observed but also the reduced angle of the anterior side of the entoplastron and the point where the sinistral and dextral portions of the gular-humeral sulcus merge are features that differ on many emydine turtles. When comparing these features, GRW2015-14 seems most comparable to *Glyptemys*. GRW2015-14 and the *Glyptemys* specimens have a reduced angle of the anterior portion of the entoplastron and the sinistral and dextral portions of the gular-humeral sulcus connect closer to the center of the entoplastron. The humeral-pectoral sulcus of GRW2015-14 crosses the entoplaston of the sinistral side of the forelobe causing the entoplastron to be more bell-shaped but it does not cross on the dextral side causing the entoplastron
to be more diamond-shaped. This might represent a deformity because of the lack of symmetry. When comparing these features (Fig. 45; Table 3), *Glyptemys valentinensis* is most comparable to GRW2015-14. The noticeable differences between *Glyptemys valentinensis* and GRW2015-14 are as follows:

(1) The epiplastral tubercles of GRW2015-14 are smaller;

(2) The angle of the anterior portion of the entoplastron is slightly reduced on *Glyptemys valentinensis*;
(3) The humeral-pectoral sulcus of GRW2015-14 crosses the entoplastron at a similar point to *Glyptemys valentinensis* but not the dextral side. If this is a deformity, whether the sinistral or dextral side represents the true position is unknown.

Biostratigraphy

Historically, fossil occurrences within the Pojoaque Member were largely represented by the “Santa Cruz fossil-collecting localities.” These localities are found within Galusha and Blick's (1971) middle tuffaceous facies and lower variegated facies represent the Pojoaque Member, which are overlain by the thick gravel-bearing sands of the upper conglomeratic facies, now known as the Cejita Member (Appendix 3, Fig. 57). Tedford and Barghoorn (1993) position the Santa Cruz sites toward the lower portion of the Pojoaque Member or within the lower variegated facies. Unfortunately, the exact stratigraphic location of the Santa Cruz sites cannot be identified because numerous fossiliferous maroon-red beds have been found throughout the Pojoaque Member. The most productive Santa Cruz sites are located within Arroyo del Llano (First Wash of the Frick Laboratory), Arroyo de Quarteles (Second Wash of the Frick Laboratory), and the western portion of Arroyo de la Morada (Third Wash of the Frick Laboratory; Aby et al., 2011). The eastern portion of Arroyo de la Morada is either the Skull Ridge or Nambé Member.
Other productive fossil collecting localities include the San Ildefonso Pueblo localities, Pojoaque Bluffs localities, Jacona Grant localities, the Jacona microfauna quarry, and West Cuyamunque localities. Most of Cope's 1874 collection originated from the exposures northeast of San Ildefonso Pueblo (Tedford and Barghoorn, 1993). The bulk of the Frick Laboratory's collections came from the Santa Cruz sites, but they also collected from the Pojoaque Bluffs. The Jacona microfauna quarry was discovered by the Frick Laboratory within the Santa Cruz collecting sites toward the middle of the Pojoaque Member.

A faunal list of all the specimens that have been taxonomically identified from each of these fossil collecting localities is found within Appendix 3 along with the approximate stratigraphic range of these localities (Fig. 57). Galusha and Blick (1971) recognized the need to know where stratigraphically these fossil collecting localities originated; thus, creating this figure. The figure has been modified to only include the Pojoaque Member as well as including Aby et al.'s (2011) simplified stratigraphic column. Figure 57 provides a stratigraphic range for future paleontologists studying Pojoaque Member fossils that are lacking stratigraphic data.

The Proboscidea, *Gomphotherium productum*, is the most age-diagnostic mammal that is found within the Pojoaque Member (Tedford and Barghoorn, 1993; Aby et al., 2011). These mastodons make their first local appearance within the
Pojoaque Member. During the early Miocene, a land-bridge opened up as the Arabian Peninsula (African side) contacted Asia allowing the mastodons to leave their native Africa to spread westward into Europe and eastward across Asia. By the end of the early Miocene, mastodons eventually crossed the Bering Isthmus inhabiting North America. The Pojoaque Member is the oldest documentation of mastodons within the southern United States (Tedford and Barghoorn, 1993; Aby et al., 2011).

The Pojoaque Member has produced a diverse collection of Artiodactyla, Perissodactyla, Carnivora, among others (Appendix 2). Some of the notable first appearances of other mammals that define the late Barstovian within the Pojoaque Member include the amphicyonid bear dog *Pseudocyon*, the mephitid carnivore *Pliogale*, the otoconid lagomorphs *Hesperolagomys*, and *Russelagus* (Tedford and Barghoorn, 1993; Aby et al., 2011). The earliest occurrences of the borophagine canids *Aelurodon ferox* and *A. stirtoni*, the 3-toed horse *Neohipparion coloradense*, the oreodont *Merychys medius*, the camelid *Procamelus*, the moschid ruminant *Longirostromeryx* and the antilocaprid *Ramoceros* were also within the Pojoaque Member (Tedford and Barghoorn, 1993; Aby et al., 2011). Now, because the vesper bat Vespertilionidae, Antrozoinae is likely a member of a new genus, it too has its first appearances within the Pojoaque Member.
RESULTS/DISCUSSION

This study began by attempting to identify the vertebrate biostratigraphy of the Pojoaque Member. The vast majority of fossils that have been discovered and described from the Pojoaque Member were from pre-1970s collections. It was not common practice for early paleontologists to identify the stratigraphic origin of a fossil that they have discovered. Despite early paleontologist not recording the stratigraphic origin of the fossil specimens that they have collected, the relative stratigraphic position of these fossils can be obtained with geographic location data based on Galusha and Blick's (1971) positioning of common fossil collecting localities. Even with the large amount of specimens’ relative stratigraphic origin identified, it is difficult if not impossible to identify if there are any biostratigraphic zones within the Pojoaque Member. Tedford and Barghoorn (1993) attempted to place some of the common collecting localities within the strata; in particular the Santa Cruz collecting sites that have produces the majority of the fossils from the Pojoaque Member. They place these sites within the lower portion of the strata, but as seen during field work, there are fossiliferous red beds found throughout the strata. As a result, the Santa Cruz fossil collecting localities cannot be restricted to the lower portion of the Pojoaque Member; these locations range from the bottom to the top of the member.
Many of the previous authors stratigraphic studies conflicted or it was difficult to coorelate their stratigraphic columns. To understand the stratigraphic position of fauna found within the Pojoaque Member, stratigraphic columns were constructed using the 7 transects (Appendix 1) acquired during field studies. The Pojoaque Member is comprised of over 200 meters of alternating alluvial-fan (lithosome A) and fluvial-floodplain (lithosome B) deposits.

Cavazza (1986) studied the channel sandstones and conglomerates and found that lithosome A is predominantly comprised of plutoniclastic and metamorphiclastic grains derived from the Precambrian Santa Fe block of the Sangre de Cristo Mountains, and lithosome B is comprised of volcaniclastic and sedimentaclasitic detritus likely derived from the Taos Plateau–Latir volcanic fields. Samples of lithosome B claystones were taken for x-ray diffraction analyses in an attempt to differentiate paleoenvironments using the clay mineralogy. It was difficult to interpret the depositional environment based on the clay mineralogy of the samples, but Cavazza’s (1986) interpretation of the Taos Plateau–Latir volcanic fields being the source area is likely correct based on the presence of mordenite within the claystone samples (Fig. 46). Mordenite is one of the most abundant zeolite minerals that is found within altered volcanic deposits such as andesite, basalt, and rhyolite (Lo et al., 1991).
Figure 46. X-ray diffraction results of UFR-01.
Fossils have only been found within lithosome B sediments; more specifically, restricted to relatively thin (<3m) maroon-red and pale green claystone to siltstone beds that are found throughout lithosome B and are generally not laterally continuous. The maroon-red claystone beds are interpreted as being either crevasse-splay or more likely lacustrine deposits, whereas, the pale green clay- to siltstone beds are interpreted as being lacustrine or backswamp deposits; both of which are being interpreted as being deposited within an anastomosing fluvial depositional environment.

It is difficult to correlate packages of lithosome A and B sediments from one area to another and it is likely lithosome A packages in one area are different lobes of alluvial-fans. This is easily explained by the migration of lithosome A and B sediments back and forth across the basin and is why past stratigraphic studies of the Pojoaque Member do not match each other or this study. It is well known that ash beds are found throughout the strata of the Pojoaque Member. If additional magnetostratigraphic analyses are added to Barghoorn’s (1981) study of the Pojoaque Member across the basin, then the packages of rock could be correlated based on the time of deposition and along with it the fossils.

While delineating transects of the area, many fossil specimens were collected. Three observations were made while collecting fossils from the maroon-red and pale green beds: 1) the majority of the fossils collected were being produced
from the maroon-red beds (2) the fossils were all found at the base of the maroon-red bed, and (3) most of the fossils were fractured. The maroon-red beds producing the majority of the fossils could be a result of higher pH levels of the ground water after burial promoting fossilization, as well as the abundance of calcite within the rock also promoting fossilization (Lymam, 1994). Three samples of the maroon-red, pale green, and unfossiliferous reddish brown beds of lithosome B were collected and 2 of 3 maroon-red, 1 of 3 pale green, and 1 of 3 reddish brown beds effervesced indicating the presence or absence of calcite. Fossils being found only at the base of the bed could be the result of how they were deposited or differential compaction from sediment overburden. Fossils being splintered or fractured could be a result of the high moisture content of the clays toward the surface triggering freeze-thaw conditions during cold months and shrink-swell of the clays during wet and dry months. Another cause of post-deposition alteration for some of the fossils could be the growth of quartz exceeding the accommodation space within the bone, as observed within a few of the specimens collected.

There were 29 samples collected during the field season and 6 of these were taxonomically identified. These specimens include 3 antilocaprids (Cosoryx, Merycodus, and Ramoceros), 1 canine (Carpocyon webbi), 1 micropteran bat (Vespertilionidae, Antrozoinae), and 1 emydine turtle (Glyptemys valentinensis).
The bat and turtle are newly-discovered vertebrates from the Pojoaque Member and were added to the faunal list within Appendix 2.

This study provides a faunal list of specimens that have been discovered and described from the Pojoaque Member (Appendix 2). To ascertain the faunal succession of the Tesuque Formation, faunal lists accompanied with first and last appearance datum must be acquired of the remaining members of the Tesuque Formation. This study also provides the first appearance datum of specimens found within the Pojoaque Member, but no last appearance datum was recognized. A list of fossil collecting localities was acquired from the literature and the New Mexico Museum of Natural History and Science (Appendix 3) and linked to their relative stratigraphic positions (Fig. 57). The specimens that have been identified are listed under their location of origin, thus representing their relative stratigraphic origin. The specimens that were collected within this study are listed within the stratigraphic columns found within Appendix 1.

The AMNH houses at least 20,000 skeletal elements from the Pojoaque, but only about 30% have been formally catalogued (Aby et al., 2011). This study has added two new species to the area and if a comprehensive assessment of the museum’s collection is conducted, it is likely that more new species will be “re-discovered.” Aby et al. (2011) also states that there is little to no location or stratigraphic information linked too much of this collection so this would provide
little more than expanding the faunal list of the Pojoaque Member. Because the microfauna of the Pojoaque Member have not been extensively studies, it is more likely that new species will be discovered rather than macrofauna.
CONCLUSIONS

Of the Tesuque Formation members, the Pojoaque Member is the most fossiliferous. Over 40 years of continuous paleontological expeditions from the 1920s to the 1960s by the Frick Laboratory and the AMNH yielded thousands of vertebrates. Because it was not common practice during this time for paleontologists to identify the stratigraphic position of these fossils, it is difficult to understand the faunal succession of the Pojoaque Member over time. This research provides the stratigraphic range of popular fossil collecting localities by the Frick Laboratory. Biostratigraphically, this member is diagnostic for the first appearance of several different aforementioned species; most notably the *Gomphotherium productum* makes its first appearance in New Mexico.

The Pojoaque Member is split into two provenances characterized as lithosomes. Lithosome A sediments are composed of only Proterozoic clast types originating from the Sangre de Cristo Mountains, located to the west, and are completely barren of fossils. Lithosome B sediments are composed of Paleozoic clast types originating from the Taos Plateau–Latir volcanic fields area, located to the northeast, and are fossil rich. Found within lithosome B sediments are maroon-red and pale green claystone to siltstone beds which are virtually the only beds that produce fossils. This might be attributed, in part, to the claystones and siltstones
being ‘limey’ causing the groundwater to be alkaline, thus, promoting fossilization by reducing bacterial activity.

The stratigraphic study of Pojoaque Member provides a record of sedimentation distribution patterns. Observations of the differences between stratigraphic sections collected during field studies as well as comparing previous author’s stratigraphic studies have revealed that lithosome A and B sediments migrated back and forth across the basin and it is difficult to correlate the stratigraphy from one area to another. There are numerous lobes of lithosome A alluvial-fan sediments that probably cannot be correlated and the fossiliferous beds of lithosome B are mostly localized and dispersed throughout the lithosome B sediments. The fossiliferous red beds are also called the Santa Cruz red beds and cannot be restricted to any portion of the Pojoaque Member. No biostratigraphic subdivisions can be made within the Pojoaque Member, but this study provides a more complete faunal list that will be important for future biostratigraphic studies of the Tesuque Formation.
LITERATURE CITED


Cope, E. D., 1874, Notes on the Santa Fe marls and some of the contained vertebrate fossils: Academy of Natural Sciences Proceedings 26, p. 147-152.


Gary S. Morgan and Nicholas J. Czaplewski, e-mail to author, January 7, 2016.


Korth, W. W., 2008a, Two new pocket mice (Mammalia, Rodentia, Heteromyidae) from the Miocene of Nebraska and New Mexico and the early evolution of the subfamily Perognathinae: Geodiversitas, v. 30, p. 593-609.


APPENDIX 1

The following includes the seven stratigraphic sections measured within this study. Figure 47 is the legend for figures 49-55. Figure 48 represents the geographic locations of each transect. The transects are correlated in figure 56. The Dead Horse (Fig. 51) and North of Cat Hill (Fig. 53) Transects are the most complete sections of the Pojoaque Member. Stratigraphic columns with lettered boxes outlining an area on the lithology column are showing blown-up portions of the stratigraphy. The thickness of each stratigraphic column started at the contact between the overlying Cejita and the Pojoaque Members and is based on the total thickness measured (280 m: North of Cat Hill Transect).

![Legend](image)

Claystone
Silty Claystone
Sandy Siltstone
Sandstone
Conglomerate
Channel Sandstone
Fossils Present

Figure 47. Legend for figures 49-55.
Figure 48. (1) Southern 1st Wash Transect 1; (2) Southern 1st Wash Transect 2; (3) Dead Horse Transect; (4) Cat Hill Transect; (5) North of Cat Hill Transect; (6) Northern 3rd Wash Transect; (7) Northeastern 3rd Wash Transect.
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Figure 49. Southern 1st Wash Transect #1 – (1) GRW2015-08; (3) Contains thin gray coarse-grained sandstone layers. Interfingering contact with the overlying Cejita Member. The Spider Hole site is located within this interfingering contact zone. GRW2015-14-23, and 29.
Figure 50. Southern 1st Wash Transect #2 – (2) This bed is more slope forming than cliff forming; (6) Transect ended at the top of the ridge.
To the east of the transect, this bed is more cliff forming; to the west of the transect, this bed is more slope forming; (13) Contains light gray ash beds that are not laterally continuous; (16) GRW2015-12; (18) GRW2015-13; (27) Contains gray crossbedded coarse channel sandstone beds and conglomeratic lenses; (29) Contains a gray crossbedded coarse-grained channel sandstone; (30) Contains a thin gray silty bed. The contact with the overlying Cejita Member is an interfingering zone.
Figure 52. Cat Hill Transect – (1) Contains numerous gray to white ash beds, as well as trough crossbedded sandstone beds. This bed is cliff forming; (3) GRW2015-01, 02, 04, 06; (5) GRW2015-05; (7) Contains a thin pinkish white ash bed; (9) The contact with the overlying Cejita Member is an interfingering zone.
Figure 53. North of Cat Hill Transect – (1) At the base is a gray mudrock which is the marker bed for the Skull Ridge/Pojoaque Member contact; (4) GRW2015-09, 10, and 11; (6) Contains 2 thin gray coarse grained crossbedded sandstone beds; (8) Contains numerous ash beds; (10) This bed is cliff forming and contains ash beds. This layer consists of alternating resistive and recessive beds. The resistive beds are coarser than the recessive beds. The ash beds are more resistive than the silty beds; (12) The layer contains alternating resistive silty and recessive mudrocks; the mudrock beds are thicker creating more of a slope; (13) This layer is more cliff forming and contains numerous crossbedded trough channel sandstone beds, as well as gray-white ash beds; (16) GRW2015-07; (19) the contact between the Pojoaque and the Cejita is not interfingering in this area.

Figure 54. Northern 3rd Wash Transect – (3) GRW2015-26; (6) GRW 2015-27; (9) GRW2015-24, 25, and 28; (11) Contains few pebbles; (14) Interbedded contact with the overlying Cejita Member.
Figure 55. Northeastern 3rd Wash Transect – (4) This layer is cliff forming and contains interbedded resistive and recessive beds along with white ash beds; (6) This layer is more slope forming with interbedded resistive and recessive beds. The recessive beds are thicker creating slopes.
Figure 56. Correlation chart of the 7 transects acquired during field studies. The datum is hung on the Cejita/Pojoaque Member contact.
APPENDIX 2

The following is a faunal list from the middle Miocene (late Barstovian, NALMA) Pojoaque Member, Tesuque Formation, Española Basin, north-central New Mexico. The majority of the faunal list is reproduced from Aby et al. (2011). Additional fauna have been added to the list as well as specimens newly described from this study.

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### Mammalian Fauna

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Plithocyon (=Hemicyon) ursinus

Amphicyonidae
Amphicyoninae
Amphicyon ingens
Pseudocyon sp.*

Canidae
Borophaginae
Aelurodon ferox*
Aelurodon stirtoni*
Carpocyon webbi
Epicyon haydeni
Epicyon saevus
Microtomarctus conferta
Paratomarctus temerarius
Strobodon stirtoni
Tomarctus confertus
Tomarctus kelloggi
Tomarctus sp.

Caninae
Leptocyon vafer

Hemicyoninae
Plithocyon ursinus

Mephitidae
Mephitinae
Martinogale nambiana
Martinogale sp.
Mustela sp.
Plionictis sp.

References

Frick (1926b), Hunt (1998a)

Jasinski (2015)


Kues et al. (1978)

Kues et al. (1978)

Jasinski (2015)


Jasinski (2015)

Jasinski (2015)

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Sthenictis sp.
Oligobuninae
Brachypsalis sp.
Felidae
Pseudaelurus marshi
Pseudaelurus stouti
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Chiroptera
Vespertilionidae
Antrozoinae
Eulipotyphla
Erinaceidae
Amphechinus sp.
Leporidae
Hypolagus sp.
Lupus sp.
Panolax sanctaeidei
Lagomorpha
Ochotonidae
Hesperolagomys sp.*
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Untermannerix copiosus
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Achlyoscapter ?
Domninoides sp.
Gaillardia sp.
Mystipterus sp.
Scapanoscapter?
Soricidae
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References
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<td>Tamias sp.</td>
<td>Chaney (2009)</td>
</tr>
<tr>
<td>Spermophilus sp.</td>
<td>Chaney (2009)</td>
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### Mammalian Fauna

<table>
<thead>
<tr>
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<th>Family</th>
<th>Genus and Species</th>
<th>References</th>
</tr>
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<tbody>
<tr>
<td>Heteromyidae</td>
<td></td>
<td><em>Diplodomys cf D. hermanni</em></td>
<td>Kues et al. (1978)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Miopergnathus willardi</em></td>
<td>Korth (2008a)</td>
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<td></td>
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<td><em>Perognathus minutus</em></td>
<td>Korth (2008)</td>
</tr>
<tr>
<td>Geomyoidea</td>
<td></td>
<td><em>Mojavemys galushai</em></td>
<td>Korth &amp; Chaney (1999)</td>
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<tr>
<td></td>
<td></td>
<td><em>Phelosaccomys neomexicanus</em></td>
<td>Korth &amp; Chaney (1999)</td>
</tr>
<tr>
<td>Castoridae</td>
<td></td>
<td><em>Dipoides cf D. planus?</em></td>
<td>Kues et al. (1978)</td>
</tr>
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<td></td>
<td></td>
<td><em>“Dipoides” williamsi</em></td>
<td>Kues et al. (1978)</td>
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<td></td>
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<td><em>Monosaulax pansus</em></td>
<td>Cope (1877), Korth (2002), Chaney (2009)</td>
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<td></td>
<td></td>
<td><em>Eucastor tortus</em></td>
<td>Korth (2008b)</td>
</tr>
<tr>
<td>Zapodidae</td>
<td></td>
<td><em>Plesiosminthus sp.</em></td>
<td>Chaney (2009)</td>
</tr>
<tr>
<td>Cricetidae</td>
<td></td>
<td><em>Copemys loxodon</em></td>
<td>Cope (1877), Chaney (2009)</td>
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### Reptilian Fauna

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<td>Cryptodira</td>
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<td>Kinosternidae</td>
<td>Kinosterninae</td>
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<td></td>
<td><em>Kinosternon pojoaque</em></td>
<td>Bourque (2012)</td>
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<td>Testudinidae</td>
<td></td>
<td><em>Geochelone (Hesperotestudo) Osborniana</em></td>
<td>Sena et al. (1989)</td>
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<td>Emydidae</td>
<td></td>
<td><em>Glyptemys valentinensis</em></td>
<td>This paper</td>
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**Note:**
Taxa followed by an (*) have their first occurrences within the Pojoaque Member.
APPENDIX 3

Schematic diagram to represent the stratigraphic equivalencies of commonly used Pojoaque Member collecting localities against an ideal-composite section (left margin) of Galusha and Blick (1971), the subdivided units (right margin) of Aby et al. (2011), and the site diagram is from Barghoorn (1985). The point of this section is to represent the approximate stratigraphic location of fossils that only have geographic locations associated with them. The numbers next to the locations refer to the fossil collecting localities listed below.

Figure 57. Schematic diagram to represent the stratigraphic equivalencies of commonly used Pojoaque Member collecting localities against an ideal-composite section (left margin) of Galusha and Blick (1971), the subdivided units (right margin) of Aby et al. (2011), and the site diagram is from Barghoorn (1985).
1. Jacona Micro Site (Quarry)
   
   Artiodactyla
   
   Antilocapridae
   
   *Cosoryx* sp.
   *Meryceros crucensis*
   *Plioceros blicki*
   *Ramoceros ramosus*
   
   Camelidae
   
   Camelinae: Camelini
   *Procamelus* sp.
   Camelinae: incertae sedis
   *Australocamelus* sp.
   Camelinae: Lamini
   *Aepycamelus* sp.
   
   Miolabinae
   *Miolabis* sp.
   *Nothotylopus* sp.
   *Paramiolabis* sp.
   
   Protolabinae
   *Michenia* sp.
   *Protolabis* sp.
   
   Dromomerycidae
   *Cranioceras teres*
   
   Leptomerycidae
   *Pseudoparablastomeryx* sp.
   
   Moschidae
   *Blastomeryx francesca*
   *Longirostromeryx blicki*
   *Longirostromeryx novomexicanus*
   *Longirostromeryx* sp.
   
   Oreodontidae
   *Merychys major*
   *Ustatochoerus* sp.
   
   Carnivora
   
   Amphicyonidae
   
   Amphicyoninae
   *Pseudocyon* sp.
Canidae  
Borophaginae  
*Aelurodon ferox* (=*A. wheelerianus*; Cope, 1877)  
*Carpocyon* sp.  
*Epicyon haydeni*  
*Epicyon saevus*  
*Microtomarctus conferta*  
*Paratomarctus temerarius*  
*Strobodon* sp.  
Ursidae  
*Plithocyon* (=*Hemicyon*; Frick, 1926b) *ursinus*  
Eulipotyphla  
Leporidae  
*Hypolagus* sp.  
*Panolax sanctaefidei*  
Lagomorpha  
Ochotonidae  
*Hesperolagomys* sp.  
*Russellagus* sp.  
Lipotyphla  
Erinaceidae  
*Metechinus amplior*  
*Untermannerix copiosus*  
Soricidae  
Talpidae  
*Gaillardia* sp.  
*Mystipterus* sp.  
Perissodactyla  
Equidae  
Anchitheriinae  
*Hypohippus* sp.  
*Megahippus* sp.  
Equinae: Equini  
*Pliohippus* sp.  
Equinae: Hipparionini  
*Hippotherium* sp.  
*Neohipparion* sp.  
*Merychippus* (=*Protohippus* sp.; Kues, 1993) *calamarius*  
Rhinocerotidae  
*Aphelops cf. A. meridianus*
A. sp.  
*Teleoceras* sp. (=*Peraceras crassus*; Prothero, 2005)

**Proboscidea**

Gomphotheriidae

*Gomphotherium productum* (=*G. obscurum*; Tobien, 1973)

**Rodentia**

Castoridae

*Eucastor tortus*

Cricetidae

*Copemys loxodon*

Geomyoidea

*Mojavemys galushai*

*Phelosaccomys neomexicanus*

Heteromyidae

*Perognathus minutus*

Mylagaulidae

*Mylagaulus laevis*

**Perissodactyla**

1. *Jacona Grant; 100 yds. SW of 4 1/2 M stake on W Tesuque Grant Boundary (Pojoaque or Skull Ridge)*

**Artiodactyla**

Equidae

2. *Jacona Grant, S end (Pojoaque)*

Antilocapridae

Camelidae

Canidae

Dromomerycidae

*Cranioceras*

Oreodontidae

**Perissodactyla**

Equidae

Rhinocerotidae

**Proboscidea**

Gomphotheriidae

**Rodentia**

3. *Jacona Grant, E boundary, in Jacona Wash (Pojoaque) included are: a) head of Jacona Wash; b) Nambe drainage system*

**Artiodactyla**

Antilocapridae

Canidae

4. *Jacona Grant, E boundary, in Jacona Wash (Pojoaque) included are: a) head of Jacona Wash; b) Nambe drainage system*
Camelidae
Oreodontidae
Carnivora
Perissodactyla
   Equidae
      Rhinocerotidae
Proboscidea
   Gomphotheriidae
Rodentia
   Castoridae
(Other)
   Gastropods
   Cast of wasp’s nest

5. Jacona Grant, Jacona microfossil quarry, in Jacona Wash (Pojoaque)
Artiodactyla
   Antilocapridae
      Ramoceros
      Ramoceros (Paramoceras)
Camelidae
   Dromomerycidae
      Cranioceras
      Cranioceras teres
Moschidae
   Blastomeryx
      Longirostromeryx
      Longirostromeryx blicki
Oreodontidae
Carnivora
   Eulipotyphla
      Erinaceidae
         Amphechinus cf.
Lagomorpha
   Leporidae
Perissodactyla
   Equidae
      Hypohippus
   Rhinocerotidae
      Teleoceras sp.
Soricomorpha
   Soricidae
Talpidae
  *Dominoides* sp.

Scalapoides?

Rodentia
  bird - 1PC, misc.

Reptilia - misc.
  Testudines
  Amphibia - misc.
  (Other)

Gastropods

6. Jacona Grant, Pojoaque Bluffs (Pojoaque)
   Artiodactyla
     Antilocapridae
     Camelidae
     Protolabinae
     Moschidae
     *Longirostromeryx* sp.
     Oreodontidae
     Protolabinae
     *Michenia* sp.

Carnivora
  Canidae
    Borophaginae
    *Aelurodon* sp.
    *Carpocyon* sp.
  Caninae
    *Leptocyon vafer*

Perissodactyla
  Equidae
  Rhinocerotidae

Proboscidea
  Gomphotheriidae

Rodentia
  Castoridae

Testudines
  (Other)

Coprolites

7. Arroyo Ancho; western limit (Skull Ridge or Pojoaque)
   Artiodactyla
     Camelidae
Perissodactyla
  Rhinocerotidae
8. Arroyo Ancho; W side (Skull Ridge or Pojoaque)
   Artiodactyla
     Oreodontidae - 1PC
   Carnivora
   Perissodactyla
   Rhinocerotidae
9. Arroyo Ancho; area E of (Pojoaque)
   Artiodactyla
     Camelidae
       Camelinae: Lamini
         Aepycamelus sp.
(Unknown)
   Mylagaulis
10. West Cuyumunque Wash, including especially the W side (Pojoaque)
    Artiodactyla
     Antilocapridae
       Merycodus (Submeryceros) minor
       Ramoceros ramosus
    Camelidae
       Camelinae: Lamini
         Aepycamelus sp.
       Miolabinae
         Miolabis sp.
       Protolabinae
         Protolabis heterodontus
    Oreodontidae
    Carnivora
       Amphicyonidae
       Amphicyoninae
         Amphicyon sp.
    Canidae
       Borophaginae
         Tomarctus confertus
       Caninae
         Leptocyon vafer
    Mephitidae
       Mephitinae
         Plionictis sp.
Procyonidae
   Procyoninae
      Bassariscus sp.
Perissodactyla
   Equidae
  Rhinocerotidae
       Teleoceras sp.
       Peraceras sp.
Proboscidea
   Gomphotheriidae
Rodentia
   Heteromyidae
       Perognathus sp.
       Mylagaulidae?
Testudines
   (Other)
      Bird tracks
      Worm trails
      Wood
11. West Cuyumunque; right fork of tributary wash (Pojoaque?)
Artiodactyla
   Antilocapridae
   Camelidae
12. West Cuyumunque; E side, 1/3 mile S of Pojoaque Grant fence (Pojoaque)
   Artiodactyla
   Oreodontidae
13. West Cuyumunque; E side, N of Pojoaque Grant fence (Pojoaque)
   Artiodactyla
   Camelidae
   Carnivora
       Canidae
           Borophaginae
               Tomarctus confertus
   Rodentia
       Mylagaulidae
14. West Cuyumunque, E side, 100 yards N of S boundary of Pojoaque Grant (Pojoaque)
   Artiodactyla
   Antilocapridae
15. West Cuyumunque; head of E fork, on Pojoaque Grant (Pojoaque)
   Artiodactyla
   Camelidae

16. Pojoaque Pueblo Grant (unspecific) (Pojoaque and Skull Ridge)
   Artiodactyla
   Antilocapridae
      *Cosoryx ilfonsensis*
   Camelidae
   Carnivora
   Felidae
      *Pseudaelurus* sp.

   Perissodactyla
   Equidae
   Rhinocerotidae

17. Pojoaque Bluffs, from Jacona to Pojoaque Grants (Pojoaque)
   Artiodactyla
   Oreodontidae

18. Pojoaque Pueblo Grant, near northern boundary (Pojoaque and Skull Ridge).
   Includes a) 50 yards N of N boundary, b) SW 1/4 sec. 30, T 20 N, R 9 E, c) 1/4 mile N of N boundary, d) NE 1/4 sec. 33, e) just SW of NE corner stake of Grant, f) 1/4 mile S of Santa Clara Grant in Pojoaque Grant
   Artiodactyla
   Antilocapridae
   Camelidae
      Miolabinae
         *Miolabis* sp.
   Merycoidodontidae
      *Brachycrus* sp.
   Oreodontidae
      *Merycodus* sp.
      *Ramoceros* sp.

   Carnivora
   Canidae
      Caninae
         *Leptocyon* sp.
   Mustelidae

   Perissodactyla
   Equidae
   Rhinocerotidae

   Proboscidea
Gomphotheriidae
Rodentia
19. Pojoaque Pueblo Grant; wash just E of stake for sec. 29, T 20 N, R 8 E, 1 mile S of N boundary of Pojoaque Grant (Pojoaque?)
Perissodactyla
Equidae
20. Pojoaque Bluffs (unspecified) (Pojoaque). Most taxa from this locality are from Central Pojoaque Bluffs
Artiodactyla
Antilocapridae
Cosoryx cerroensis
Merycodus crucensis
M. major
Ramoceros ramosus
R. marthae
R. ramosus quadratus
Camelidae
Camelinae: Lamini
Aepycamelus sp.
Protolabinae
Protolabis sp.
Leptomerycidae
Pseudoparablastomeryx francescita
Moschidae
Longirostromeryx blicki
Oreodontidae
Merychyus sp.
Ustatochoerus sp.
Carnivora
Amphicyonidae
Canidae
Borophaginae
Aelurodon sp.
Epicyon haydeni
Tomarctus sp.
Caninae
Leptocyon vafer
Mephitidae
Mephitinae
Mustela sp.
*Plionictis* sp.
Perissodactyla
  Equinae
  Rhinocerotidae
    Aceratheriinae
      *Aphelops* sp.
      *Peraceras* (small species)
      *Teleoceras* sp.
Proboscidea
  Gomphotheriidae
    *Gomphotherium productum*
Rodentia
  Castoridae
    *Eucastor tortus*
21. "Below Pojoaque Bluffs" (Pojoaque)
Artiodactyla
  Antilocapridae
    *Merycodus crucensis*
22. Pojoaque Pueblo Grant; South Pojoaque Bluffs (Pojoaque and Skull Ridge)
Artiodactyla
  Antilocapridae
    *Merycodus crucensis*
  Camelidae
    Camelinae: Lamini
      *Aepycamelus* sp.
  Protolabinae
    *Michenia* sp.
    *Protolabis* sp.
Oreodontidae
Carnivora
  Canidae
    Borophaginae
      *Tomarctus* sp.
  Felidae
    *Pseudoaelurus* sp.
    *P. marshi*?
Lagomorpha
  Leporidae
Perissodactyla
Equidae
Rhinocerotidae
  Aceratheriinae
    Aphelops sp.
    Peraceras (small species)
Rodentia
  Castoridae
    Eucastor tortus
  Mylagaulidae
  (Other)
    Bird
    Coprolite
23. Lower Pojoaque Bluffs; S and 3/4 mile SE of Round Mountain (Pojoaque)
Artiodactyla
  Antilocapridae
    Merycodus crucensis
    Plioceros blicki
    Ramoceros ramosus
Camelidae
  Camelinae: Camelini
    Procamelus sp.
  Camelinae: Lamini
    Aepycamelus sp.
  Protolabinae
    Protolabis sp.
Dicotylidae
Oreodontidae
Carnivora
  Amphicyonidae
  Canidae
    Borophaginae
      Aeluropot sp.
      Carpocyon
      Tomarctus confertus
Perissodactyla
  Equinae
  Rhinocerotidae
    Aceratheriinae
      Peraceras (small species)
      Teleoceras sp.
Proboscidea
   Gomphotherium productum
Rodentia
   Castoridae
   Dipoides cf D. planus?
   Eucastor tortus

24. Lower Pojoaque Bluffs; first wash to enter Rio Grande N of Nambe Creek
   (Pojoaque)
   Proboscidea
   Gomphotheriidae

25. Lower Pojoaque Bluffs; E of central fault, W of Mesilla-San Ildefonso Road
   (Pojoaque)
   Artiodactyla
   Camelidae
   Carnivora
   Felidae
   Perissodactyla
   Equidae
   Proboscidea
   Gomphotheriidae

26. Lower Pojoaque Bluffs; W of central fault (Pojoaque)
   Artiodactyla
   Antilocapridae
   Carnivora
   Canidae
   Borophaginae
   Carpocyon sp.

27. "Southwest Pojoaque Bluffs" (Pojoaque)
   Artiodactyla
   Antilocapridae
   Cosoryx ilfonsensis
   Ramoceros ramosus
   Camelidae
   Protolabinae
   Protolabis sp.
   Oreodontidae
   Ustatochoerus sp.
   Carnivora
   Canidae
   Borophaginae
Aelurodon sp.
Perissodactyla
Rhinocerotidae
Proboscidea
Gomphotheriidae
Gomphotherium productum
Rodentia
Mylagaulidae
Mylagaulus sp.
Castoridae
28. 'Southeast Pojoaque Bluffs" (Pojoaque)
Artiodactyla
Antilocapridae
Ramoceros
Ramoceros ramosus
Oreodontidae
Carnivora
Canidae
Borophaginæ
Aelurodon sp.
Mustelidae
Lagomorpha
Leporidae
Lepus sp.
Perissodactyla
Equidae
Rodentia
29. "Central Pojoaque Bluffs"; unspecified, plus several well defined localities: a) NW 1/4 SE 1/4 sec. 36, T 20 N, R 8 E, b) SW 1/4 SE 1/4 sec. 36, c) SE 1/4 sec. 36, d) NW 1/4 NE 1/4 sec. 36, e) NE 1/4 sec. 1, T 19 N, R 8 E (Pojoaque)
Artiodactyla
Antilocapridae
Ramoceros
Camelidae
Camelinae: Camelini
Procamelus sp.
Camelinae: Lamini
Aepycamelus sp.
Oreodontidae
Moschidae
Longirostromeryx novomexicanus

Carnivora
   Canidae
      Borophaginae
         Aelurodon sp.
   Caninae
      Leptocyon vafer
   Felidae
      Pseudaelurus
   Mephitidae
      Mephitinae
         Sthenictis sp.

Eulipotyphla
   Erinaceidae
      Amphechinus sp.

Perissodactyla
   Equidae
      Anchitheriinae
         Megahippus
      Rhinocerotidae

Rodentia
30. Central Pojoaque Bluffs; Needle tributary of first large wash between Splinter and Barrancos faults at stake sec. 25 & 36, T 20 N, R 8 E (Pojoaque)

Artiodactyla
   Antilocapridae
      Merycodus
      Ramoceros

Camelidae
31. Central Pojoaque Bluffs; SW 1/4 sec. 2, T 19 N, R 8 E (Pojoaque)

Perissodactyla
   Rhinocerotidae
32. Central Pojoaque Bluffs, sec. 2, T 19 N, R 8 E (Pojoaque)

Artiodactyla
   Antilocapridae
   Camelidae

Carnivora
   (Other)
      Lizard
33. Central Pojoaque Bluffs; NW 1/4 sec. 11, T 19 N, R 8 E (Pojoaque)
Antilocapridae
   *Ramoceros*
Perissodactyla
Rhinocerotidae
34. Pojoaque Bluffs; tributary W of 2nd west Pojoaque fault (Pojoaque)
   Artiodactyla
   Camelidae
   Carnivora
35. Pojoaque Bluffs; S tributary E of 2nd west Pojoaque fault (Pojoaque)
   Artiodactyla
   Oreodontidae
36. SW 1/4 NE 1/4 NW 1/4 sec. 21, T 20 N, R 8 E, Santa Clara Pueblo Grant
   (Pojoaque)
   Carnivora
   Includes "Pojoaque Bluffs, Santa Clara Grant". (Pojoaque)
   Artiodactyla
   Antilocapridae
      *Cosoryx ilfonsensis*
      *Merycodus crucensis*
      *M. major*
      *M. (Submeryceros) minor*
      *Plioceros blicki*
      *Ramoceros (Paramoceros) marthae*
      *R. ramosus*
      *R. r. quadratus*
Camelidae
   Camelinae: Lamini
      *Aepycamelus* sp.
   Protolabinae
      *Michenia* sp.
      *Protolabis* sp.
Moschidae
   *Blastomeryx francesca*
   *?Longirostromeryx blicki*
Oreodontidae
Carnivora
   Amphicyonidae
      *Amphicyoninae*
      *Amphicyon* sp.
Canidae
  Borophaginae
    Aelurodon sp.
    Carpocyon sp.
    Strobodon sp.
    Tomarctus sp.
  Caninae
    Leptocyoon vafer
Felidae
  Pseudaelurus sp.
    P. marshi
Mephitidae
  Mephitinae
    Mustela sp.
    Sthenictis sp.
Procyonidae
  Procyoninae
    Bassariscus sp.
Perissodactyla
  Equinae
  Rhinocerotidae
    Aceratheriinae
      P. (small species)
      Teleoceras sp.
Proboscidea
  Gomphotheriidae
    Gomphotherium productum
Rodentia
  Soricomorpha
    Talpidae
      Domninoides?
(Other)
  Lizard
38. North Pojoaque Bluffs; several specific localities in sec. 25, T 20 N R 8 E: a) NW 1/4, b) SE 1/4 NW 1/4, c) SW 1/4 SE1/4 NW 1/4, d) Arroyo Madrid, NE 1/4 SW 1/4, e) NW 1/4 SW 1/4, f) SW 1/4 NE 1/4, g) line between SW 1/4 & SE 1/4 (Pojoaque)
Artiodactyla
  Antilocapridae
    Merycodus
Camelidae
Merycoidodontidae
Oreodontidae
Perissodactyla
Rhinocerotidae
Proboscidea
Gomphotheriidae
Carnivora
Rodentia
(Other)
Wood

39. North Pojoaque Bluffs, Santa Clara Grant; First wash N of S boundary of grant (probably in sec. 25) (Pojoaque)
Artiodactyla
Antilocapridae
Merycodus
Ramoceros
Camelidae
Camelinae: Lamini
Aepycamelus sp.
Oreodontidae
Carnivora
Canidae
Perissodactyla
Equinae
Anchitheriinae
Megahippus
Rhinocerotidae
Proboscidea
Gomphotheriidae

40. Santa Clara Grant; 2nd wash N of S boundary of grant (Pojoaque)
Artiodactyla
Oreodontidae

41. Pojoaque Bluffs; E boundary of Santa Clara Grant (Pojoaque)
Artiodactyla
Antilocapridae
Perissodactyla
Rhinocerotidae

42. North Pojoaque Bluffs; about 425 yards N60°E of highest point on bluffs (Pojoaque)
Artiodactyla
   Antilocapridae
      Ramoceros
   Camelidae
   Oreodontidae
Carnivora
   Felidae
      Pseudaelurus
Perissodactyla
   Equidae
   Rhinocerotidae
Proboscidea
   Gomphotheriidae

43. Pojoaque Bluffs, Santa Clara Grant; Mesilla Prospect, SW 1/4 NE 1/4 sec. 27, T 20 N, R 8 E (Pojoaque)
   Artiodactyla
      Antilocapridae
         Merycodus
      Camelidae
      Oreodontidae
Carnivora
Rodentia

44. West side, North Pojoaque Bluffs (Pojoaque)
   Artiodactyla
      Antilocapridae
         Ramoceros ramosus
            R. (Paramoceros) marthae
      Camelidae
      Protolabinae
         Protolabis sp.

45. East slope, North Pojoaque Bluffs (Pojoaque)
   Artiodactyla
      Antilocapridae
         Merycodus crucensis
      Camelidae
      Camelinae: Camelini
         Procamelus sp.

46. East Pojoaque Bluffs (Pojoaque)
   Artiodactyla
      Antilocapridae
Ramoceros ramosus
Camelidae
Camelinae: Lamini
Aepycamelus sp.

Carnivora
Canidae
Borophaginae
Aelurodon sp.

47. West Pojoaque Bluffs (Pojoaque)
Artiodactyla
Antilocapridae
Merycodus crucensis
Ramoceros ramosus
R. (Paramoceros) marthae

Camelidae
Camelinae: Camelini
Procamelus sp.
Camelinae: Lamini
Aepycamelus sp.

Oreodontidae
Carnivora
Canidae
Borophaginae
Aelurodon sp.
Caninae
Leptocyon vafer

Perissodactyla
Equinae
Rhinocerotidae
Aceratheriinae
Peraceras (small species)
Tomarctus sp.

Rodentia
Castoridae
Eucastor tortus
Mylagaulidae
Mylagaulus sp.

48. Santa Clara Canyon (Pojoaque? and Chamita)
Artiodactyla
Antilocapridae
Cosoryx ilfonsensis
Merycodus crucensis
Camelidae
Camelinae: Camelini
**Procamelus** sp.
Moschidae
**Blastomeryx francesca**
?**Longirostromeryx blicki**
*L.* sp.
Oreodontidae
**Merychys**
Carnivora
Canidae?
Proboscidea
Gomphotheriidae
Rodentia
Castoridae
**Eucastor tortus**
Mylagaulidae
**Mylagaulus**

49. **Upper Santa Clara Canyon** (Chamita)
Artiodactyla
Camelidae
Camelinae: Lamini
**Megatylopus** sp.

50. **Santa Clara Canyon**, S side (Chamita)
Artiodactyla
Antilocapridae
Camelidae
Perissodactyla
Rhinocerotidae
**Teleoceras** sp.

51. **S of Santa Clara Canyon** (Pojoaque? or Chamita)
Carnivora

52. **First wash** S of Santa Clara Canyon (Pojoaque)
Artiodactyla
Camelidae
Alticamelinae

53. **Santa Clara; NE of Round Mountain Quarry** (Pojoaque)
Carnivora
54. Santa Clara Quarry (Pojoaque or Chamita)
Artiodactyla
   Antilocapridae
       *Merycodus crucensis*
   Oreodontidae

55. San Ildefonso (nonspecific) West of fault and extending north of Sacred Spring to Battleship Mountain. (Pojoaque and Chamita)
Artiodactyla
   Antilocapridae
       *Cosoryx?*
       *C. ilfonsensis*
       *Merycodus crucensis*
       *Plioceros blicki*
Camelidae
   Camelinae: Camelini
       Procamelus sp.
   Camelinae: Lamini
       Aeypcamelus sp.
Moschidae
   *Longirostromeryx novomexicanus*
Oreodontidae
   *Ustatochoerus* sp.
Carnivora
   ?Amphicyonidae
Canidae
   Borophaginae
       *Aelurodon* sp.
       *Carpocyon* sp.
       *Tomarctus* sp.
Caninae
       *Leptocyon* vafer
       *L.* sp.
Mephitidae
   Mephitinae
       *Mustela* sp.
Mustelidae
   *Pliogale nambianus*
Procyonidae
   Procyoninae
       *Bassariscus* sp.
Ursidae
  *Plithocyon*

Perissodactyla
  Equinae
  Rhinocerotidae
    Aceratheriinae
      *Peraceras* (small species)
      *Teleoceras* sp.

Proboscidea
  Gomphotheriidae
    *Gomphotherium productum*

Rodentia
  Castoridae
    *Eucastor tortus*

Mylagaulidae

56. San Ildefonso, Rodent Pocket; N side of large wash 1 mile N of Sacred Springs and E of Sacred Springs fault (Pojoaque?)

Artiodactyla
  Antilocapridae
    *Cosoryx*
  Moschidae
    *Longirostromeryx*
  Oreodontidae

Carnivora

Rodentia
  Heteromyidae
    *Dipodomys* cf *D. hermanni*

Testudines

(Other)

Bird

57. San Ildefonso; E of Sacred Springs fault (Pojoaque)
Anchitheriinae
   *Hypohippus*
Equinae: Equini
   *Pliohippus*
Rodentia
58. San Ildefonso Pueblo Grant; wash E of E boundary fence (Pojoaque)
Artiodactyla
   Camelidae
Eulipotyphla
59. Battleship Mountain (Pojoaque or Chamita)
Artiodactyla
   Camelidae
Camelinae: Lamini
   *Aepycamelus* sp.
Proboscidea
   Gomphotheriidae
     *Gomphotherium productum*
60. Santa Cruz (general, area) (Pojoaque and Skull Ridge)
Artiodactyla
Antilocapridae
   *Cosoryx major*
   *C. ilfonsensis*
   *Merycodus cruciensis*
   *M. (Submeryceros) crucianus*
   *Plioceros bicki*
   *Ramoceros ramosus*
   *R. r. quadratus*
   *R. (Paramoceros) marthae*
Camelidae
   Camelinae: Camelini
     *Procamelus* sp.
   Camelinae: Lamini
     *Aepycamelus* sp.
Dromomerycidae
   *Cranioceras teres*
Leptomerycidae
   *Pseudoparablastomeryx francescita*
Moschidae
   *Blastomeryx francesca*
   *Longirostromeryx bicki*
Longirostromeryx novomexicanus
Longirostromeryx sp.

Oreodontidae
Merychys medius novomexicanus

Carnivora
Amphicyonidae
Canidae
Borophaginae
Aeluropus sp.
Carpocyon sp.
Strobodon sp.
Tomarctus kelloggi
Tomarctus sp.

Caninae
Leptocyon vafer

Felidae
Pseudaelurus sp.
P. marshi

Mephitidae
Mephitinae
Mustela?
Plionictis sp.
Sthenictis sp.

Lipotyphla
Erinaceidae
Metechinus amplior

Perissodactyla
Equinae
Rhinocerotidae
Aceratheriinae
Aphelops sp.
Teleoceras sp.

Proboscidea
Gomphotheriidae
Gomphotherium productum
Megabelodon joraki

Rodentia
Castoridae
"Dipoides" williamsi
Mylagaulidae
Mylagaulus sp.
Promylagaulus novellus
(Uunknown)
E. cf. E. planus
61. West edge of Santa Cruz area (Pojoaque?)
Artiodactyla
Antilocapridae
Camelidae
Oreodontidae
Ustatochoerus profectus espanolensis
Carnivora
Canidae
Borophaginae
Strobdon sp.
Tomarctus sp.

Mustelidae
Rodentia
(Other)
Snake?
62. Santa Cruz - sec. 6, T 20 N, R 9 E (Pojoaque)
Carnivora
Canidae
Borophaginae
Aelurodon
63. North side, Santa Cruz Wash (Pojoaque or Skull Ridge)
Artiodactyla
Camelidae
64. Santa Cruz, First Wash (Pojoaque). Includes a) NE 1/4 SW 1/4 sec. 31 T 21 N, R 9 E
Artiodactyla
Antilocapridae
Cosoryx ilfonsensis
Merycodus
M. crucensis
M. major
Plioceros blicki
Ramoceros
R. (Paramoceros) marthae
R. ramosus
R. r. quadratus

Camelidae
Camelinae: Camelini
Procamelus sp.
Camelinae: Lamini
Aepycamelus sp.
Protolabinae
Protolabis sp.
Dromomerycidae
Cranioceras

Moschidae
Blastomeryx francesca
Longirostromeryx bicki

Oreodontidae
Merychys medius novomexicanus
Ustatochoerus californicus raki
U. skinneri santacruzensis
U. sp.

Carnivora
Canidae
Borophaginæ
Aelurodon sp.
Carpocyon sp.
Strobodon sp.
Tomarctus sp.
Caninae
Leptocyon vafer

Felinae
Pseudaelurus marshi

Mustelidae

Perissodactyla
Equidae
Anchithériinae
Hypohippus
Rhinocerotidae
Aceratheriinae
Teleoceras sp.

Proboscidea
Gomphotheriidae
Rodentia
  Castoridae
    Eucastor tortus

(Other)
  Invertebrates

65. Santa Cruz, Second Wash (Pojoaque)
Artiodactyla
  Antilocapridae
    Merycodus crucensis
    Ramoceros
  Camelidae
    Camelinae: Lamini
      Aepycamelus sp.
    Protolabinae
      Protolabis sp.
  Dromomerycidae
    Cranioceras teres
  Moschidae
    Longirostromeryx blicki?
    L. sp.
  Oreodontidae
Carnivora
  Canidae
    Borophaginae
      Aelurodon sp.
      Tomarctus sp.
    Caninae
      Leptocyon vafer
  Felidae
    Pseudaelurus stouti.
    P. sp.
Eulipotyphla
  Erinaceidae
    cf. Amphichinus
  Leporidae
Lipotyphla
  Talpidae
    Domninoides
Perissodactyla
  Equidae
Rhinocerotidae
   Aceratheriinae
      *Peraceras* (small species)
      *Teleoceras* sp.

Rodentia
   Castoridae
      *Eucastor tortus*
   Mylagaulidae
      *Mylagaulus*

66. Santa Cruz, Third Wash. Includes Rodent Prospect, on W side of wash about 1.5 miles above point where wash crosses Chimayo Road (a) and Near divide with Second Wash (b) (Pojoaque)

Artiodactyla
   Antilocapridae
      *Paracosoryx Alticornis?*
   Camelidae
      Camelinae: Lamini
         *Aepycamelus* sp.
      Protolabinae
         *Protolabis* sp.
   Moschidae
   Longirostromeryx sp.
   Osteodontidae

Carnivora
   Canidae
      Borophaginae
         *Aelurodon* sp.
      Caninae
         *Leptocyon vafer*

Perissodactyla
   Equidae
      Anchitheriinae
         *Hypohippus*

Proboscidea
   Gomphotheriidae

Rodentia
   Castoridae

67. Santa Cruz, W fork of Third Wash (Pojoaque)

Artiodactyla
   Camelidae
68. Between Arroyo Second Wash and Santa Cruz River. Includes (a) South of Santa Cruz River (Pojoaque and Skull Ridge)
Artiodactyla
  Antilocapridae
  Camelidae
    Camelinae: Lamini
      Aepycamelus sp.
    Protolabinae
      Michenia sp.
      Protolabis sp.
  Merycoidodontidae
  Merycohoerinae
    Brachycrus sp.
Carnivora
  Mustelidae
Perissodactyla
  Equidae

69. S of Arroyo Second (=Big) Wash (general) (Skull Ridge and Pojoaque)
Artiodactyla
  Antilocapridae
    Merycodus crucianus?
  Camelidae
    Camelinae: Lamini
      Aepycamelus sp.
    Miolabinae
      Miolabis sp.
  Oreodontidae
Carnivora
  Canidae
    Borophaginae
      Tomarctus confertus
      "T." kelloggi
Eulipotyphla
  Leporidae
Perissodactyla
  Equinae
    Rhinocerotidae
      Teleoceras sp.

70. W side of Arroyo Second Wash (Pojoaque?)
Carnivora
Canidae  
Perissodactyla  
Rhinocerotidae

*Teleoceras sp.*

71. S of Arroyo Second, SW 1/4 sec. 22, T 20 N, R 9 E (Skull Ridge)
Artiodactyla
Camelidae

72. S of Arroyo Second, NE 1/4 NW 1/4 sec. 28, T 20 N, R 9 E (Skull Ridge)
Artiodactyla
Camelidae
Perissodactyla
Equidae
Rhinocerotidae

73. Unit 3
Perissodactyla
Equinae

Equinae: Hipparionini

*Nephipparion coloradense* (NMMNH 63417)

Proboscidea
Gomphotheriidae

*Gomphotherium productum* (NMMNH 28972)

Testudines
Cryptodira
Testudinidae

*Hesperotestudo* (NMMNH 63420)

74. Unit 4
Artiodactyla
Oreodontidae

*Merychys medius* (NMMNH 63419, NMMNH 63418; Site L-7782)

Carnivora
Felidae

*Pseudaelurus stouti* (NMMNH 63413)

Rodentia
Cricetidae

*Copemys loxodon* (NMMNH 63416)

75. Unit 5
Artiodactyla
Antilocapridae

*Merycodus (=Meryceros) crucensis* (NMMNH 57608)
Carnivora
Canidae
  Borophaginae
    *Aelurodon ferox* (NMMNH 57620, NMMNH 63412)
Mustelidae
  *Pliogale nambiana* (NMMNH 63415)
VITA

After completing his work at Rensselaer Central High School, Rensselaer, Indiana, in 2008, Garrett Williamson entered Ivy Tech Community College at Lafayette, Indiana. During the fall of 2009 he transferred to the Wayland Baptist University Lubbock Campus at Lubbock, Texas in hopes to achieve a business degree. He later changed his major to geology and transferred to the Wayland Baptist University Plainview Campus at Plainview, Texas. He received the degree of Bachelor of Science in Geology from Wayland Baptist University in May 2014. During the summer of 2014 he was employed as an intern at the Bureau of Land Management in Santa Fe, New Mexico. In August 2014, he entered the Graduate School of Stephen F. Austin State University at Nacogdoches, Texas, and received the degree of Master of Science in Geology in May of 2016.

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Style manual designation

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