Stephen F. Austin State University

SFA ScholarWorks

Electronic Theses and Dissertations

5-9-2016

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

Garrett R. Williamson

Stephen F. Austin State University, gwilliamson1989@gmail.com

Follow this and additional works at: <https://scholarworks.sfasu.edu/etds>

Part of the [Geochemistry Commons](#), [Geology Commons](#), [Geomorphology Commons](#), [Paleobiology Commons](#), [Paleontology Commons](#), and the [Stratigraphy Commons](#)

[Tell us](#) how this article helped you.

Repository Citation

Williamson, Garrett R., "THE STRATIGRAPHIC POSITION OF FOSSIL VERTEBRATES FROM THE POJOAQUE MEMBER OF THE TESUQUE FORMATION (MIDDLE MIOCENE, LATE BARSTOVIAN) NEAR ESPAÑOLA, NEW MEXICO" (2016). *Electronic Theses and Dissertations*. 41.

<https://scholarworks.sfasu.edu/etds/41>

This Thesis is brought to you for free and open access by SFA ScholarWorks. It has been accepted for inclusion in Electronic Theses and Dissertations by an authorized administrator of SFA ScholarWorks. For more information, please contact cdsscholarworks@sfasu.edu.

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

Creative Commons License

This work is licensed under a [Creative Commons Attribution-Noncommercial-No Derivative Works 4.0 License](https://creativecommons.org/licenses/by-nc-nd/4.0/).

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.

Presented to the Faculty of the Graduate School of

Stephen F. Austin State University

In Partial Fulfillment

Of the Requirements

For the Degree of

Master of Science

STEPHEN F. AUSTIN STATE UNIVERSITY

May, 2016

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.

APPROVED:

Dr. LaRell Nielson, Thesis Chair

Dr. Kevin Stafford, Committee Member

Dr. Timothy Walsh, Committee Member

Dr. Stephen Mullin, Committee Member

Richard Berry, D.M.A.
Dean of the Graduate School

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.

ACKNOWLEDGMENTS

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 stimulating 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 with 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.

TABLE OF CONTENTS

Abstract	iii
Acknowledgments	v
List of Figures	x
List of Tables	xx
Introduction	1
Research Area	4
Purpose of Study	8
Methods	11
Field Methods	11
Laboratory Methods	13
Fossil Locality Data	14
Geographic Information Systems (GIS)	14
Stratigraphic Identification of Fossils	15
X-ray Powder Diffraction (XRD) Analysis	16
Taxonomic Identification	17
Geologic Setting	22
Stratigraphy	22
Tesuque Formation	23

Pojoaque Member, Tesuque Formation	28
Lithosome A, Pojoaque Member	29
Lithosome B, Pojoaque Member	30
Salmon-Colored Unit, Pojoaque Member	32
Structural Setting	33
Geomorphology	37
Paleontology of the Pojoaque Member	49
Taphonomy	49
Taxonomic Analyses	51
Qualitative and Quantitative Analyses	52
Antilocapridae	52
<i>Cosoryx</i>	56
<i>Merycodus</i>	57
<i>Ramoceros</i>	60
Canidae	62
<i>Carpocyon webbi</i>	62
Vespertilionidae	67
Antrozoinae	67
Emydidae	70
<i>Glyptemys valentinensis</i>	70

Biostratigraphy	.	.	.	.	.	.	.	.	75
Results/Discussion	.	.	.	.	.	.	.	.	78
Conclusion	.	.	.	.	.	.	.	.	85
Literature Cited	.	.	.	.	.	.	.	.	87
Appendix 1	.	.	.	.	.	.	.	.	100
Appendix 2	.	.	.	.	.	.	.	.	111
Appendix 3	.	.	.	.	.	.	.	.	118
Vita	.	.	.	.	.	.	.	.	150

LIST OF FIGURES

<u>No.</u>	<u>Page</u>
1. The extent of the Española Basin. The red box outlines the study area (modified from Sawyer, 2004).	1
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).	2
3. Schematic diagram of the Santa Fe Group within the Española Basin including North American Land Mammal Ages (NALMA). This diagram is not to scale (modified from Barghoorn 1981).	4
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).	5
5. Study area (outlined in black) within section 27, 28, 29, 30 (part), 31 (part), 32, 33, and 34 (part); T21N, R9E.	7
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.	12
7. A–A sample is being pulverized using a porcelain mortar and pestle. B–The pulverized sediment is being run through a sieve. C–The sediment is being measured prior to being sent for XRD analyses.	17

8. Definition of dental measurements for p4–m2 (modified Wang et al., 1999).	21
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).	23
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).	24
11. Northwest-southeast cross-section through the study . area (adapted from Koning et al., 2003).	25
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).	27
13. Geologic time scale with North American Land Mammal . Ages (NALMA) and affiliated age ranges (adapted from Riddle et al., 2014).	28
14. A model depicting the sediment dispersal system in . the Española Basin during deposition (adapted from Cavazza, 1986).	29
15. Photograph representing lithosome A. Note the . channel sandstone bed toward the base of the cliff.	30
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.	31

17. Gray coarse-grained, crossbedded channel sandstone. . .	32
18. The interfingering contact of the Salmon-Colored Unit (SCU) and Cejita Member. . .	33
19. The major geologic structures are represented by the white lines, with the small perpendicular bars indicating throw direction of normal and normal-oblique faults. Faults are abbreviated as: PFZ = Pajarito fault zone, SCF = Santa Clara fault, OCF = Ojo Caliente fault, BMF = Black Mesa fault, LMF = La Mesita fault, EF = Embudo fault, SDCF = Sangre de Cristo fault and PPF = Pecos-Picuris fault (adapted from Koning et al., 2005). . .	34
20. Faults with a miniscule amount of displacement. . . Note rock hammer for scale. . .	35
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. . .	36
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). . .	38
23. An example of a thin gray crossbedded channel sandstone bed. . .	39

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).	41
25. Plot of stable isotopes of oxygen and climatic interpretations (modified from Koning et al., 2005).	43
26. Picture of a thin limestone bed (middle of picture) above a pale green bed that has surficial red staining.	45

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).	46
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 possibly depositing the sediments of the maroon-red beds.	47
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.	52
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).	54
31. Phylogeny of Antilocapridæ based on North American Land Mammal Age (NALMA) divisions (adapted from Davis, 2007).	55
32. Lateral view of GRW2015-02 discovered 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 <i>Cosoryx</i> .	56

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*. 58
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 F:A.M.31454 is the right horn on cranial fragment without a burr and with a narrow waist (modified from Frick, 1937). 59
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). 60
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*. 61

37. Posterior views of F:A.M.31619 and F:A.M.31624 . . . 62
representing *Ramoceros* (*Paramoceros*) *marthæ*
(left) and GRW2015-19 (right). The scale only
applies to GRW2015-19 (modified from Frick, 1937).
38. A–C represents the ramus and tooth positioning of . . . 63
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).
39. Sinistral (upper) and top (bottom) views of the . . . 64
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.
40. *Carpocyon webbi*; A, lower teeth; B, ramus; A-B from . . . 65
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).
41. Distal fragment of right humerus (GRW2015-23) from . . . 67
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.

42. Lateral view of the distal portion the humerus of	68
vespertilionid bats. Left, distal portion of the humerus of a <i>Bauerus dubiaquercus</i> . Right distal portion of the humerus of GRW2015-23.	
43. Proximal and distal portions of the right humerus of a	69
bat <i>Karstala silva</i> (Miocene, Florida) part of the Vespertilionidae Family (modified from Czaplewski et al., 2008).	
44. Outline of forelobe of plastron of GRW2015-14 from	71
the Spider Hole Site within the Pojoaque Member (Middle Miocene: Late Barstovian), Rio Arriba County, New Mexico. Left, ventral view; right, dorsal view. Abbreviations: AC, acromial depression; ENT, entoplastron; EPI, epiplastron; ET, epiplastral tubercle; GHS, gular-humeral sulcus; GSO, gular scute overlap; HPS, humeral-pectoral sulcus; HSO, humeral scute overlap; HYO, hyoplastron; PAS, pectoral- abdominal sulcus. The solid line that outlines the epiplastral tubercle on the dorsal view does not indicate a separate scute but merely the robustness of the tubercle.	
45. Drawings of emydine turtles in ventral view	74
representing the forelobes of the plastra. A – <i>Clemmys guttata</i> ; B – <i>Glyptemys muhlenbergii</i> ; C – <i>Glyptemys insculpta</i> ; D – <i>Glyptemys valentinensis</i> ; E – GRW2015-14; F – <i>Emys orbicularis</i> ; G – <i>Emydoidea blandingii</i> ; H – <i>Terrapene carolina</i> . Not to scale (modified from Holman et al., 2001).	
46. X-ray diffraction results of UFR-01.. . . .	80
47. Legend for figures 49-55.	100
48. (1) Southern 1 st Wash Transect 1; (2) Sothern 1 st Wash	101
Transect 2; (3) Dead Horse Transect; (4) Cat Hill Transect; (5) North of Cat Hill Transect; (6) Northern 3 rd Wash Transect; (7) Northeastern 3 rd Wash Transect.	

49. Southern 1 st 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.	. .	102
50. Southern 1 st Wash Transect #2 – (2) This bed is more slope forming than cliff forming; (6) Transect ended at the top of the ridge.	. .	103
51. Dead Horse Transect – (9) 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 conglomerate 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.	. .	104
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.	. .	106

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 beds. 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.	107
54. Northern 3 rd 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.	108
55. Northeastern 3 rd 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.	109
56. Correlation chart of the 7 transects acquired during field studies. The datum is hung on the Cejita/Pojoaque Member contact.	110
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).	118

LIST OF TABLES

<u>No.</u>	<u>Page</u>
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 of on the surface, the general area where the sample was collected, and a brief description of the contents of each sample.	19
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 (<i>modified</i> Wang et al., 1999).	66
3. Skeletal characteristics of GRW2015-### 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 epiplastra, A = autapomorphic, D = derived, P = primitive, <i>gut</i> = <i>guttata</i> , <i>mar</i> = <i>marmorata</i> , <i>bla</i> = <i>blandingii</i> , <i>hutc</i> = <i>hutchisoni</i> , <i>orb</i> = <i>orbicularis</i> , <i>inscu</i> = <i>insculpta</i> , <i>muh</i> = <i>muhlenbergii</i> , <i>va</i> = <i>valentinensis</i> , <i>car</i> = <i>carolina</i> , <i>coa</i> = <i>coahuila</i> , <i>orn</i> = <i>ornata</i> . The diagnostic features were acquired from Holman et al. (2001), Holman (2002), and Angielczyk et al. (2010).	72

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, mastodonts 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.

Figure 3. Schematic diagram of the Santa Fe Group within the Española Basin including North American Land Mammal Ages (NALMA). This diagram is not to scale (modified from Barghoorn 1981).

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 on 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.

Figure 7. A–A sample is being pulverized using a porcelain mortar and pestle. B–The pulverized sediment is being run through a sieve. C–The sediment is being measured prior to being sent for XRD analyses.

Taxonomic Identification

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.

Sample Number	Date	In Place?	General Area	Description
GRW2015-01	7/1/2015	Surface	Second Wash	Juvenile <i>Merycodus</i> ? Jaw fragment, frog bones, misc. small mammal bones
GRW2015-02	7/1/2015	Surface	Second Wash	Horn core (<i>Cosoryx</i>) with skull fragment attached and a tooth fragment. Bone have red mud on them.
GRW2015-03	7/1/2015	Surface	First Wash	Rabbit p3 and astragales
GRW2015-04	7/1/2015	Surface	Second Wash	Horse tooth fragments, metatarsals (toe bone) and jaw fragments
GRW2015-05	7/2/2015	Surface	Second Wash	Camel? Jaw. Lots of fragments found in this area
GRW2015-06	7/3/2015	Surface	Second Wash	Turtle shell and oreodont? toe bone
GRW2015-07	7/3/2015	Surface	Second Wash?	Jaw fragment and end pieces of limbs
GRW2015-08	7/7/2015	Surface	First Wash	End piece of limb and shards
GRW2015-09	7/9/2015	Surface	Third Wash	Tooth fragment, jaw fragment and vertebrae
GRW2015-10	7/9/2015	Surface & in place	Third Wash	Small mud turtle with vertebrae and limb bones
GRW2015-11	7/9/2015	Surface	Third Wash	End piece of limb, toe bone, rib fragments and vertebrae
GRW2015-12	7/10/2015	Surface & in place	First Wash	Jaw (camel? pronghorn?) there is a pie with this bag. Many limbs (at least 6)
GRW2015-13	7/10/2015	Surface	First Wash	Horn core of <i>Merycodus</i>
GRW2015-14	7/12/2015	Surface & in place	Spider Hole	"Black turtle" <i>Glyptemys valentinensis</i>
GRW2015-15	7/12/2015	Surface	Spider Hole	Turtle fragments
GRW2015-16	7/12/2015	Surface & in place	Spider Hole	Large bones including teeth and jaw fragments (probably more than one animal in the bag)
GRW2015-17	7/12/2015	Surface	Spider Hole	Beaver jaw, vertebrae and other bone fragments found near the jaw
GRW2015-18	7/12/2015	Surface	Spider Hole	Beaver jaw (unrelated to GRW2015-17)
GRW2015-19	7/12/2015	Surface	Spider Hole	Horn cores (left and right) of <i>Ranoceros</i>
GRW2015-20	7/12/2015	Surface	Spider Hole	Camel? jaw fragment (canine tooth on jaw)
GRW2015-21	7/12/2015	Surface	Spider Hole	Large vertebrae
GRW2015-22	7/12/2015	Surface	Spider Hole	Tooth found near camel? jaw (GRW2015-20) unrelated
GRW2015-23	7/12/2015	Surface	Spider Hole	Small limbs and teeth (bird, rodent, and bat - Vespertilionidae-Antrozoinae)
GRW2015-24	7/13/2015	Surface	Third Wash	"Toothless" jaw fragment of <i>Carpocyon webbi</i>
GRW2015-25	7/13/2015	Surface & in place	Third Wash	Sharp pointy teeth locality with pie. Lots of bone/jaw fragments
GRW2015-26	7/15/2015	In place	Third Wash	Whole limb bone broken in 2 place. There are 3 pieces and the middle piece is splintered
GRW2015-27	7/13/2015	Surface	Third Wash	End of limb piece fragments
GRW2015-28	7/13/2015	Surface	Third Wash	Small pelvis fragment
GRW2015-29	7/12/2015	Surface	Spider Hole	Large limb bones and vertebrae

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 contained 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).

CROSS-SECTION EXPLANATION

CHAMITA FORMATION

Tccu	Coarse, upper lithosome A unit of Chamita Fm
Tch	Hernandez member
Tcce	Cejita Member, east of Rio Grande it is part of Tesuque Fm
Tcv	Vallito member

ABIQUIU & PICURIS FORMATIONS

Tap	Undivided Abiquiu and Picuris Formations
-----	--

PROTEROZOIC ROCKS

Pzu	Undifferentiated Paleozoic rocks
-----	----------------------------------

PROTEROZOIC ROCKS

Xyu	Undifferentiated Proterozoic rocks
-----	------------------------------------

TESUQUE FORMATION

Tccu	Coarse, upper lithosome A unit of Tesuque Fm
Ttbc	Cejita Member, east of Rio Grande it is part of Chamita Fm
Tto	Ojo Caliente Sandstone
Ttbp1-2	Lower and upper, mixed and/or interfingering lithosomes A and B of Pojoaque Member
Ttch	Chama-Ei Rito Member
Ttbp2	Upper lithosome B unit of the Pojoaque Member
Ttbp3n	Lithosome B, Pojoaque-Skull Ridge-Nambe Members

TEPHRA ZONES

x x x x x	Chamita upper tuffaceous zone (Peralta tuff, 6.8-6.9 Ma)
••••••••••	Chamita lower tuffaceous zone (7.7-8.4 Ma)
••••••••••	Española tephra zone (10.2-12.4 Ma); most tephra are probably between 10.2-11.5
o o o o o o o o o o	main coarse white ash zone (generally 12.0-12.8 Ma)
□ □ □ □ □ □ □ □	Pojoaque white ash zone (13.2-14.0 Ma)

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

Epoch	NALMA	Formation	Member	Lithosome
Miocene	late	Clarendonian	Cuarteles	A
			Ojo Caliente Cejita	
	middle	Barstovian	Chama el Rito	A & B
			Pojoaque	
	early		Skull Ridge	A & B
			Nambé	

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).

Figure 13. Geologic time scale with North American Land Mammal Ages (NALMA) and affiliated age ranges (adapted from Riddle et al., 2014).

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

Figure 14. A model depicting the sediment dispersal system in the Española Basin during deposition (adapted from Cavazza, 1986).

Rift in the late Cenozoic. Lithosome B displays consistent south-southwest-directed paleocurrents and is characterized by a substantial quantity of volcanoclastic and sedimentoclastic 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).

Figure 15. Photograph representing lithosome A. Note the channel sandstone bed toward the base of the cliff.

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

Figure 19. The major geologic structures are represented by the white lines, with the small perpendicular bars indicating throw direction of normal and normal-oblique faults. Faults are abbreviated as: PFZ = Pajarito fault zone, SCF = Santa Clara fault, OCF = Ojo Caliente fault, BMF = Black Mesa fault, LMF = La Mesita fault, EF = Embudo fault, SDCF = Sangre de Cristo fault and PPF = Pecos-Picuris fault (adapted from Koning et al., 2005).

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 (Baldrige 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 20. Faults with a miniscule amount of displacement. Note rock hammer for scale.

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; 1980) 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.

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

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).

river 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

Figure 25. Plot of stable isotopes of oxygen and climatic interpretations (modified from Koning et al., 2005).

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).

- (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 Antilocapridæ 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.

Genus – *Merycodus* (= *Meryceros*, Frick, 1937)

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 F:A.M.31454 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.

Figure 37. Posterior views of F:A.M.31619 and F:A.M.31624 representing *Ramoceros* (*Paramoceros*) *marthæ* (left) and GRW2015-19 (right). The scale only applies to GRW2015-19 (modified from Frick, 1937).

Order – Carnivora
 Suborder – Caniformia
 Infraorder – Cynoidea
 Family – Canidae
 Subfamily – Borophaginae
 Genus – *Carpocyon*
 Species – *C. webbi*

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).

Genus/Species	Body Size	BL	Lp1	Lp2	Lp3	Lp4	Wp4	Lm1	Wm1tr	Wm1t1	Lm2	Wm2
GRW2015-24			4.74	8.35	9.99	11.46	6.45	21.48	8.37	8.21	12.02	6.51
<i>Aelurodon ferox</i>	Large											
Mean		216.21	7.55	11.39	13.42	16.52	9.46	28.24	10.96	9.94	12.01	8.24
Standard Deviation		12.68	1.19	1.00	1.13	1.35	0.87	1.59	0.75	0.65	0.92	0.58
Coefficient of Variation		5.86	15.79	8.75	8.45	8.15	9.15	5.64	6.86	6.53	7.65	7.01
Maximum		243.00	9.60	13.50	16.20	21.00	11.60	32.50	12.70	11.50	14.50	9.80
Minimum		197.00	5.30	9.40	11.00	13.90	7.80	24.20	9.40	8.50	9.70	7.20
Number		14	18	58	68	80	70	86	70	74	66	61
<i>Aelurodon stirtoni</i>	Large											
Mean		174.33	6.25	9.16	11.18	14.18	9.25	24.69	10.13	8.48	8.90	7.12
Standard Deviation		2.05	0.75	0.59	0.70	0.89	0.59	1.13	0.66	0.44	0.92	0.50
Coefficient of Variation		1.18	12.00	6.45	6.25	6.30	6.38	4.57	6.54	5.18	10.35	6.96
Maximum		177.00	7.00	10.40	12.10	15.70	10.00	26.20	11.60	9.10	10.00	7.80
Minimum		172.00	5.50	8.30	10.00	12.60	8.30	22.30	9.40	7.80	7.50	6.20
Number		3	2	9	11	11	11	12	11	12	10	10
<i>Carpocyon webbi</i>	Large											
Mean		205.00	5.90	9.51	11.22	13.45	7.60	24.65	9.55	9.65	13.29	8.26
Standard Deviation		0.00	0.10	0.79	0.90	0.86	0.44	1.70	0.65	0.56	0.74	0.24
Coefficient of Variation		0.00	1.69	8.34	8.06	6.37	5.80	6.90	6.84	5.84	5.57	2.95
Maximum		205.00	6.00	10.70	12.20	14.80	8.20	27.50	10.60	10.50	14.50	8.60
Minimum		205.00	5.80	8.30	9.50	11.50	6.70	21.50	8.50	8.50	11.80	7.90
Number		1	2	10	6	13	11	16	11	13	16	13
<i>Tomarctus hippophaga</i>	Small											
Mean		161.63	4.35	7.99	9.30	11.19	6.23	19.84	7.72	8.07	10.52	6.75
Standard Deviation		11.54	0.49	0.49	0.53	0.62	0.52	1.22	0.57	0.48	0.68	0.44
Coefficient of Variation		7.14	11.20	6.09	5.69	5.51	8.40	6.14	7.42	5.94	6.47	6.52
Maximum		186.00	5.70	8.80	10.30	12.50	7.40	22.50	9.10	9.20	12.50	7.50
Minimum		145.00	3.40	6.00	8.00	9.40	4.90	16.50	6.30	7.10	8.60	5.80
Number		8	22	60	69	90	82	113	94	97	73	59

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.

Figure 42. Lateral view of the distal portion the humerus of vespertilionid bats. Left, distal portion of the humerus of a *Bauerus dubiaquercus*. Right distal portion of the humerus of GRW2015-23.

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-hyoplastral 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).

Figure 44. Outline of forelobe of plastron of GRW2015-14 from the Spider Hole Site within the Pojoaque Member (Middle Miocene: Late Barstovian), Rio Arriba County, New Mexico. Left, ventral view; right, dorsal view. Abbreviations: AC, acromial depression; ENT, entoplastron; EPI, epiplastron; ET, epiplastral tubercle; GHS, gular-humeral sulcus; GSO, gular scute overlap; HPS, humeral-pectoral sulcus; HSO, humeral scute overlap; HYO, hyoplastron; PAS, pectoral-abdominal sulcus. The solid line that outlines the epiplastral tubercle on the dorsal view does not indicate a separate scute but merely the robustness of the tubercle.

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).

Genera Species Characters	<i>Clemmys</i> :		<i>Emydoidea</i> :		<i>Emys</i> :	<i>Glyptemys</i> :			<i>Terrapene</i> :		
	<i>gut</i>	<i>mar</i>	<i>bla</i>	<i>hutc</i>	<i>orb</i>	<i>inscu</i>	<i>muh</i>	<i>va</i>	<i>caro</i>	<i>coah</i>	<i>orn</i>
ovoid plastral shape	X	X	✓	✓	X	X	X	✓	✓	✓X	X
oval acromial excavations on epiplastra	✓	✓	✓	✓*	✓	✓	✓	✓	✓	✓	✓
pronounced epiplastral tubercle	✓V	✓V	✓W	✓V	✓M	✓M	✓V	✓	✓M	✓V	✓W
posterior end of entoplastron crossed by humeral-pectoral sulcus	X	✓	✓X	✓X	✓	✓	✓	✓	✓	✓	✓
pectoral scute overlaps hyoplastron dorsally	✓	✓	✓	X	✓X	✓	✓	✓	✓X	✓	✓X
bell shaped entoplastron	X	X	X	X	X	✓	X	✓	X	X	X
akinetetic plastron	✓	✓	✓	✓	X	✓	✓	✓	X	X	X

Table 3. Skeletal characteristics of GRW2015-### 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 epiplastra, 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)

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 plastra 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 entoplastron 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

Figure 45. Drawings of emydine turtles in ventral view representing the forelobes of the plastra. A – *Clemmys guttata*; B – *Glyptemys muhlenbergii*; C – *Glyptemys insculpta*; D – *Glyptemys valentinensis*; E – GRW2015-14; F – *Emys orbicularis*; G – *Emydoidea blandingii*; H – *Terrapene carolina*. Not to scale (modified from Holman et al., 2001).

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 ocotonid 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 locactions range from the bottom to the top of the member.

Many of the previous authors stratigraphic studies conflicted or it was difficult to correlate 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 sedimentastic 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 studied, 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

- Aby, S. B., Morgan, G. S., and Koning, D. J., 2011, A paleontological survey of a part of the Tesuque Formation near Chimayó, New Mexico, and a summary of the biostratigraphy of the Pojoaque Member (Middle Miocene, Late Barstovian): *in* New Mexico Geological Society Guidebook, 62nd Field Conference, Geology of the Tusas Mountains-Ojo Caliente, p. 347-358.
- Angielczyk, K. D., Feldman, C. R., and Miller, G. R., 2010, Adaptive evolution of plastron shape in Emydine turtles: *Evolution*, v. 65, no. 2, p. 377-394.
- Axelrod, D. I. and Bailey, H. P., 1976, Tertiary vegetation, climate, and altitude of the Rio Grande Depression, New Mexico-Colorado: *Paleobiology*, v. 2, p. 235-254.
- Baker, V. R., 1978, Adjustment of fluvial systems to climate and source terrain in tropical and subtropical environments: *in* Miall, A. D. (Ed.), *Fluvial Sedimentology*: Canadian Society of Petroleum Geologists Memoir 5, Calgary, p. 211-230.
- Baldrige, W. S., Ferguson, J. F., Braile, L. W., Wang, B., Eckhardt, K., Evans, D., Schultz, C., Gilpin, B., Jiracek, G., and Biehler, S., 1994, The western margin of the Rio Grande Rift in northern New Mexico: An aborted boundary?: *Geological Society of America Bulletin*, v. 105, p. 1538-1551.
- Barghoorn, S., 1981, Magnetic-polarity stratigraphy of the Miocene type Tesuque Formation, Santa Fe Group, in the Española Valley, New Mexico: *Geological Society of America Bulletin*, v. 92, p. 1027-1041.
- Barghoorn, S., 1985, Magnetic polarity stratigraphy of the Tesuque Formation, Santa Fe Group in the Española Valley, New Mexico, with a taxonomic review of the fossil camels [PhD dissertation]: Columbia University, New York, 430 p.
- Baskin, J. A., 1998, Chapter 9. Mustelidae; *in* Janis, C. M., Scott, K. M., and Jacobs, I. L., eds., *Evolution of Tertiary Mammals of North America*, v. 1: Terrestrial Carnivores, Ungulates, and Ungulatelike Mammals: Cambridge, Cambridge University Press, p. 152-173.

- Baxter, K., 2004, Extrinsic factors that effect the preservation of bone: Nebraska Anthropologist, vol. 62.
- Bourque, J., 2012, An extinct mud turtle of the *Kinosternon flavescens* group (Testudines, Kinosternidae) from the middle Miocene (late Barstovian) of New Mexico: Journal of Vertebrate Paleontology, v. 32, no. 1, p. 68-81.
- Brinkman, P., 2009, Modernizing American fossil preparation at the turn of the 20th century: *in* Brown, M. A., Kane, J. F., and Parker, W. G., eds., Methods In Fossil Preparation: Proceedings of the First Annual Fossil Preparation and Collections Symposium, p. 21-34.
- Bryan, K., 1938, Geology and ground-water conditions of the Rio Grande depression in Colorado and New Mexico: Washington, Regional Planning, pt. 6, Rio Grande Joint Investigation in the Upper Rio Grande Basin, National Resources Committee, v. 1, pt. 2, sect. 1, p. 197-225.
- Burnett, A. W. and Schumm, S. A., 1983, Alluvial river response to neotectonic deformation in Louisiana and Mississippi: Science, v. 222, p. 49-50.
- Cavazza, W., 1986, Miocene sediment dispersal in the central Española Basin, Rio Grande Rift, New Mexico, USA: Sedimentary Geology, v. 51, p. 119-135.
- Cavazza, W., 1989, Sedimentation pattern of a rift-filling unit, Tesuque Formation (Miocene), Española Basin, Rio Grande Rift, New Mexico: Journal of Sedimentary Petrology, v. 59, no. 2, p. 287-296.
- Chaney, D. S., 2009, A brief overview of the geology, taphonomy, and paleoenvironment of the Jacona Microfauna (Miocene, late Barstovian), Pojoaque Member, Tesuque Formation, north-central New Mexico: Museum of Northern Arizona, Bulletin 65, p. 185-196.
- 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.

- Cope, E. D., 1875a, Report on the geology of that part of north-western New Mexico examined during the field season of 1875: *in* Wheeler, G. M., Annual report upon the geographical explorations and surveys west of the one hundredth meridian, in California, Nevada, Nebraska, Utah, Arizona, Colorado, New Mexico, Wyoming, and Montana. Washington, App. LL Annual Report Chief of Engineers for 1875, App. GI, p. 61-97.
- Cope, E. D., 1875b, On some new fossil Ungulata: Academy of Natural Sciences, Philadelphia Proceedings 27, p. 258-261.
- Cope, E. D., 1877, Report upon the extinct Vertebrata obtained in New Mexico by parties of the expedition of 1874, *in* Wheeler, G. M., Report upon United States Geological Surveys West of the One Hundredth Meridian: Washington, v. 4, pt. 2, p. 1-370.
- Czaplewski, N. J., Morgan, G. S., and McLeod, S. A., 2008, Chapter 12. Chiroptera: *in* C. M., Janis, Gunnell, G. E., and Uhen, M. D., (eds.), Evolution of Tertiary Mammals of North America. Volume 2: Small mammals, xenarthrans, and marine mammals, Cambridge University Press, Cambridge, p. 174-197.
- Davis, E. B., 2007, Family Antilocapridae: *in* Prothero, D. and S. Foss (eds.), The Evolution of the Artiodactyls, Johns Hopkins University Press, Baltimore, p. 227-240.
- Denny, C. S., 1940, The Santa Fe Formation in the Española Valley, New Mexico: Geological Society of American Bulletin, v. 51, pt. 4, p. 677-694.
- Dethier, D. P., and Martin, B., 1984, Geology and structure along part of the north-east Jemez Mountains, New Mexico: New Mexico Geological Society, 35th Field Conference Guidebook, p. 145-150.
- Dethier, D. P., and Manely, K., 1985, Geologic map of the Chili quadrangle, Rio Arriba County, New Mexico: U. S. Geological Survey, Miscellaneous Field Studies Map MF-1814, scale 1:24,000.
- Einsele, G., 2000, Sedimentary Basins: Evolution, Facies, and Sediment Budget: Berlin, Springer, 791 p.

- Ekas, L. M., Ingersoll, R. V., Baldrige, W. S., and Shafiqullah, M., 1984, The Chama-El Rito Member of the Tesuque Formation, Española Basin, New Mexico: New Mexico Geological Society, 35th Field Conference Guidebook, p. 137-143.
- Ernst, C. H., Barbour, R. W., and Lovich, J. E., 1994, Turtles of the United States and Canada: Washington, Smithsonian Institution, 578 p.
- Foote, M. J., Miller, A. I., Raup, D. M., and Stanley, S. M., 2007, Principles of Paleontology: W. H. Freeman and Company, 371 p.
- Franklin, C. J., 2007, Turtles: An Extraordinary Natural History 245 Million Years in the Making: St. Paul, MN, Voyageur, 165 p.
- Frick, C., 1926a, Prehistoric evidence: Natural History, v. 26, p. 440-448.
- Frick, C., 1926b, The Hemicyoninae and an American Tertiary bear: Bulletin of the American Museum of Natural History, v. 56, p. 1-119.
- Frick, C., 1933, New remains of trilophodont-tetrabelodont mastodons: Bulletin of the American Museum of Natural History, v. 59, p. 505-652.
- Frick, C., 1937, Horned ruminants of North America: Bulletin of the American Museum of Natural History, v. 69, p. 1-669.
- Gaffney, E. S. and Meylan, P. A., 1988, A phylogeny of turtles: *in* Benton, M. J. (ed.): The Phylogeny and Classification of the Tetrapods, Volume 1: Amphibians, Reptiles, Birds: Oxford Clarendon Press, p. 157-172.
- Galusha, T., and Blick, J. C., 1971, Stratigraphy of the Santa Fe Group, New Mexico: Bulletin of the American Museum of Natural History, v. 144, 127 p.
- Garner, H. F., 1959, Interpretation of globally distributed anastomosing channel drainages: Geological Society of America Bulletin, v. 70, no. 12, 1607 p.
- Garner, H. F., 1967, Rivers in the making: Scientific America, v. 216, p. 84-94.
- Gary S. Morgan and Nicholas J. Czaplewski, e-mail to author, January 7, 2016.

- Golombek, M. P., 1983, Geology, structure, and tectonics of the Pajarito fault zone in the Española Basin of the Rio Grande rift, New Mexico: Geological Society of America Bulletin, v. 94, p. 192-205.
- Harrington, C. D., and Aldrich, M. L., 1984, Development and deformation of Quaternary surfaces on the northeastern flank of the Jemez Mountains: New Mexico Geological Society, 35th Field Conference Guidebook, p. 235-239.
- Hayden, F. V., 1869, Preliminary field report of the United States geological survey of Colorado and New Mexico: Washington, Government Printing Office, p. 1-99.
- Holman, J. A. and Fritz, U., 2001, A new emydine species from the Medial Miocene (Barstovian) of Nebraska, USA with a new generic arrangement for the species of *Clemmys* sensu McDowell (1964) (Reptilia: Testudines: Emydidae): Zoologische Abhandlung Staatliches Museum Für Tierkunde Dresden, v. 51, no. 19, p. 321-344.
- Holman, J. A., 2002, Additional specimens of the Miocene turtle *Emydoidea hutchisoni* Holman 1995 – New temporal occurrences, taxonomic characters, and phylogenetic inferences: Journal of Herpetology, v. 36, no. 3, p. 436-446.
- Honey, J. G., Harrison, J. A., Prothero, D. R., and Stevens, M. S., 1998, Chapter 30, Camelidae; in Janis, C. M., Scott, K. M., and Jacobs, L. L., eds., Evolution of Tertiary Mammals of North America, v. 1: Terrestrial Carnivores, Ungulates, and Ungulatelike Mammals: Cambridge, Cambridge University Press, p. 439-462.
- Hunt, R. M., Jr., 1998a, Chapter 10, Ursidae; in Janis, C. M., Scott, K. M., and Jacobs, L. L., eds., Evolution of Tertiary Mammals of North America, v. 1: Terrestrial Carnivores, Ungulates, and Ungulatelike Mammals: Cambridge, Cambridge University Press, p. 174-195.
- Hunt, R. M., Jr., 1998b, Chapter 11, Amphicyonidae; in Janis, C. M., Scott, K. M., and Jacobs, L. L., eds., Evolution of Tertiary Mammals of North America, v. 1: Terrestrial Carnivores, Ungulates, and Ungulatelike Mammals: Cambridge, Cambridge University Press, p. 196-227.

- Janis, C. M., and Manning, E., 1998a, Chapter 32, Dromomerycidae; *in* Janis, C. M., Scott, K. M., and Jacobs, L. L., eds., *Evolution of Tertiary Mammals of North America*, v. 1: Terrestrial Carnivores, Ungulates, and Ungulatelike Mammals: Cambridge, Cambridge University Press, p. 477-490.
- Janis, C. M., and Manning, E., 1998b, Chapter 33, Antilocapridae; *in* Janis, C. M., Scott, K. M., and Jacobs, L. L., eds., *Evolution of Tertiary Mammals of North America*, v. 1: Terrestrial Carnivores, Ungulates, and Ungulatelike Mammals: Cambridge, Cambridge University Press, p. 491-507.
- Jansinski, S. E., 2015, Middle Miocene carnivora of New Mexico (Tesuque Formation): species patterns, richness, and faunal turnover: *in* Sullivan, R. M., and Lucas, S. G., eds., 2015, *Fossil Record 4: New Mexico Museum of Natural History and Science Bulletin* 67, p. 89-106.
- Kelley, V. C., 1978, *Geology of the Española Basin, New Mexico*: New Mexico Bureau of Mines and Mineral Resources, Geologic Map 48, scale 1:125,000.
- Kidwell, S. M., 1986, Models for fossil concentrations: paleobiologic implications: *Paleobiology*, vol. 12, no. 1, p. 6-24.
- Koning, D. J., and Maldonado, F., 2001, Geologic map of the Horcado Ranch quadrangle, Santa Fe county, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-file Geologic Map OF-GM-54, scale 1:24,000.
- Koning, D. J., 2002, revised July-2005, Geology of the Española 7.5-minute quadrangle and implications regarding middle Miocene deposition and tectonism in the Ro Grande rift, north-central New Mexico: *New Mexico Geology [abstract]*, v. 42, no. 2, p. 63.
- Koning, D. J., Nyman, M., Horning, R., Eppes, M., and Rogers, S., 2002, Geology of the Cundiyo 7.5-min, quadrangle, Santa Fe County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-file Geologic Map OF-GM-56, scale 1:24,000.
- Koning, D. J., 2003, revised July-2005, Geologic map of the Chimayó 7.5-minute quadrangle, Rio Arribo and Santa Fe counties, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-file Geologic Map OF-GM-71, scale 1:24,000.

- Koning, D. J., and Manley, K., 2003, revised July-2005, Geologic map of the San Juan Pueblo quadrangle, Rio Arriba and Santa Fe counties, New Mexico: New Mexico Bureau of Geology and Mineral Resources, Open-file Geologic Map OF-GM-70, scale 1:24,000.
- Koning, D. J., 2004, Geologic map of the Lyden 7.5-minute quadrangle, Rio Arriba and Santa Fe counties, New Mexico: New Mexico Bureau of Geology and Mineral Resources, Open-file Geologic Map OF-GM-54, scale 1:24,000.
- Koning, D. J., Ferguson, J. F., Paul, P. J., and Baldrige, W. S., 2004a, Geologic structure of the Velarde graben and southern Embudo fault system, north-central N.M.: New Mexico Geological Society, 55th Field Conference Guidebook, p. 158-171.
- Koning, D. J., May, J., Aby, S., and Horning, R., 2004b, Geologic map of the Medanales 7.5-minute quadrangle, Rio Arriba county, New Mexico: New Mexico Bureau of Geology and Mineral Resources, Open-file Geologic Map OF-GM-89, scale 1:24,000.
- Koning, D. J., Connell, S. D., Morgan, G. S., Peters, L., and McIntosh, W. C., 2005, Stratigraphic and depositional trends in the Santa Fe Group near Española, north-central New Mexico: tectonic and climatic implications: *in* New Mexico Geological Society, 56th Field Conference Guidebook, Geology of the Chama Basin, p. 237-257.
- Koning, D. J., Connell, S. D., Slate, J. L., and Wan, E., 2007, Stratigraphic constraints for Miocene-age vertical motion along the Santa Clara Fault, Española Basin, north-central New Mexico: *in* New Mexico Geological Society Guidebook, 58nd Field Conference, Geology of the Jemez Mountains Region II, p. 225-238.
- Koning, D. J., Grauch, V. J. S., Connell, S. D., Ferguson, J., McIntosh, W., Slate, J. L., Wan, E., Baldrige, W. S., 2013, Structure and tectonic evolution of the eastern Española Basin, Rio Grande rift, north-central New Mexico, *in* Hudson, M. R., and Grauch, V. J. S., eds., *New Perspectives on Rio Grande Basins: From Tectonics to Groundwater*: Geological Society of America Special Paper 494, p. 185-219.
- Korth, W. W. and Chaney, D. S., 1999, A new subfamily of geomyoid rodents (Mammalia) and a possible origin of Geomyidae: *Journal of Paleontology*, v. 73, p. 1191-1200.

- Korth, W. W., 2002, Topotypic cranial material of the beaver *Monosaulax pansus* Cope (Rodentia, Castoridae): *Paludicola*, v. 4, p. 1-5.
- 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.
- Korth, W. W., 2008b, Cranial morphology, systematics and succession of beavers from the middle Miocene Valentine Formation of Nebraska, USA: *Acta Palaeontologica Polonica*, v. 53, no. 2, p. 169-182.
- Kues, B. S., Ingersoll, R. V. and Lucas, S. G., 1978, Paleontological survey, resource assessment, and mitigation plan for the southern half of the Rio Grande Resource Area, north-central New Mexico: Report to U. S. Bureau of Land Management, Albuquerque, 298 p.
- Kues, B. S. and Lucas, S. G., 1979, Summary of the paleontology of the Santa Fe Group (Mio-Pliocene), North-Central New Mexico: *in* New Mexico Geological Society 30th Annual Fall Field Conference Guidebook, p. 237-241.
- Kues, B. S., 1993, Bibliographic catalogue of New Mexico vertebrate fossils: *in* Lucas, S. G. and Zidek, J., (eds.), *Vertebrate Paleontology in New Mexico*, Bulletin of the New Mexico Museum of Natural History and Science, no. 2, p. 199-280.
- Lambert, W. D., and Shoshani, J., 1998, Chapter 42, Proboscidea; *in* Janis, C. M., Scott, K. M., and Jacobs, L. L., eds., *Evolution of Tertiary Mammals of North America*, v. 1: Terrestrial Carnivores, Ungulates, and Ungulatelike Mammals: Cambridge, Cambridge University Press, p. 606-621.
- Lander, B., 1998, Chapter 27, Oreodontoidea; *in* Janis, C. M., Scott, K. M., and Jacobs, L. L., eds., *Evolution of Tertiary Mammals of North America*, v. 1: Terrestrial Carnivores, Ungulates, and Ungulatelike Mammals: Cambridge, Cambridge University Press, p. 402-425.
- Lee, W. T., 1907, Water resources of the Rio Grande Valley in New Mexico and their development: U. S. Geological Survey Water-Supply Paper 188, p. 1-59.
- Leininger, M. R., 1982, Cenozoic evolution of the southernmost Taos Plateau, New Mexico [M.S. thesis]: Austin, University of Texas, 110 p.

- Lo, H.-J., Song, S.-R., and Wen, S. -B., 1991, High potassium mordenite in the andesite from the Coastal Range, eastern Taiwan: *Proc. Geological Society, China (Taiwan)*, v. 24, p. 293-304.
- Lyman, R. L., 1994, *Vertebrate Taphonomy*: Cambridge University Press, 524 p.
- MacFadden, B. J., 1998, Chapter 37, Equidae; *in* Janis, C. M., Scott, K. M., and Jacobs, L. L., eds., *Evolution of Tertiary Mammals of North America*, v. 1: Terrestrial Carnivores, Ungulates, and Ungulatelike Mammals: Cambridge, Cambridge University Press, p. 537-559.
- Makaske, B., 2001, Anastomosing rivers: a review of their classification, origin and sedimentary products: *Earth-Science Reviews*, v. 53, p. 149-196.
- Manley, K., 1976, The Late Cenozoic history of the Española Basin, New Mexico [Ph.D. dissertation]: University of Colorado, 171 p.
- Manley, K., 1977, Geologic map of the Cejita Member (new name) of the Tesuque Formation, Española Basin, New Mexico: U. S. Geological Survey Miscellaneous Field Studies Map MF-877, scale 1:24,000.
- May, J., 1980, Neogene geology of the Ojo Caliente-Rio Chama area, Española Basin, New Mexico [Ph.D. dissertation]: Albuquerque, New Mexico, University of New Mexico, 204 p.
- May, J., 1984, Miocene stratigraphic relations and problems between the Abiquiu, Los Pinos, and Tesuque Formations near Ojo Caliente, northern Española Basin: *New Mexico Geological Society, 35th Field Conference Guidebook*, p. 129-135.
- McCarthy, T. S., 1993, The great inland deltas of Africa: *Journal of African Earth Sciences*, v. 17, p. 275-291.
- Ouchi, S., 1985, Response of alluvial rivers to slow active tectonic movement: *Geological Society of America Bulletin*, v. 96, p. 504-515.
- Petticrew, E. L., and Kalff, J., 1991, Predictions of surficial sediment composition in the littoral zone of lakes: *Limnology and Oceanography*, v. 36, no. 2, p. 384-392.

- Prothero, D. R., 1998, Chapter 42, Rhinocerotidae; *in* Janis, C. M., Scott, K. M., and Jacobs, L. L., eds., *Evolution of Tertiary Mammals of North America*, v. 1: Terrestrial Carnivores, Ungulates, and Ungulatelike Mammals: Cambridge, Cambridge University Press, p. 595-605.
- Prothero, D. R., 2005, *The Evolution of North American Rhinoceroses*: Cambridge University Press, 219 p.
- Prothero, D. R., 2008, Systematics of the musk deer (Artiodactyla: Moschidae: Blastosomerycinae) from the Miocene of North America: *New Mexico Museum of Natural History and Science, Bulletin* 44, p. 207-223.
- Prothero, D. R., and Liter, M. R., 2008, Systematics of the dromomerycines and aletomerycines (Artiodactyla: Palaeomerycidae) from the Miocene and Pliocene of North America: *New Mexico Museum of Natural History and Science, Bulletin* 44, p. 273-298.
- Rich, T. H. V., 1981, Origin and history of the Erinaceinae and Brachyericinae (Mammalia, Insectivora) in North America: *Bulletin of the American Museum of Natural History*, v. 171, p. 1-116.
- Riddle, B. R., Jezkova, T., Hornsby, A. D., and Matocq, M. D., 2014, Assembling the modern Great Basin mammal biota: insights from molecular biogeography and the fossil record: *Journal of Mammalogy*, v. 95, no. 6, p. 1107-1127.
- Rothwell, T., 2003, Phylogenetic systematics of North American *Pseudaelurus* (Carnivora: Felidae): *American Museum Novitates*, no. 3403, 64 p.
- Sawyer, D. A., 2004, Processed Landsat 7 satellite imagery of the Española Basin region, New Mexico: U. S. Geological Survey Open-File Report 2004-1040A.
- Schultz, C. B., and Falkenbach, C. H., 1941, Ticholeptinae, a new subfamily of oreodonts: *Bulletin of the American Museum of Natural History*, v. 79, p. 1-105.
- Schumm, S. A., 1968, Speculations concerning paleohydraulic controls on terrestrial sedimentation: *Geological Society of America Bulletin* 79, p. 1573-1588.

- Smith, D. G., 1983, Anastomosed fluvial deposits: modern examples from Western Canada: *in* Collinson, J., Lewin, J (eds.), *Modern and Ancient Fluvial Systems: Special Publication of the International Association of Sedimentologists*, Blackwell, Oxford, v. 6, p. 155-168.
- Smith, D. G., 1986, Anastomosing river deposits, sedimentation rates and basin subsidence, Magdalena River, northwestern Colombia, South America: *Sedimentary Geology*, v. 46, p. 177-196.
- Smith, D. G. and Putnam, P. E., 1980, Anastomosed river deposits: modern and ancient examples in Alberta, Canada: *Canadian Journal of Earth Sciences*, v. 17, p. 1396-1406.
- Sena, A. and Thomas, T., 1989, A giant land tortoise (*Geochelone*) from the Santa Fe Group (Miocene), near Española, New Mexico: *New Mexico Journal of Science*, v. 29, no. 2, p. 69-78.
- Simmons, N. B. and Conway, T. M., 2001, Phylogenetic relationships of Mormoopid bats (Chiroptera: Mormoopidae) based on morphological data: *Bulletin of the American Museum of Natural History*, no. 258, 97 p.
- Spiegel, Z., and Baldwin, B., 1963, Geology and water resources of the Santa Fe area, New Mexico: U. S. Geological Survey Water Supply Paper 1525, 258 p.
- Steinpress, M. G., 1980, Neogene stratigraphy and structure of the Dixon area, Española Basin, north-central New Mexico [M.S. thesis]: University of New Mexico, Albuquerque, N. M., 127 p.
- Steinpress, M. G., 1981, Neogene stratigraphy and structure of the Dixon area, Española Basin, north-central New Mexico: *Geological Society of America Bulletin, Part II*, v. 92, no. 12, p. 2553-2671.
- Taylor, B. E. and Webb. S. D., 1976, Miocene Leptomerycidae (Artiodactyla, Ruminantia) and their relationships: *American Museum Novitates*, no. 2596, 1-22.
- Tedford, R. H., and Barghoorn, S., 1993, Neogene stratigraphy and mammalian biochronology of the Española Basin, northern New Mexico: *Vertebrate Paleontology in New Mexico*, New Mexico Museum of Natural History and Science, Bulletin 2, p. 159-168.

- Tedford, R. H., and Barghoorn, S., 1997, Miocene mammals of the Española and Albuquerque basins, north-central New Mexico: *in* Lucas, S. G., Kalep, J. W., Williamson, T. E. and Morgan, G. S. eds., 1997, New Mexico's Fossil Record 1, New Mexico Museum of Natural History and Science Bulletin, no. 11, p. 77-96.
- Tedford, R. H., Albright, III, L. B., Barnosky, A. D., Ferrusquia-Villafrance, I., Hunt, Jr., R. M., Storer, J. E., Swisher, III, C. C., Voorhies, M. R., Webb, S. D., and Whistler, D. P., 2004, Mammalian biochronology of the Arikareean through Hemphillian interval (late Oligocene through early Pliocene epochs): *in* Woodburne, M. O., Late Cretaceous and Cenozoic mammals of North America: Biostratigraphy and Geochronology. Columbia University Press, New York, p. 169-231.
- Tedford, R. H., Wang, X., and Taylor, B. E., 2009, Phylogenetic systematics of the North American fossil Caninae (Carnivora: Canidae): Bulletin of the American Museum of Natural History, no. 11, p. 77-95.
- Thewissen, J. G. M. and Smith, G. R., 1987, Vespertilionid bats (Chiroptera, Mammalia) from the Pliocene of Idaho: Contributions from the Museum of Paleontology, The University of Michigan, v. 27, no. 9, p. 237-245.
- Tobien, H., 1973, On the evolution of mastodonts (Proboscidea, Mammalia), part 1: The bunodont trilophodont groups: Notizblatt des Hessischen Landesamtes für Bodenforschung zu Wiesbaden, v. 101, p. 202-276.
- Truchan J. J., 2009, Genesis of carbonate lakes on perennial siliciclastic floodplains [Master's thesis]: Ohio University, 112 p.
- USGS, 2002, San Juan Pueblo Quadrangle, New Mexico: U. S. Geological Survey, scale 1:24 000, 1 sheet.
- Wang, X., Tedford, R. H., and Taylor, B. E., 1999, Phylogenetic systematics of the Borophaginae (Carnivora: Canidae): Bulletin of the American Museum of Natural History, no. 243, 391 p.
- Webb, S. D., 1998, Chapter 31, Hornless ruminants; *in* Janis, C. M., Scott, K. M., and Jacobs, L. L., eds., Evolution of Tertiary Mammals of North America, v. 1: Terrestrial Carnivores, Ungulates, and Ungulate like Mammals: Cambridge, Cambridge University Press, p. 463-476.

- White, J. A., 1987, The Archaeolaginae (Mammalia, Lagomorpha) of North America, excluding *Archaeolagus* and *Panolax*: Journal of Vertebrate Paleontology, v. 7, p. 425-450.
- Zachos, J., Pagani, M., Sloan, L., Thomas, E., Billups, K., 2001, Trends, rhythms, and aberrations in global climate 65 Ma to present: Science, v. 292, no. 5517, p. 686-693.

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).

Figure 47. Legend for figures 49-55.

— Transect Line

Figure 48. (1) Southern 1st Wash Transect 1; (2) Sothern 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.

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.

Figure 51. Dead Horse Transect – (9) 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 conglomerate 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.

a			
LITHOLOGY	MUD SANDGRAVEL	BED	FOSSILS
	<div> <div>clay</div> <div>silt</div> <div>vf</div> <div>m</div> <div>vc</div> <div>gran</div> <div>pebb</div> <div>cobb</div> <div>boul</div> </div>		
		25	Pale Green Mudrock
			Alternating Light & Dark Brown Mudrock
		24	
		23	Maroon-Red Mudrock
		22	Pale Green Mudrock
			Reddish Brown Mudrock
		21	
			Light Reddish Brown Mudrock
		20	Reddish Brown Mudrock

b			
LITHOLOGY	MUD SANDGRAVEL	BED	FOSSILS
	<div> <div>clay</div> <div>silt</div> <div>vf</div> <div>m</div> <div>vc</div> <div>gran</div> <div>pebb</div> <div>cobb</div> <div>boul</div> </div>		
		18	Pale Green Mudrock
			Light Reddish Brown Mudrock
		17	
		16	Maroon-Red Mudrock
			Brown Mudrock
		15	
		14	Pale Green Mudrock

c			
LITHOLOGY	MUD SANDGRAVEL	BED	FOSSILS
	<div> <div>clay</div> <div>silt</div> <div>vf</div> <div>m</div> <div>vc</div> <div>gran</div> <div>pebb</div> <div>cobb</div> <div>boul</div> </div>		
		8	Pale Green Mudrock
			Light Tan Silty Mudrock
		7	
		6	Light Tan Siltstone

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 beds. 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 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.

Order

Suborder

Family

Subfamily:Tribe

Genus/Species

Mammalian Fauna

References

Artiodactyla

Merycoidodontidae

Merychochoerinae

Brachycrus sp.

Kues et al. (1978)

Oreodontidae

Merychys major

Schultz & Falkenbach (1941), Lander (1998)

*Merychys medius**

Schultz & Falkenbach (1941), Lander (1998)

Merychys medius novomexicanus

Kues et al. (1978)

Ustatochoerus californicus raki

Kues et al. (1978), Kues (1993)

Ustatochoerus medius

Tedford et al. (1997)

Ustatochoerus novontexicanus

Tedford et al. (1997)

Ustatochoerus profectus espanolensis

Kues et al. (1978), Kues (1993)

Ustatochoerus skinneri santacruzensis

Kues et al. (1978), Kues (1993)

Camelidae

Alticamelinae

Kues et al. (1978)

Miolabinae

Miolabis fissidens

Barghoorn (1985)

Mammalian Fauna

Miolabis sp.

Nothotylopus variegatus

Nothotylopus sp.

Paramiolabis sp.

Protolabinae

Michenia sp.

Protolabis heterodontus

Protolabis inaequidens

Protolabis sp.

Camelinae: Camelini

Procamelus sp.

Camelinae: Lamini

Aepycamelus sp.

Megatylopus sp.

Camelinae: incertae sedis

Australocamelus gracilis

Australocamelus intermedius

Australocamelus orarius

Australocamelus sp.

Leptomerycidae

Pseudoparablastomeryx francescita

Moschidae

Blastomeryx francesca

*Longirostromeryx blicki**

*Longirostromeryx novomexicanus**

References

Barghoorn (1985), Honey et al. (1998)

Barghoorn (1985)

Barghoorn (1985), Honey et al. (1998)

Barghoorn (1985), Honey et al. (1998)

Barghoorn (1985), Honey et al. (1998)

Kues et al. (1978)

Barghoorn (1985)

Barghoorn (1985), Honey et al. (1998)

Barghoorn (1985), Honey et al. (1998)

Barghoorn (1985), Honey et al. (1998)

Kues et al. (1978)

Barghoorn (1985)

Barghoorn (1985)

Barghoorn (1985)

Barghoorn (1985), Honey et al. (1998)

Frick (1937), Taylor & Webb (1976), Webb (1998)

Frick (1937), Webb (1998), Prothero (2008)

Frick (1937), Webb (1998), Prothero (2008)

Frick (1937), Webb (1998), Prothero (2008)

Mammalian Fauna

Dromomerycidae (=Palaeomerycidae)

Cranioceras teres

Antilocapridae

Cosoryx cerroensis

Cosoryx ilfonsensis

Cosoryx sp.

Merycodus (=Meryceros) *crucensis*

Merycodus (=Meryceros) *major*

Merycodus (*Submeryceros*) *minor*

Paracosorx alticornis

Plioceros blicki

Ramoceros (*Paramoceros*) *marthae**

*Ramoceros ramosus**

*Ramoceros ramosus quadratus**

Submeryceros crucianus

Dicotylidae

Carnivora

Procyonidae

Procyoninae

Bassariscus sp.

Mustelidae

*Pliogale nambiana**

Ursidae

References

Cope (1877), Frick (1937),
Janis & Manning (1998a),
Prothero and Liter (2008)

Frick (1937), Kues et al.
(1978)

Frick (1937), Kues et al.
(1978)

Frick (1937)

Frick (1937), Janis &
Manning (1998b)

Frick (1937), Janis &
Manning (1998b)

Frick (1937), Kues et al.
(1978)

Kues et al. (1978), Davis
(2007)

Frick (1937), Janis &
Manning (1998b)

Frick (1937), Janis &
Manning (1998b)

Frick (1937), Janis &
Manning (1998b)

Frick (1937), Kues et al.
(1978)

Frick (1937), Janis &
Manning (1998b)

Kues et al. (1978)

Chaney (2009), Jasinski
(2015)

Cope (1877), Baskin (1998)

Mammalian Fauna

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)
Hunt (1998b), Jasinski (2015)

Wang, Tedford & Taylor (1999), Jasinski (2015)
Wang, Tedford & Taylor (1999), Jasinski (2015)
Wang, Tedford & Taylor (1999), Jasinski (2015)
Jasinski (2015)
Wang, Tedford & Taylor (1999), Jasinski (2015)
Jasinski (2015)
Wang, Tedford & Taylor (1999), Jasinski (2015)
Tedford et al. (1997)
Kues et al. (1978)
Kues et al. (1978)

Jasinski (2015)

Tedford, Wang & Taylor (2009), Jasinski (2015)

Jasinski (2015)

Jasinski (2015)
Jasinski (2015)
Jasinski (2015)
Jasinski (2015)

Mammalian Fauna

Sthenictis sp.
Oligobuninae
Brachypsalis sp.
Felidae
Pseudaelurus marshi
Pseudaelurus stouti
Pseudaelurus sp.
Chiroptera
Vespertilionidae
Antrozoinae
Eulipotyphla
Erinaceidae
Amphechinus sp.
Leporidae
Hypolagus sp.
Lupus sp.
Panolax sanctaefidei
Lagomorpha
Ochotonidae
Hesperolagomys sp.*
Russellagus sp.*
Lipotyphla
Erinaceidae
Metechinus amplior
Untermannerix copiosus
Talpidae
Achlyoscapter ?
Domninoidea sp.
Gaillardia sp.
Mystipterus sp.
Scapanoscapter?
Soricidae
Adeloblarina sp.
Alluvisorex sp.

References

Jasinski (2015)
Jasinski (2015)
Rothwell (2003), Jasinski (2015)
Rothwell (2003), Jasinski (2015)
Jasinski (2015)
This paper
Kues et al. (1978)
Chaney (2009)
Kues et al. (1978)
Cope (1877), White (1987), Chaney (2009)
Chaney (2009)
Chaney (2009)
Rich (1981)
Rich (1981)
Chaney (2009)
Kues et al. (1978)
Chaney (2009)
Chaney (2009)
Chaney (2009)
Chaney (2009)
Chaney (2009)
Chaney (2009)

Mammalian Fauna

References

<i>Limnoecus</i> sp.	Chaney (2009)
Perissodactyla	
Equidae	
Anchitheriinae	
<i>Hypohippus</i> sp.	MacFadden (1998)
<i>Megahippus mckennai</i>	MacFadden (1998)
Equinae: Hipparionini	
<i>Cormohipparion</i> sp.	MacFadden (1998)
<i>Hippotherium</i> sp.	MacFadden (1998)
<i>"Merychippus" calamarius</i>	MacFadden (1998)
<i>Neohipparion affine</i>	MacFadden (1998)
<i>Neohipparion coloradense</i> *	MacFadden (1998)
Equinae: Equini	
<i>Pliohippus supremus</i>	MacFadden (1998)
Rhinocerotidae	
Aceratheriinae	
<i>Aphelops megalodus</i>	Prothero (1998)
<i>Aphelops</i> cf. <i>A. meridianus</i>	Prothero (1998)
<i>Peraceras hessei</i>	Prothero (1998)
<i>Peraceras profectum</i>	Prothero (1998)
<i>Peraceras superciliosum</i>	Prothero (1998)
<i>Teleoceras</i> sp.	Prothero (1998)
Proboscidea	
Gomphotheriidae	
<i>Gomphotherium productum</i> *	Cope (1877), Tobien (1973), Tedford et al. (1997)
<i>Megabelodon joraki</i> *	Frick (1933), Lambert & Shoshani (1998)
Rodentia	
Mylagaulidae	
<i>Mylagaulus laevis</i>	Chaney (2009)
<i>Promylagaulus novellus</i>	Kues et al. (1978)
Sciuridae	
<i>Tamias</i> sp.	Chaney (2009)
<i>Spermophilus</i> sp.	Chaney (2009)
cf. <i>Petauristodon</i> sp.	Chaney (2009)

Mammalian Fauna

Heteromyidae

Diplodomys cf *D. hermanni*

References

Kues et al. (1978)

Mioperognathus willardi

Korth (2008a)

Perognathus minutus

Korth (2008)

Geomyoidea

Mojavemyinae

Mojavemys galushai

Korth & Chaney (1999)

Phelosacomys neomexicanus

Korth & Chaney (1999)

Castoridae

Dipoides cf *D. planus*?

Kues et al. (1978)

"*Dipoides*" *williamsi*

Kues et al. (1978)

Monosaulax pansus

Cope (1877), Korth (2002),

Chaney (2009)

Eucastor tortus

Korth (2008b)

Zapodidae

Plesiosminthus sp.

Chaney (2009)

Cricetidae

Copemys loxodon

Cope (1877), Chaney
(2009)

Reptilian Fauna

References

Testudines

Cryptodira

Kinosternidae

Kinosterninae

Kinosternon pojoaque

Bourque (2012)

Testudinidae

Geochelone (Hesperotestudo) Osborniana Sena et al. (1989)

Emydidae

Glyptemys valentinensis

This paper

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).

APPENDIX 3 CONTINUED

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

Ustatchoerus 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
Phelosacomys neomexicanus
 Heteromyidae
Perognathus minutus
 Mylagaulidae
Mylagaulus laevis
2. Jacona Grant; 100 yds. SW of 4 1/2 M stake on W Tesuque Grant Boundary (Pojoaque or Skull Ridge)
 Perissodactyla
 Equidae
3. Jacona Grant, S end (Pojoaque)
 Artiodactyla
 Antilocapridae
 Camelidae
 Canidae
 Dromomerycidae
Cranioceras
 Oreodontidae
 Perissodactyla
 Equidae
 Rhinocerotidae
 Proboscidea
 Gomphotheriidae
 Rodentia
4. Jacona Grant, E boundary, in Jacona Wash (Pojoaque) included are: a) head of Jacona Wash; b) Nambe drainage system
 Artiodactyla
 Antilocapridae

- 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
 - Domninoidea* sp.
- Scalopoides?
- Rodentia
- bird - 1PC, misc.
- Reptilia - misc.
- Testudines
- Amphibia - misc.
- (Other)
- Gastropods
- 6. Jaona 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

Merychius 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*
 - Ramoceros*
 - Camelidae
 - Camelinae: Lamini
 - Aepycamelus* sp.
 - Protolabinae
 - Michenia* sp.
 - Protolabis* sp.
 - Oreodontidae
 - Carnivora
 - Canidae
 - Borophaginae
 - Tomarctus* sp.
 - Felidae
 - Pseudaelurus* 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
 - Aelurodon* 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
 - Borophaginae
 - Aelurodon sp.*
 - Mustelidae
 - Lagomorpha
 - Leporidae
 - Lepus sp.*
 - Perissodactyla
 - Equidae
 - Rodentia
- 29. "Central Pojoaque Bluffs"; unspecified, plus several well defined localities: a) NW 1/4 SE1/4 sec. 36, T 20 N, R 8 E, b) SW 1/4 SE 1/4 sec. 36, c) SE1/4 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)

Artiodactyla

- 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
- 37. North (Upper) Pojoaque Bluffs (largely in sections 24 & 25, T 20 N, R 8 E). 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
 - Leptocyon 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
 - Domninoidea?*
 - (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 SE 1/4 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

Aepycamelus 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)
 - Artiodactyla
 - Camelidae
 - Oreodontidae
 - Carnivora
 - Canidae
 - Borophaginae
 - Mustelidae
 - Perissodactyla
 - Equinae

- 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 blicki*
 - 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 blicki*

Longirostromeryx novomexicanus
Longirostromeryx sp.
 Oreodontidae
Merychys medius novomexicanus
 Carnivora
 Amphicyonidae
 Canidae
 Borophaginae
 Aelurodon 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
- (Unknown) *E. cf. E. planus*
61. West edge of Santa Cruz area (Pojoaque?)
- Artiodactyla
- Antilocapridae
- Camelidae
- Oreodontidae
- Ustatchoerus profectus espanolensis*
- Carnivora
- Canidae
- Borophaginae
- Strobodon* 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 blicki
 Oreodontidae
 Merychys medius novomexicanus
 Ustatoceros californicus raki
 U. skinneri santacruzensis
 U. sp.

 Carnivora
 Canidae
 Borophaginae
 Aelurodon sp.
 Carpocyon sp.
 Strobodon sp.
 Tomarctus sp.
 Caninae
 Leptocyon vafer
 Felidae
 Pseudaelurus marshi
 Mustelidae
 Perissodactyla
 Equidae
 Anchitheriinae
 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
 Domninoidea
 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.
- Oreodontidae
- 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

Merycochoerinae

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
- Neohipparion 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.

Permanent Address: 714 East Starr Ave. Apt. B10
 Nacogdoches, TX 75961

Style manual designation

This thesis was typed by Garrett R. Williamson