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SMALL MAMMAL FOSSILS AND CORRELATION OF CONTINENTAL DEPOSITS,
SAFFORD AND DUNCAN BASINS, ARIZONA

by

Yukimitsu Tomida

A Dissertation Submitted to the Faculty of the
DEPARTMENT OF GEOSCIENCES
In Partial Fulfillment of the Requirements
For the Degree of
DOCTOR OF PHILOSOPHY
In the Graduate College
THE UNIVERSITY OF ARIZONA

1985
As members of the Final Examination Committee, we certify that we have read the dissertation prepared by Yukimitsu Tomida entitled Small Mammal Fossils and Correlation of Continental Deposits, Safford and Duncan Basins, Arizona and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy.

Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copy of the dissertation to the Graduate College.

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To my parents, who encouraged and supported me during my graduate years of study in the United States, I dedicate this work.
<table>
<thead>
<tr>
<th>TABLE OF CONTENTS</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF TABLES</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF ILLUSTRATIONS</td>
<td>x</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>xii</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>METHODS AND ABBREVIATIONS</td>
<td>4</td>
</tr>
<tr>
<td>GEOLOGIC SETTING</td>
<td>8</td>
</tr>
<tr>
<td>PALEOMAGNETIC ANALYSIS</td>
<td>13</td>
</tr>
<tr>
<td>Sampling</td>
<td>13</td>
</tr>
<tr>
<td>AF Demagnetization Studies</td>
<td>13</td>
</tr>
<tr>
<td>Thermomagnetic Studies</td>
<td>16</td>
</tr>
<tr>
<td>Magnetic Polarity Zonation</td>
<td>19</td>
</tr>
<tr>
<td>Correlation with Magnetic Polarity Time Scale</td>
<td>20</td>
</tr>
<tr>
<td>MAMMALIAN FAUNAS AND CHRONOLOGY</td>
<td>28</td>
</tr>
<tr>
<td>History of Investigation</td>
<td>28</td>
</tr>
<tr>
<td>Present Studies</td>
<td>31</td>
</tr>
<tr>
<td>SYSTEMATICS</td>
<td>49</td>
</tr>
<tr>
<td>Insectivora</td>
<td>49</td>
</tr>
<tr>
<td>Chiroptera</td>
<td>55</td>
</tr>
<tr>
<td>Lagomorpha</td>
<td>56</td>
</tr>
<tr>
<td>Rodentia</td>
<td>79</td>
</tr>
<tr>
<td>Sciuridae</td>
<td>79</td>
</tr>
<tr>
<td>Geomyidae</td>
<td>82</td>
</tr>
<tr>
<td>Heteromyidae</td>
<td>105</td>
</tr>
<tr>
<td>Cricetidae</td>
<td>125</td>
</tr>
<tr>
<td>Arvicolidae</td>
<td>216</td>
</tr>
<tr>
<td>Hydrochoeridae</td>
<td>235</td>
</tr>
<tr>
<td>Table Content</td>
<td>Page</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>SUMMARY AND CONCLUSIONS</td>
<td>236</td>
</tr>
<tr>
<td>REFERENCES CITED</td>
<td>245</td>
</tr>
</tbody>
</table>
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Faunal list of Bear Springs and San Simon Power Line areas</td>
<td>21</td>
</tr>
<tr>
<td>2. Faunal list of Country Club, Duncan, and Pearson Mesa areas</td>
<td>22</td>
</tr>
<tr>
<td>3. Faunal list of lll Ranch area</td>
<td>23</td>
</tr>
<tr>
<td>4. Comparative small mammal fossil list of 11 Blancan and early Irvingtonian faunas</td>
<td>38</td>
</tr>
<tr>
<td>5. Comparative small mammal fossil list arranged by the order of first appearance within 11 faunas in Table 4</td>
<td>39</td>
</tr>
<tr>
<td>6. Measurements of Soricidae</td>
<td>52</td>
</tr>
<tr>
<td>7. Measurements of Notolagus and Hypolagus</td>
<td>58</td>
</tr>
<tr>
<td>8. Measurements of Hypolagus virginiae</td>
<td>62</td>
</tr>
<tr>
<td>9. Measurements of Sylvilagus or Lepus sp.</td>
<td>74</td>
</tr>
<tr>
<td>10. Measurements of recent species of Lepus and Sylvilagus and UALP 904</td>
<td>77</td>
</tr>
<tr>
<td>11. Measurements of Sciuridae</td>
<td>80</td>
</tr>
<tr>
<td>12. Measurements of Geomys cf. persimilis</td>
<td>84</td>
</tr>
<tr>
<td>13. Cranial and mandibular measurements of Geomys cf. persimilis and topotypic G. persimilis</td>
<td>85</td>
</tr>
<tr>
<td>15. Measurements of Pappogeomys sansimonensis n. sp.</td>
<td>100</td>
</tr>
<tr>
<td>16. Measurements of Perognathus gidleyi</td>
<td>106</td>
</tr>
<tr>
<td>17. Measurements of Dipodomys hibbardi</td>
<td>114</td>
</tr>
<tr>
<td>Table</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>18.</td>
<td>Measurements of <em>Dipodomys</em> cf. <em>gidleyi</em></td>
</tr>
<tr>
<td>19.</td>
<td>Measurements of <em>Onychomys pedroensis</em></td>
</tr>
<tr>
<td>20.</td>
<td>Measurements of <em>Peromyscus hagermanensis</em></td>
</tr>
<tr>
<td>21.</td>
<td>Measurements of <em>Baiomys minimus</em> and <em>Baiomys</em> sp.</td>
</tr>
<tr>
<td>22.</td>
<td>Measurements of <em>Baiomys</em> cf. <em>brachygnathus</em></td>
</tr>
<tr>
<td>23.</td>
<td>Measurements of <em>Reithrodontomys</em> species</td>
</tr>
<tr>
<td>24.</td>
<td>Measurements of <em>Calomys</em> (<em>Bensonomys</em>) <em>arizonae</em> and <em>? Calomys</em> (<em>Bensonomys</em>) sp.</td>
</tr>
<tr>
<td>25.</td>
<td>Measurements of <em>Sigmodon medius</em> from UA localities 7937, 15-24, and 7933</td>
</tr>
<tr>
<td>26.</td>
<td>Measurements of <em>Sigmodon medius</em> from various UA locs.</td>
</tr>
<tr>
<td>27.</td>
<td>Development of roots in <em>Sigmodon medius</em> (in %)</td>
</tr>
<tr>
<td>28.</td>
<td>Development of anterior cingulum in <em>Sigmodon medius</em> (in %)</td>
</tr>
<tr>
<td>29.</td>
<td>Statistical comparisons of three samples of <em>Sigmodon medius</em> and <em>S. minor</em> using student's t-test</td>
</tr>
<tr>
<td>30.</td>
<td>Measurements of <em>Sigmodon minor</em> from UA loc. 25-3, Curtis Ranch, San Pedro Valley, Arizona</td>
</tr>
<tr>
<td>31.</td>
<td>Measurements of <em>Neotoma fossilis</em></td>
</tr>
<tr>
<td>32.</td>
<td>Measurements of <em>Neotoma tayloiri</em></td>
</tr>
<tr>
<td>33.</td>
<td>Measurements of <em>Repomys arizonensis</em> n. sp. and ratios of measurements in average between two species of the genus <em>Repomys</em></td>
</tr>
<tr>
<td>34.</td>
<td>Statistical comparison of mean length and width of <em>Repomys arizonensis</em></td>
</tr>
</tbody>
</table>
LIST OF TABLES--Continued

<table>
<thead>
<tr>
<th>Table</th>
<th>Measurements of Ophiomys cf. taylori</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>35.</td>
<td>Measurements of Mictomy (Metaxyomys) vetus</td>
<td>220</td>
</tr>
<tr>
<td>36.</td>
<td>Mictomy (Metaxyomys) vetus</td>
<td>228</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>----------</td>
<td>-----------------------------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>1.</td>
<td>Map showing study area with location of paleomagnetic sections</td>
<td>5</td>
</tr>
<tr>
<td>2.</td>
<td>Lithostratigraphy along with the position and polarity of paleomagnetic sites of Bear Springs and San Simon Power Line</td>
<td>9</td>
</tr>
<tr>
<td>3.</td>
<td>Lithostratigraphy along with the position and polarity of paleomagnetic sites of Country Club, Duncan, and Pearson Mesa</td>
<td>11</td>
</tr>
<tr>
<td>4.</td>
<td>Vector demagnetization diagram showing AF demagnetization behavior of samples SS001A and SS017A</td>
<td>15</td>
</tr>
<tr>
<td>5.</td>
<td>Direction of magnetization in Bear Springs section</td>
<td>17</td>
</tr>
<tr>
<td>6.</td>
<td>Strong-field thermomagnetic (J_s - T) curve for magnetic concentrate from the site SS013 in Duncan Basin</td>
<td>18</td>
</tr>
<tr>
<td>7.</td>
<td>Correlation of magnetic polarity columns of the Safford and Duncan Basins with the magnetic polarity time scale</td>
<td>24</td>
</tr>
<tr>
<td>8.</td>
<td>Map showing the small mammal fossil localities at the III Ranch area</td>
<td>33</td>
</tr>
<tr>
<td>9.</td>
<td>Small mammal biostratigraphy of the III Ranch area</td>
<td>34</td>
</tr>
<tr>
<td>10.</td>
<td>Correlation of faunas in Safford and Duncan Basins, San Pedro Valley, and other areas with the magnetic polarity time scale</td>
<td>36</td>
</tr>
<tr>
<td>11.</td>
<td>Soricidae, Chiroptera, Sciuridae, Heteromyidae, and Cricetidae</td>
<td>51</td>
</tr>
<tr>
<td>12.</td>
<td>Leporidae</td>
<td>57</td>
</tr>
<tr>
<td>13.</td>
<td>Geomys cf. persimilis and G. persimilis</td>
<td>83</td>
</tr>
<tr>
<td>14.</td>
<td>Pappogeomys sansimonensis n. sp.</td>
<td>99</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>15</td>
<td>Dipodomys hibbardi and D. sp. cf. D. gidleyi</td>
<td>113</td>
</tr>
<tr>
<td>16</td>
<td>Cusp and fold terminology of Cricetidae used in this paper, slightly changed after Reig (1977)</td>
<td>128</td>
</tr>
<tr>
<td>17</td>
<td>Peromyscus, Baiomys, and Reithrodontomys</td>
<td>135</td>
</tr>
<tr>
<td>18</td>
<td>Variation in tooth measurements of 4 fossil Sigmodon samples</td>
<td>175</td>
</tr>
<tr>
<td>19</td>
<td>Occlusal patterns and side views of the cheek teeth of Neotoma (Paraneotoma) species</td>
<td>190</td>
</tr>
<tr>
<td>20</td>
<td>Scatter diagram of length and width of M₁/₁ and M₂-₃ of Neotoma species</td>
<td>200</td>
</tr>
<tr>
<td>21</td>
<td>Occlusal enamel patterns of Repomys arizonensis, n. sp.</td>
<td>208</td>
</tr>
<tr>
<td>22</td>
<td>Scatter diagram of length and width of M₁/₁ and M₂/₂ of Repomys species</td>
<td>209</td>
</tr>
<tr>
<td>23</td>
<td>Cusp and fold terminology of Arvicolidae used in this paper, simplified after Van der Meulen (1973)</td>
<td>217</td>
</tr>
<tr>
<td>24</td>
<td>Arvicolidae from Duncan and Ill Ranch</td>
<td>219</td>
</tr>
</tbody>
</table>
ABSTRACT

Fossil bearing continental deposits, the Gila Conglomerate, of Safford and Duncan Basins, Arizona were correlated with the magnetic polarity time scale by means of magnetostratigraphy and biochronology of mammalian fossils. Within the Safford Basin, the Bear Springs section with a middle Blancan fauna is correlated with the lower or upper Gauss chron; the III Ranch section with a middle to late Blancan fauna is correlated with the upper Gauss to early Matuyama chron; and the San Simon Power Line section with probably a latest Blancan fauna is correlated with the early Matuyama chron. In the Duncan Basin, the Duncan section with a middle Blancan fauna is correlated with the middle Gauss chron; the Pearson Mesa section with a middle Blancan fauna is correlated with the upper Gauss chron; and the Country Club section with a middle Blancan fauna is correlated with the lastest Gilbert to early Gauss chron or from the middle Gauss to the earliest Matuyama chron. A late Blancan fauna is not recognized in the Duncan Basin at least within the study area, whereas the Gila Conglomerate in the Safford Basin includes deposits and fauna of the latest Blancan (latest Pliocene) age.

A minimum of 37 taxa of small mammals are recognized among the approximately 1,600 specimens from the Gila Conglomerate of the Safford and Duncan Basins. Three new rodent species are described; they are Pappogeomys (Cratogeomys) sansimonensis, new species;
Reithrodontomys galushai, new species; and Repomys arizonensis, new species. One new combination of genus and species, Hypolagus virginiae, is described. In the Safford Basin, a minimum of 26 small mammal taxa are now recognized in the III Ranch fauna, of which three genera (Dipodomys, Peromyscus, and Repomys) are new records to the fauna; a minimum of 6 taxa of small mammals are recognized and described for the first time in the San Simon Power Line fauna. In the Duncan Basin, a minimum of 15 small mammal taxa are recognized and described for the first time.
Southeastern Arizona is a part of the Basin and Range province (one of three major physiographic provinces in Arizona), where the mountains and valleys alternate with a N-S or NW-SE orientation. Late Cenozoic and Quaternary terrestrial sediments had filled the valleys to a thickness of about 1,000 to over 2,000 m (Scarborough and Peirce, 1978). Some of those basin fill deposits contain mammalian fossil remains which yield useful information on the age of those deposits, and on the history of the basin-forming tectonics.

Safford Basin is one of those basins in the Basin and Range province, that has been studied by a number of geologists interested in the geology, hydrology, and history of basin fill deposits (Knechtel, 1938; Davidson, 1960; Harbour, 1966; Houser, 1984). Presence of vertebrate fossils in the Safford Basin has been reported since 1936 (Knechtel). A large number of fossils were collected by the Frick Laboratory of the American Museum of Natural History (F:AM) and University of Arizona from several areas within the Safford Basin, but many of them remain undescribed, except for certain taxa found from 111 Ranch area (Downey, 1962; Cantwell, 1969; Ahearn and Lance, 1980) and a recent study on magnetostratigraphy and biostratigraphy of 111 Ranch area (Galusha et al., 1984).

The Duncan Basin is another similar basin, but it has been less studied than the Safford Basin (Feth, 1952; Morrison, 1965). Vertebrate
fossils in the Duncan Basin have been collected from several localities since 1932 mainly by collectors for the F:AM and UA, but none of them have been described. Basin fill deposits of both Safford and Duncan Basins have been called Gila Conglomerate, though the vertebrate fossils are known mainly from lacustrine or fluvial overbank facies of the Gila Conglomerate.

The purpose of this study is to correlate fossil bearing deposits in both the Safford and Duncan Basins by means of magnetostratigraphy and biochronology of the mammalian fossils, as well as to describe the small mammal fauna for biochronological correlation. This will provide a temporal framework similar to the work done in the nearby San Pedro Valley (Johnson, Opdyke, and Lindsay, 1975). In the San Pedro Valley, Johnson et al. (1975) correlated a number of mammalian fossil localities, that range from Pliocene to early Pleistocene, with several paleomagnetic sections and provided a well documented framework for geochronology and biostratigraphy of the younger part of the basin fill, as well as a framework for mammalian evolution in North America during that interval.

Small mammal fossils have been given more attention recently by vertebrate paleontologists for biostratigraphic and biochronological purposes, as well as for evolutionary analysis, mainly because large samples of small mammals can be developed using simple collecting methods. Small mammals were the focus in this study also. As a result, a minimum of 37 taxa of small mammals are now recognized from six faunas
within the Safford and Duncan Basins. Three new species and one new combination of genus and species are described.
Paleomagnetic samples were collected in Spring of 1984 from five areas (sections 1 and 3 to 6 in Fig. 1). Detailed description and measurement of the stratigraphy at each section was made along with the collection of magnetic samples. For sampling technique and method of magnetic measurement, see the chapter of paleomagnetic analysis below. Results of the paleomagnetic analysis at 111 Ranch area by Galusha et al. (1984) were followed in this paper without any change.

Small mammal fossils were collected by surface pick-up and screen-washing technique developed by Hibbard (1949b) and modified by numerous researchers. In this study tandem boxes similar to those described by Lindsay (1972) were used. Approximately 1.5 tons of matrix was collected from mainly three sites in 1979 and 1980. Screen-washing of the matrix resulted with discovery of about 500 identifiable specimens. Most of them are isolated teeth, but some are maxilla and dentary fragments with more than one tooth. Technique of mounting the specimens on pins is the same as that described by Lindsay (1972). In addition to these newly collected specimens, approximately 1,100 specimens of small mammals that had previously been collected from 111 Ranch area (mostly from UA loc. 15-24) were utilized in this study. Most of the specimens previously collected had been mounted on clay; they were cleaned by acetone and glyptal, then remounted on pins.
Figure 1. Map showing study area with location of paleomagnetic sections
Many specimens utilized in this study, especially those collected by screen-washing, are isolated cheek teeth. Methods used to associate isolated teeth into composite dentitions of taxa are comparison with previously identified specimens, relative abundance of similar forms at a given locality, the size relations of various forms, and the morphological consistency between teeth grouped into a same taxon (Jacobs, 1978).

Although not described herein, all the mammalian fossils collected from the Safford and Duncan Basins other than small mammals were also briefly examined and utilized for the faunal list. Specimens collected by Galusha and others for Frick Laboratory of American Museum of Natural History (F:AM) in the Safford and Duncan Basins since 1932 were also briefly examined and included in the faunal lists. Most of F:AM collections have been unpublished, except for those from III Ranch area which were compiled as a detailed faunal list (Galusha et al., 1984). The specimens that were studied by Gazin (in Knechtel, 1936) and are stored in the US National Museum were also briefly examined.

Measurements were made with the aid of a reticle in a microscope. Dimensions of teeth were read to the nearest either 0.02 or 0.04 millimeter (mm), depending on the size of tooth, or the nearest 1/12 mm in case of the full dentition. All measurements are maximum dimensions regardless of wear, unless noted; transverse dimensions are perpendicular to anteroposterior dimensions.

Abbreviations used in the text are:
UALP, UA University of Arizona Laboratory of Paleontology
Abbreviations used with tables of measurements:

- **N** number of measured specimens
- **O.R.** observed range of measurements
- **S.D.** standard deviation
- **C.V.** coefficient of variation
- **t** student's t value for testing the difference between two samples
- **D.F.** degree of freedom
- **P** probability
- **L, W, H** length, width, height
- **L, R** left (never used with L for length on a same table), right
GEOLOGIC SETTING

The Safford and Duncan Basins are located in southeastern Arizona near the New Mexico border (Fig. 1), and are one of several structural basins formed by Basin and Range extentional tectonics. Sediments of the Safford Basin (more precisely the interconnected Safford-San Simon Basin) are divided into: (1) lower Miocene volcaniclastic conglomerate, (2) upper Miocene (?) to early Pleistocene Gila Conglomerate, and (3) Quaternary alluvium and surficial deposits (Houser, 1984). The volcaniclastic conglomerate is part of the bed rock deposited prior to the formation of the structural basin. The Gila Conglomerate is the main component of basin fill deposits, and consists of more than 1,200-m thick of sedimentary rocks. Most of the thick lower units are locally derived alluvial fan deposits; e.g., fanglomerate. Upper units of the Gila Conglomerate include more lacustrine deposits, interbedded with alluvial fan deposits. Thick halite and gypsum deposits are reported from wells, implying playa deposits at depth (Houser, 1984). Davidson (1960) recognized four types of basin fill sediments: (a) gravel and grit, (b) silt and sand, (c) green and black clay, (d) limestone, deposited in fresh-water lakes. All of those except (a) form the valley-center facies of Scarborough and Peirce (1978). Fossiliferous sediments at the Bear Springs area and the San Simon Power Line area include the silt and sand facies (stratigraphic columns in Fig. 2). The sediments in the III Ranch area were studied
Figure 2. Lithostratigraphy along with the position and polarity of paleomagnetic sites of Bear Springs and San Simon Power Line.
in detail by Seff (1960) and consist of a complex of fluviatile, paludal, and lacustrine facies in addition to limestone facies. Davidson (1960) classified sediments in the 111 Ranch area that include widespread diatomites and marls as the limestone facies (for further detailed geology of 111 Ranch area, see Galusha et al., 1984).

Basin fill deposits of the Duncan Basin are similar to those of the Safford Basin and are divided by the same manner. Gila Conglomerate in the Duncan Basin consists of alluvium, playa, and shallow-lake sediments deposited while the Duncan Basin had closed drainage prior to development of through drainage by the Gila River (Morrison, 1965). Morrison (1965) estimated that the Gila Conglomerate is probably equivalent to the upper part of the Quiburis Fm., which is correlated with the magnetic chron V, part of Hemphillian land mammal age, and late Miocene in age (Lindsay, Opdyke and Johnson, 1984). As a result of the present study, the Gila Conglomerate in the Duncan Basin, at least in the study area (which is the upper units) can be assigned to, more or less, middle to late Pliocene age, and younger than the Quiburis Fm. Only the upper units of the Gila Conglomerate are exposed in the study area. Beds in the study area are horizontal to very gently inclined, rarely more than 3°. Gravel is restricted to a thin zone along the margins of the older rocks, except for the Pearson Mesa and the lower part of the Country Club area where gravel occurs in several zones alternating with layers of sand, silt, and clay (Fig. 3). In most other parts of the interior of the Duncan Basin the Gila Conglomerate consists mainly of alternating sand, silt, and clay beds with local interbeds of gravel,
Figure 3. Lithostratigraphy along with the position and polarity of paleomagnetic sites of Country Club, Duncan, and Pearson Mesa
limestone, tuff, marl, diatomite, etc. (Morrison, 1965). The Duncan section represents this facies (Fig. 3).
PALEOMAGNETIC ANALYSIS

Sampling

Three oriented samples were collected from each of 23 sites at five sections in the Gila Conglomerate of Safford and Duncan basins, southeastern Arizona (sections 1 and 3-6 of Fig. 1). Where suitable lithologies could be found, the stratigraphic separation between sites was intended to be about 6 m. Care was taken to collect the finer grained sediments, preferably clay or silty clay. Three oriented samples were chiseled from each site after removal of weathered surficial material. The sampling technique was similar to that of Johnson, Opdyke, and Lindsay (1975). Along with collections of the magnetic samples, a detailed description and measurement of the stratigraphy was made (Figs. 2 and 3).

Bulk samples (about 1 kg) were also collected from one level of each of the Bear Springs and Pearson Mesa sections for thermomagnetic studies.

AF Demagnetization Study

All measurements of remanent magnetism were performed with a Superconducting Technology C-102 cryogenic magnetometer. Alternating field (AF) demagnetization was carried out by a Schonstedt GSD-1 single-axis demagnetizer equipped with specimen tumbles.
The intensity of natural remanent magnetism (NRM) before magnetic cleaning ranges from $5.1 \times 10^{-4}$ to $7.8 \times 10^{-6}$ gauss, which are rather strongly magnetized continental sedimentary rocks relative to other similar studies (Neville et al., 1979; Tomida and Butler, 1980).

Examples of behavior during progressive AF demagnetization are shown in the vector demagnetization (Zijderveld) diagrams of Fig. 4. The majority of samples contained a primary NRM component which was isolated by AF demagnetization of 150 oe peak field. A secondary component of normal polarity was rather weak, and was usually removed by AF demagnetization to 150 oe peak field. SS017A in Fig. 4 illustrates the demagnetization behavior typical to the majority of the samples. There is some minor oscillation of the remaining NRM vector about a line through the origin in other samples, but the basic pattern is a progression toward the origin with increasing peak AF field.

At a few sites, however, AF demagnetization did not prove effective. Sample SS001A of Fig. 4 shows drastic reduction in NRM by AF demagnetization at low fields. After 50 oe peak field, it decays slowly toward zero within the normal polarity direction, but does not display stabilization of direction. Note especially that the declination rotates toward a reversed polarity at 600 oe. Galusha et al. (1984) had a similar problem at 111 Ranch section and solved this difficulty by thermal demagnetization at 300°C, assuming that low blocking temperature components with high coercivities were due to the presence of goethite. In order to ensure that possible normal polarity overprints due to goethite were removed, all samples from sites with
Figure 4. Vector demagnetization diagram showing AF demagnetization behavior of samples SS001A and SS017A. In sample SS001A, the figure on left shows an enlargement of the area on right included in the box. Declination is given by triangles, inclination by squares. Scale of tick marks (in gauss) is indicated for each diagram.
apparent normal polarity following AF demagnetization to 150 oe were also thermally demagnetized to 320°C. In addition, a few selected samples were subjected to progressive thermal demagnetization up to 610°C.

Figure 5 gives a comparison of the magnetic stratigraphy after AF demagnetization to 150 oe and after thermal demagnetization to 320°C. It can be seen that the lower two sites changed polarity, probably because a dominant secondary component of normal polarity was carried by goethite. One site (SS009) that exhibited normal polarity after AF demagnetization at 150 oe became ambiguous in its polarity after thermal demagnetization. No other changes of polarity were observed following thermal demagnetization.

**Thermomagnetic Study**

The procedure of yielding the concentrate of magnetic particles from bulk samples as well as the procedure of the strong-field thermomagnetic ($J_s$-$T$) experiment are the same as those in Butler (1982, p.7844-7845). $J_s$-$T$ experiment on both samples (SS005 and SS013) were performed in argon gas atmosphere to avoid oxidation of magnetic particles. An earlier experiment in air resulted in an irreversible $J_s$-$T$ curves. The $J_s$-$T$ curves for the two samples are nearly identical. Results for sample SS013 are shown in Fig. 6 as an example. $J_s$-$T$ behavior of both samples shows a minor inflection at about 350°C and a dominant Curie temperature at 580°C. This behavior indicates the presence of a mixture of a small amount of titanomagnetite (?) with much larger portion of magnetite.
Figure 5. Direction of magnetization in Bear Springs section.
Figure 6. Strong-field thermomagnetic \( (J_s-T) \) curve for magnetic concentrate from the site SS013 in Duncan Basin.

**SS013**

*In Argon*
Magnetic Polarity Zonation

From the site mean directions of NRM after AF and thermal demagnetization, resultant virtual geomagnetic pole (VGP) latitude (e.g. Fig. 5), and NRM vector motions during demagnetization, the polarity of each site was interpreted. Polarities are shown on the right of each section in Figs. 2 and 3. Although the polarity columns are not illustrated in those figures, magnetozone boundaries are placed midway between the sites of opposite polarity.

The 55-m thick Bear Springs section contains two magnetozones, 11-m long reversed zone at the bottom and 44-m long normal zone at the top. Most of the fossil localities occur at the horizons near this polarity boundary. Polarity determination could not be made on the San Simon Power Line section because of the random and unstable NRM directions.

Although the Duncan section includes 20-m long stratigraphic section, the first 5 m or so should be omitted from the magnetic section due to the lack of the paleomagnetic sites. 15-m long Duncan magnetic section contains two magnetozones, a short normal zone at the bottom and a longer reversed zone at the top. Horizon of most fossil localities are concentrated near the polarity boundary.

The 35-m long Pearson Mesa section consists of only one normal magnetozone, and fossil localities occur in the lower part of the section. The 44-m long Country Club section is the only section that contains three magnetozones. The bottom reversed, middle normal, and top reversed polarity zones are 18 m, 18.5 m and 7.5 m in thickness,
Horizon of all the fossil localities are within the bottom reversed polarity magnetozone.

**Correlation with the Magnetic Polarity Time Scale**

Each magnetic polarity column contains only one to three magnetozones so that no individual section shows characteristic pattern necessary for correlation with the MPTS. However, each stratigraphic section contains fossil localities that produced mammalian fossils characteristic of the Blancan land mammal age (Tables 1-3). The Blancan land mammal age ranges approximately from 4 to 2 Ma, or from the younger part of the Gilbert chron to older part of the Matuyama chron (Lindsay, Johnson, and Opdyke, 1975; Lindsay et al., 1984). The III Ranch section has already been correlated with the magnetic polarity time scale (MPTS), with the aid of radiometric dating (Galusha et al., 1984; Fig. 7). In addition, similar faunas in San Pedro Valley, roughly 100 miles southwest from the present study area (Johnson et al., 1975), as well as other important Blancan-Irvingtonian faunas (Lindsay et al., 1975) are correlated with the MPTS. Thus, the precise correlation of the faunas in Safford and Duncan basins with those faunas whose ages have been correlated with the MPTS can help significantly in the correlation. Detailed discussion on the age of faunas will appear in the next chapter, but the following discussions on the correlation of individual magnetic polarity columns are based mainly on the conclusion on the faunal ages.

The Bear Springs fauna is indicative of Blancan age, but does not contain any taxa that are more precise in assigning an age within
Table 1. Faunal list of Bear Springs and San Simon Power Line areas

<table>
<thead>
<tr>
<th></th>
<th>Bear Springs</th>
<th>San Simon Power Line</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>UA</td>
<td>F:AM</td>
</tr>
<tr>
<td>Edentata</td>
<td></td>
<td></td>
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<tr>
<td>Glyptodontidae</td>
<td></td>
<td></td>
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<tr>
<td>Glyptotherium texanum</td>
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<tr>
<td>Glyptotherium sp.</td>
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<tr>
<td>Lagomorpha</td>
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<td></td>
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<tr>
<td>Leporidae</td>
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<td></td>
</tr>
<tr>
<td>Hylpalagus virginiae</td>
<td></td>
<td></td>
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<tr>
<td>Sylvilagus or Lepus sp.</td>
<td>X</td>
<td></td>
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<tr>
<td>Rodentia</td>
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<td></td>
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<tr>
<td>Sciuridae</td>
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<td></td>
</tr>
<tr>
<td>Spermophilus cf. bensoni</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Geomyidae</td>
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<td></td>
</tr>
<tr>
<td>Geomys (Nerterogeomys) cf. persimilia</td>
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<td></td>
</tr>
<tr>
<td>Geomys sp.</td>
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<td>X</td>
</tr>
<tr>
<td>Pappogeomys (Cratogeomys) sansimonensis</td>
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<td>Dipodomys hibbardi</td>
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<tr>
<td>Cricetidae</td>
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<tr>
<td>Sigmomys sp.</td>
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<td>X</td>
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<tr>
<td>Carnivora</td>
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<tr>
<td>Canidae</td>
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<tr>
<td>Mustelidae</td>
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<tr>
<td>Trigonictis macrodon</td>
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<td>X</td>
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<td>Taxidea sp.</td>
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<tr>
<td>Ursidae</td>
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<tr>
<td>Arctodus sp.</td>
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<tr>
<td>Felidae</td>
<td></td>
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<tr>
<td>? Felis sp.</td>
<td></td>
<td></td>
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<tr>
<td>Proboscidea</td>
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<tr>
<td>Gomphotheriidae</td>
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<tr>
<td>Cuvieronius sp.</td>
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<tr>
<td>? Rhynchotherium sp.</td>
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<td>Perissodactyla</td>
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<tr>
<td>Equidae</td>
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<tr>
<td>Nannippus phileon</td>
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<td>X</td>
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<tr>
<td>Equus sp.</td>
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<td>X</td>
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<tr>
<td>Artiodactyla</td>
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<td></td>
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<td>Tayassuidae</td>
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<tr>
<td>Hemiauchenia sp.</td>
<td></td>
<td>X</td>
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<tr>
<td>Camelops sp.</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Antilocapridae</td>
<td></td>
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Table 2. Faunal list of Country Club, Duncan, and Pearson Mesa areas

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<th>Taxonomic Group</th>
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<th>Duncan</th>
<th>Pearson Mesa</th>
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<td>Sorex sp.</td>
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<tr>
<td>Edentata</td>
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<tr>
<td>Megalonychidae</td>
<td>Megalonyx sp.</td>
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<td><strong>Lagomorpha</strong></td>
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<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>gen. &amp; sp. indet</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Rodentia</td>
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<td>Geomyidae</td>
<td>Geomys (Nerterogeomys) cf. persimilis</td>
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<td>Geomys sp.</td>
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<td>Felidae</td>
<td>Felis sp.</td>
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<td>Proscidea</td>
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<td>Equus sp.</td>
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<tr>
<td>Tayassuidae</td>
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<td>Hemiauchenia sp.</td>
<td>X</td>
<td>X</td>
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<tr>
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<td>Camelops sp.</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>gen. &amp; sp. indet.</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Antilocapridae</td>
<td>cf. Tetramerex sp.</td>
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<td>Cervidae</td>
<td>Odocoileus sp.</td>
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Figure 3. Faunal list of 111 Ranch area.

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<tr>
<th>Insectivora</th>
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<th>15-17</th>
<th>7933</th>
<th>Galvesto</th>
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<td>Chiroptera</td>
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<tr>
<td>Rodentia</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**Leporidae**

- Lepus sp.
- Hystrix sp.

**Hyracoidea**

- Heterohyrax burtoni

**Artiodactyla**

- Camelidae
  - Camelus sp.
- Bovidae
  - Bovini
  - Odocoileus virginiae
  - Odocoileus hemionus

**Carnivora**

- Canidae
  - Canis latrans
  - Canis lupus
- Felidae
  - Felis montana
  - Felis silvestris
- Mustelidae
  - Mustela vison
- Ursidae
  - Ursus arctos
- Procyonidae
  - Procyon lotor
  - Procyon lotor intermedia
- Procyonidae
  - Procyon lotor

**Perissodactyla**

- Equidae
  - Equus caballus
  - Equus przewalskii
  - Equus caballus
- Artiodactyla
  - Bovidae
  - Bovini
  - Caprini
  - Capra hircus

**Hemionini**

- Hemionus leucopus

**Antilocapridae**

- Antilocapra americana
Figure 7. Correlation of magnetic polarity columns of the Safford and Duncan Basins with the magnetic polarity time scale. Magnetic polarity time scale is after mankind and Dalrymple (1979), with the boundary ages after Nes, Levi, and Couch (1980). Black bar indicates normal, and white indicates reversed polarities.
the Blancan. Presence of *Sigmodon* and *Geomys*, and the presence of *Nannippus phlegon* restrict its lower and upper time limits, respectively, and indicate its age is more or less within the Gauss magnetic chron. Thus, the long normal polarity zone of the Bear Springs section could represent one of three normal zones within the Gauss magnetic epoch. However, the short normal zone between the Kaena and Mammoth events is least likely simply because of its short time span. Thus, the Bear Springs long normal zone could be either the lower normal or upper long normal zone of the Gauss epoch, but the fauna is not sufficiently represented to make that age determination (Fig. 7-1).

The Duncan fauna contains many taxa indicative of early to middle Blancan age (Table 3), including those that are common with the Hagerman, Rexroad, and Benson faunas, but do not include those taxa that are indicative of the late Blancan. Hagerman fauna contains fossils from many localities that range from the top reversed polarity zone of the Gilbert chron to the lower normal polarity zone of the Gauss chron (Neville et al., 1979). The Rexroad fauna is correlative with the lower normal polarity zone of the Gauss chron (Linday et al., 1975), while the Benson fauna (Post Ranch) is correlative with the upper part of the lower normal polarity zone of the Gauss (Johnson et al., 1975). Thus, the lower normal polarity and upper reversed polarity zones of the Duncan section are most likely correlated with the upper part of the lower normal polarity zone and the Mammoth subchron of the Gauss chron (Fig. 7-4). It is also possible that the Duncan section is correlated with the upper part of the middle normal
zone and Kaena subchron of the Gauss chron. However, the faunal restriction is not precise enough to distinguish approx. 0.2 Ma (3.17 and 2.98 Ma) difference at presently available data. Thus, the Duncan section is correlated roughly with the middle Gauss chron.

The Pearson Mesa fauna (Table 3) contains just a few taxa, but the combined occurrence of *Nannippus phlegon* and *Equus* sp. restricts its age, more or less, within the Gauss chron (Lindsay et al., 1984; Galusha et al., 1984). The presence of a gopher similar to late Blancan–early Irvingtonian species (*Q. cf. persimilis*) suggests a later age within the Gauss. In addition, Pearson Mesa section is taken roughly from 3860 to 3980 feet in altitude, while the Duncan section is roughly from 3770 to 3820 feet. Both sections are less than 5 miles apart within the same sedimentary basin. Thus, both biochronologic and topographic data suggest the Pearson Mesa section should be younger than the Duncan section. Based on the faunal and altitudinal data, along with the greater length of the normal polarity zone relative to the polarity zones of the Country Club section (see below), the Pearson Mesa section is most likely correlated with the upper normal polarity zone of the Gauss chron (Fig. 7).

The Country Club fauna contains only several taxa, but a few small mammals are indicative of the early-middle Blancan age, especially the Rexroad fauna which is correlated with the lower normal polarity zone of the Gauss chron. The Country Club section has a reversed-normal-reversed polarity pattern. Thus, it is most likely correlated with the upper-most part of the Gilbert chron through the Mammoth
subchron of the Gauss chron (Fig. 7), which is about the same age as the Hagerman fauna (Neville et al., 1979). It is also possible that the Country Club section is correlative with the Mammoth subchron through Kaena subchron in the Gauss chron. However, this is less likely because of the shortness of the time involved, especially if the correlation of the Pearson Mesa section is correct. It is probably not possible to correlate the Country Club section with the Cochiti normal subchron and reversed zones below and above it of the Gilbert chron, because of the presence of *Sigmodon* (Martin, 1979), *Neotoma quadripli-catus*, and *Equus* (Lindsay et al., 1984), which are not recorded together in other faunas older than the Gauss chron.
MAMMALIAN FAUNAS AND CHRONOLOGY

History of Investigation

Fossil mammal remains in the Safford Basin were first recognized and collected in 1933 and 1934 by Knechtel during his study of the geology and ground water resources of the Gila and San Simon drainage, and were identified by Gazin (in Knechtel, 1936, 1938). Most of the fossils were collected from the I11 Ranch area, and were identified as *Hipparion* (Nannippus) sp., equid (large form), camelid sp., *Platygonus* sp., and megalonychid sp. In addition, *Plesippus* sp. and camelid sp. were identified from the Henry Ranch locality, about 10 miles north of the Bear Springs locality, which is not included in the present study. *Rhynchotherium* ? sp. was identified from the Bear Springs locality. Description of the Bear Springs locality places it in an area with no exposures, and I suspect it should have been the NE ¼ rather than the SE ¼ of section 9, T 7 S, R 23 E. If so, *Rhynchotherium* ? sp. would be from any level in the Bear Springs section (Fig. 2). Gazin (in Knechtel, 1936) was prescient in his correlation and age determinations, considering the state of knowledge at that time. He concluded there was probably little or no time differences between those three localities, and suggested that the assemblage is "probably not greatly separated in time from the Blanco of Texas", may be older than the Curtis Ranch fauna of San Pedro Valley, and is "younger than, or possibly equivalent to" the Benson fauna of the San Pedro Valley.
The history of investigation at 111 Ranch area is explained in detail in Galusha et al. (1984), but is reviewed briefly below. Theodore Galusha began collecting at the 111 Ranch area in late 1937 and early 1938 and returned in late 1938 and early 1939 also. This work included the type specimen of *Capromeryx arizonensis*. Galusha again returned to the 111 Ranch area in 1954 and expanded collecting area to the south. But, most of the fossils were remained unpublished until Galusha et al. (1984) utilized them in a detailed list, but still undescribed. The University of Arizona sent field parties to the Safford Basin under John F. Lance's direction in the late 1950's-early 1960's and under Everett H. Lindsay's direction in 1969 and later. Their effort was especially concentrated in the 111 Ranch area and resulted in the discovery of *Neochoerus* and distinction of lower Blancan fauna and upper Irvingtonian fauna (Lance, 1958). Lance (1960) gave the names Flat Tire Claim and Tusker Claim as locality names of those two faunas, respectively. Wood (1960, 1962) described the fossil material accumulated at UALP by then in his dissertation, modified Lance's locality names to faunal names, and agreed with Lance (1958) in the faunal age. Downey (1962) recognized *Hypolagus* and *Lepus* in the "Tusker local fauna." Lindsay and Tessman (1974) published a faunal list of the Flat Tire and Tusker assemblages then known and assigned both of them to the Blancan age.

When Galusha collected at the 111 Ranch area in 1937-1938, he also collected the Matthew Wash (= Bear Springs) area for the Frick Laboratory of the American Museum of Natural History. In late 1953 to
early 1954, he worked toward the south from the 111 Ranch area along the western flank of the Whitlock Mts., and collected in the vicinity of the San Simon Power Line area (area 3 of Fig. 1). Most of these materials have not appeared in the published literature. A few exceptions are two specimens of *Trigonictis macrodon* from Matthew Wash (Ray, Anderson, and Webb, 1981), and two scutes of *Glyptotherium texanum* (Gillette and Ray, 1981) from south Whitlock Mts. locality (vicinity of the San Simon Power Line area). The University of Arizona field parties (as mentioned above) collected several fossils from the Bear Springs area. Faunal list of then known fossils from the Safford and Duncan Basins was summarized by Lindsay and Tessman (1974). The 111 Ranch area was recently studied in detail using both magnetostratigraphy and biostratigraphy by Galusha et al. (1984). Their results are followed nearly entirely here, except for a few minor corrections on the range zones and faunal identifications.

Mammalian fossil remains from the Duncan Basin were first recognized and collected by C. H. Falkenbach for the Frick Laboratory in 1932. When Galusha returned to the 111 Ranch area in late 1938 and early 1939, he also collected fossils in the Duncan area, covering nearly all exposures along the Gila River in the Duncan basin. None of these materials, however, had appeared in the published literature until Tedford (1981) briefly summarized faunal list. The only exception known to me was a lower jaw specimen of *Anancus bensonensis* (F:AM 23338 = *Stegomastodon mirificus*; Kurten and Anderson, 1980) that was illustrated in Frick (1933, p. 628). The University of Arizona had collected a few
mammalian remains from the Duncan area before the present study began (Lindsay and Tessman, 1974).

Present Studies

The present study began in 1976 with the extensive prospecting and collection of fossil remains at the San Simon Power Line area that was discovered in 1975. Work was expanded to the Bear Springs area in 1978, and to the Duncan Basin in 1979 and 1980, along with further prospecting in Ill Ranch area at the same time. Effort was especially concentrated on the recovery of small mammals and resulted in the discovery of several productive screen wash sites in the Ill Ranch and Duncan areas, plus several small mammal localities. F:AM collections made by Falkenbach, Galusha, and Tedford (as mentioned above), as well as the specimens identified by Gazin (in Knechtel, 1936) and stored at the US National Museum, were briefly examined in 1984.

Lists of faunas from the Bear Springs and San Simon Power Line areas, and the Country Club, Duncan, and Pearson Mesa areas are given in Tables 1 and 2, respectively, including F:AM collections from the same areas for the first time. Although the stratigraphic levels of most University of Arizona localities (except for the San Simon Power Line area) are illustrated in Figs. 2 and 3, the lists are compiled using all the localities in each area. In most instances the localities are restricted to a narrow stratigraphic interval in each section. A revised (from Galusha et al., 1984) list of the fauna from the Ill Ranch area is given in Table 3; for the stratigraphic distribution of
the III Ranch localities, see Fig. 5 of Galusha et al. (1984). In addition, geographic distribution of the small mammal localities and the stratigraphic distribution of small mammal taxa in III Ranch area are illustrated in Figs. 8 and 9, respectively.

BEAR SPRINGS FAUNA—The Bear Springs fauna contains a minimum of 12 taxa identified mostly from the lower part of the section. An antilocaprid is recorded from the upper part of the section (UA loc. 78139 in Fig. 2). Small mammals are very rare in the Bear Springs fauna. Geomys sp. and Sigmodon sp. are represented by fragmentary specimens, but their presence in the fauna is important biochronologically. The mustelid genus Trigonictis was reviewed recently by Ray et al. (1981), and the material from the Bear Springs was identified as T. macrodon which has a wide geographic distribution and is Blancan in age. Gomphotheriid remains are among the most common fossils in the fauna, represented by F:AM collection, but Gomphotheria systematics, especially of Blancan age, is in need of revision, and the gomphotheres provide little useful information at this time. Location of the original specimen of ? Rhynchotherium sp., identified by Gazin (in Knechtel, 1936), is unknown. US National Museum stores only a plaster mold of the occlusal surface of a molar. Equus remains are another common element in the fauna. Nannippus phlegon is represented by a single specimen (MW-SA 38 of F:AM), but is important biochronologically. Camelids are dominant elements in the fauna, represented by Hemiauchenia and Camelops, but are of lesser interest biochronologically. The presence of Sigmodon sp., Trigonictis macrodon, and Equus sp. limits the oldest
Figure 8. Map showing the small mammal fossil localities at the Illi Ranch area. Base map is reproduced after Galusha et al. (1984).
Figure 9. Small mammal biostratigraphy of the Ill Ranch area
possible age, while the presence of *Nannippus phlegon* limits the youngest possible age (Lindsay et al., 1984), and thus, the age of the Bear Springs fauna is approximately the middle Blancan age, or within the Gauss magnetic chron more or less. As discussed in the magnetic analysis above, the Bear Springs section contains a lower short reversed and an upper long normal polarity zones. However, since the fauna does not include diagnostic species which would place them more precisely within the Gauss, and the paleomagnetic polarity pattern is too short to correlate with the MPTS, a secure correlation of the fauna and section with other faunas and the MPTS cannot be determined, and two possible correlations are illustrated (Fig. 10).

**SAN SIMON POWER LINE FAUNA**—The San Simon Power Line fauna consists of the fossils from a number of localities distributed approximately within 1 mile square, in sect. 9 and vicinity, T 10 S, R 28 E. Exposures are widespread, but stratigraphic extent is short (Fig. 2); essentially all the localities are placed stratigraphically within 15 m or so. A minimum of 16 taxa are recorded in the list (Table 1). The genus *Glyptotherium* was reviewed by Gillette and Ray (1981), and the two scutes from the southern Whitlock Mts. locality of Galusha (F:AM) collection, which is considered in the present paper, more or less equivalent to the San Simon Power Line area) were referred to *G. tex-anum*. I suspect this reference is given mainly because they are similar to specimens in the "Tusker fauna," the younger part of the 111 Ranch fauna (Galusha et al., 1984), which includes better specimens of the species. However, as discussed below other elements of the San Simon Power Line fauna are similar to the latest Blancan-early
Figure 10. Correlation of faunas in Safford and Duncan Basins, San Pedro Valley, and other areas with the magnetic polarity time scale. -- The MPTS is the same as Figure 7.
Irvingtonian faunas. I believe the distinction between G. texanum and G. arizonae near their transition is difficult, especially when based on only fragmentary scutes. Thus, one should not rely too heavily on the presence of G. texanum when the age of the fauna is considered.

Table 4 is a list of small mammal fossils that are known from the present study area, including only taxa that are identified at the species level. Table 5 is the same list as Table 4 but is arranged by the order of first appearances of these species within 11 Blancan and early Irvingtonian faunas. Hypolagus virginiae (see systematics section below) is well represented in the fauna and used as the basis of generic change of the species from the genus Aluralagus to Hypolagus. H. virginiae is known from the Curtis Ranch fauna in San Pedro Valley, which is correlated near the base of the Olduvai event of the Matuyama magnetic chron (Johnson et al., 1975). Although Spermophilus species that is similar to the middle Blancan species, S. bensoni, is present, one should not rely too much on that because the identification of Spermophilus species is very difficult, especially on a single specimen. Although Geomys persimilis is described from the Curtis Ranch fauna, it is also known from the Wolf Ranch fauna, and a comparable form is known from the Duncan and III Ranch faunas (Tables 4 and 5; see also Cuncan fauna below). The age of the Wolf Ranch fauna has been correlated with near the boundary of the Gauss-Matuyama magnetic chron (Johnson et al., 1975). Dipodomys hibbardi was described from the Borchers fauna, but also known from the 30-85 m level of the III Ranch section (see below; Fig. 9), and is thus indicative of the late Blancan age. The presence of bears, Arctodus sp., is interesting, although not much of interest
Table 4. Comparative small mammal fossil list of 11 Blancan and early Irvingtonian faunas

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2. Country Club: this study.
5. Duncan: this study.
7. 111 Ranch, lower part: Galusha et al. (1984), this study.
8. 111 Ranch, upper part: Galusha et al. (1984), this study.
Table 5. Comparative small mammal fossil list arranged by the order of first appearance within 11 faunas in Table 4

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biochronologically. Horses are one of the most common elements of the fauna, and are represented by the genus Equus. Although it is negative evidence, the absence of Nannippus is important biochronologically. Camels are the most dominant large mammal of the fauna and are represented by mainly Hemiauchenia sp.; they are of less significance biochronologically.

Thus, the age of the San Simon Power Line fauna can be narrowed to the late Blancan and early Irvingtonian, or from the Gauss-Matuyama boundary to the Olduvai subchron on the MPTS. More precise correlation is not possible using faunal evidence alone. However, the San Simon Power Line area is just 6-7 miles south of the 111 Ranch area along the west flank of the Whitlock Mts., and the sediments are more or less continuous between them (Richter, Shafiquillar, and Lawrence, 1981). Level of the fossil localities at the San Simon Power Line area is the same approximate elevation as the middle part of the 111 Ranch section. Thus, the San Simon Power Line fauna is more likely correlative with the upper part of the 111 Ranch section (or slightly younger than that), and probably not as young as the Curtis Ranch fauna (Fig. 10). In order to be correlated with the Curtis Ranch fauna, there should be a stratigraphic gap of nearly 100 m thick between the San Simon Power Line section and the middle part of the 111 Ranch section.

DUNCAN FAUNA--The Duncan fauna contains a minimum of 25 taxa of which 14 are small mammals (Table 2). Soricids are represented by two different forms, but cannot be identified to species level. Leporids are represented by a few specimens and are very poor in contrast to the
diverse rodent fauna. Geomyids are represented by a species that is tentatively identified as *G. (Nerterogeomys) cf. persimilis*, which may be identical with *G. anzensis* (see systematics section below). *G. anzensis* is known from the Anza-Borrego Desert, and ranges from the middle Blancan to the early Irvingtonian, or from near the base of the Gauss chron to slightly above the Olduvai subchron in the MPTS (Becker and White, 1981). *G. persimilis* is known from the Wolf Ranch fauna to the Curtis Ranch fauna, or from the Gauss-Matuyama boundary to the Olduvai subchron in the MPTS (Johnson et al., 1975). *Perognathus gidleyi* has a rather wide range geographically and in age, spanning from the middle Blancan Rexroad fauna to the latest Blancan Borchers fauna in Kansas and the Wolf Ranch fauna in Arizona (Table 5). Cricetid rodents are diverse and are represented by six taxa, most of which are dominant in the fauna. They are all characteristic middle Blancan forms, and particularly *Baiomys minimus, Sigmodon medius,* and *Neotoma fossilis* share occurrences with the Benson fauna. Arvicolids are rare in number of specimens but are represented by two forms. *Ophiomys taylori* is known from the Hagerman fauna and marks the Blancan II and III boundary of Repenning (1980), though it has a considerable stratigraphic range from approximately the middle part of the Hagerman to the Grand View local fauna within the Glenns Ferry Formation.

Horses are dominant elements in the fauna and are represented by at least three taxa; *Nannippus phlegon, Equus (Dolichohippus)* and *E. (Asinus)*. Presence of *Nannippus phlegon* suggests the age of the fauna older more or less than the Gauss-Matuyama boundary (Lindsay
et al., 1984). Camels are also common elements in the fauna, though they are of less significance biochronologically again. A cervid is represented by a single jaw of *Odocoileus* and an unidentified antler fragment. This is interesting taxon, indicating, at oldest the uppermost reversed zone of Gilbert epoch (Lindsay et al., 1984). Thus, the Duncan fauna is most similar to the Benson fauna and is considered middle Blancan in age. With the paleomagnetic data, the Duncan fauna is most likely correlated with the base of the Mammoth or Kaena subchron of the Gauss magnetic chron, or more roughly the middle Gauss (Fig. 10).

**PEARSON MESA FAUNA**--The Pearson Mesa fauna is poor both in number of individuals and in diversity of taxa. It is represented by 5 taxa (Table 2). *Geomys* cf. *persimilis* has been discussed above and has a rather long time range. A gomphothere, *Stegomastodon mirificus*, is represented by a jaw identified and illustrated by Frick (1933, p. 628) as *Anancus bensonensis*, although the precise locality is not given (noted as southeast of Duncan, which is most likely Pearson Mesa). *Stegomastodon mirificus* is also in need of revision, but ranges more or less from the Blancan to early Irvingtonian age (Kurten and Anderson, 1980). Horses are the most common elements in the fauna and are represented by two taxa, *Nannippus phlegon* and *Equus* sp., indicating the age of the fauna is not as late as the late Blancan. Thus, the Pearson Mesa fauna is middle Blancan in age, or roughly within the Gauss magnetic chron, and no more precise correlation is possible by faunal evidence alone. As discussed in the correlation of the paleomagnetic
section above, the long normal polarity zone of Pearson Mesa is most likely correlated with the upper long normal polarity zone of the Gauss magnetic chron, in relation to the Duncan and Country Club sections (see below; Fig. 10).

COUNTRY CLUB FAUNA—The Country Club fauna consists of a minimum of 11 taxa (Table 2). Megalonyx is represented by a single specimen of the phalanx, but the genus has a long range in North America from Hemphillian to Rancholabrean (Hirschfeld and Webb, 1968). Leporids are represented by a jaw (Notolagus lepusculus) and unidentified molars. N. lepusculus is a rather rare species among the diverse Blancan leporids, and is also known from the Rexroad fauna. Although N. cf. lepusculus was reported from the Wolf Ranch fauna (Harrison, 1978), I am doubtful of that generic identification based primarily on a jaw with P4–M2 which, I suspect, could also be a small species of Hypolagus. Four rodent taxa are recorded in the list, but are all represented by rather fragmentary material. Of those, Neotoma (Paraneotoma) quadruplicatus is of great interest: it is known from the Rexroad fauna and the Beck Ranch fauna (Dalquest, 1978), and a comparable form is also known from the Hagerman and White Bluffs faunas. Sigmodon medius is a middle Blancan form (I follow Martin, 1979, on his taxonomic framework, distinguishing S. medius from S. minor). Carnivores are represented by a small species of mustelid and Taxidea sp. Horses are represented by Equus sp., which is a common element of the fauna but is represented by fragmentary material. The absence of Nannippus may have no significance. Camels are another common element of the fauna. The Country
Club fauna, thus, is probably comparable with the Rexroad fauna and is considered early middle Blancan in age. Combining this age with the results of the magnetic polarity zonation discussed above, the Country Club section is most likely correlated with the uppermost Gilbert magnetic chron to the Mammoth subchron (Fig. 10).

Although not listed in Table 2 nor studied in this paper, there are several collecting sites on the east side of the Gila River between Duncan and the Country Club area. They are mostly along the Sand Wash (a wash just north of Duncan in Fig. 5; noted "Duncan Nada" in F:AM collection and Sand Wash localities in UA collection) and include Nan­nippus, Equus spp., cf. Hemiauchenia, and a gomphothere, etc., which does not contradict the correlation of the three faunas discussed above. However, a partial skeleton of Glossotherium chapadmalense (F:AM 96370; Tedford, 1981, p. 1020) was collected from the locality noted as "11 mile Wash locality" in F:AM collection; this is supposed to be somewhere in NW ¼ of sect. 2 and NE ¼ of sect. 3, T 6 S, R 31 E (Tedford pers. comm., 1984). G. chapadmalense is known in North America from Haile XV-A and Inglis 1A in Florida, Blanco in Texas (Kurten and Anderson, 1980), and near the Gauss-Matuyama boundary of the III Ranch section (Galusha et al., 1984), and thus it is considered late Blancan-early Irvingtonian in age. Other Blancan localities that recorded Glossotherium sp. are also late Blancan (Kurten and Anderson, 1980; I believe they mistakenly listed the White Bluffs which is early-middle Blancan age; Gustafson, 1978, does not list the genus in his White Bluffs fauna). The locality ("11 mile wash") is about 4 miles
directly to the south from the Country Club area, and is about the same elevation. Thus, the presence of *G. chapadmalense* obviously contradicts the correlation of the Country Club section discussed above. Assuming that the identification of *G. chapadmalense* is correct, two hypotheses can solve the contradiction. One is to correlate the Country Club section near the base of the Mammoth subchron up to the lower most part of the Matuyama chron, assuming the short normal zone between the Mammoth and Kaena subchrons was not represented in the Country Club section. This correlation requires a range extension of *Neotoma quadriplicatus* and *Notolagus lepusculus* upward to the middle part of the Gauss chron, and a possible range extension of *G. chapadmalense* slightly downward to somewhere in the upper Gauss chron. Another hypothesis is to simply assume that *G. chapadmalense* appeared much earlier than is presently known. The Blancan records of *Glossotherium* remains are still poor and it is probable to extend the record of *Glossotherium* first appearance in North America. I believe that both hypotheses are equally plausible, and correlations of the Country Club section with MPTS and other faunas are shown in Fig. 10 according to both hypotheses.

III RANCH FAUNA--The III Ranch fauna has recently been studied in detail with paleomagnetic analysis (Galusha et al., 1984). Most of their results are followed here, but the discovery of new small mammal localities added some new knowledge. Following discussion is mainly on the small mammals; for the discussion on the large mammals see Galusha et al. (1984).
Main contribution of this paper to the Illl Ranch fauna is the addition of productive small mammal sites at lower (about 30 m level) and upper (about 85 m level) parts of the section, and description of their fossils. A revised list of taxa from the Illl Ranch area is given in Table 3. Stratigraphic distributions of small mammal taxa are illustrated in Fig. 9. A soricid insectivore and bats are recorded at the 85 m level of the section for the first time in Illl Ranch area, but are of less significance biochronologically. Although no additional taxa have been known, some leporids are revised taxonomically and listed by different names. Aluragus sp. and Nekrolagus sp. in Galusha et al. (1984) are the same taxa as ?Hypolagus virginiae and gen. & sp. indet. in Table 3, respectively. Geomys sp. in Galusha et al. is referred to G. (Nerterogeomys) cf. persimilis, which may be the same taxon as G. anzensis as discussed above, and is known from Duncan through the San Simon Power Line faunas (Table 5). Heteromyids are represented by a minimum of 4 taxa. Perognathus gidleyi has a long range as pointed out above (in Duncan fauna). Prodipodomys sp. in Galusha et al. (1984) is now recognized as three taxa: rare Prodipodomys sp., dominant Dipodomys hibbardi, and somewhat common D. cf. gidleyi. Zakrzewski (1981) reexamined Dipodomys material from the Borchers fauna and redefined the genera Prodipodomys and Dipodomys, which I follow in this paper (see also systematics section below). D. hibbardi had been known only from the Borchers fauna, but is recognized in this paper from the Illl Ranch and San Simon Power Line faunas (Tables 4 and 5). Prodipodomys in the Wolf Ranch is also very likely D. hibbardi.
Cricetidae are represented by a minimum of 11 taxa. At UA loc. 15-24 *Sigmodon medius* and *Neotoma taylori* are predominantly abundant, and other small to medium sized cricetines are all relatively rare. At UA loc. 7933, on the other hand, small forms such as *Peromyscus*, *Baiomys*, and *Reithrodontomys*, and large forms such as *Sigmodon* and *Neotoma* are similar in abundance in the fauna. Most specimens from loc. 15-24 were collected by hand before screen washing (Hibbard, 1949b) became a common technique among vertebrate paleontologists, and thus, the compositional difference between these two sites are probably, at least partly, an artifact. *Onychomys* has been reviewed by Carleton and Eshelman (1979) and I agree with their taxonomic framework. *O. pederoensis* has a long range from the late Blancan to the Rancholabrean. *Peromyscus hagermanensis* has been known from the Hagerman, and also is identified from the Duncan fauna in this paper. *Baiomys* is represented by two taxa in the 111 Ranch. *B. sp.* from the lower part of the section is a small form and is similar to *B. rexroadensis*, *B. aquilonius*, and *B. taylori* among the presently known species, whereas *B. cf. brachygynathus* from the upper section is a large form (Fig. 9). *Reithrodontomys* material from UA loc. 15-24 is identified as *R. rexroadensis*, known from the Fox Canyon fauna in Kansas and Duncan fauna, whereas the material from loc. 7933 is different and is described as a new species below. The absence of *Calomys* (*Bensonomys*) *arizonae* on the upper half of the section may indicate the termination of its range, though in the San Pedro Valley a few fragmentary specimens are known above the Gauss-Natuyama boundary (Johnson et al., 1975). *Neotoma* sp. in Galusha et al.
is identified as *N. taylori*, which is known from the Borchers fauna, and probably from the Curtis Ranch also (see systematics section below). Repomys material was mixed with *Neotoma* sp. material before and is described as a new species in this paper (below), which might represent a different lineage from *R. panacaensis* known from the middle Blancan Panaca fauna of Nevada (May, 1981).

No additional arvicolids have been added to the III Ranch fauna, but *Pliophenacomys* sp. in Galuska et al. (1984) is identified as *P. primaevus*. Zakrzewski's (1984) recent revision of "*P. osborni" straightened the ambiguity of this species (Martin, 1972) and related genera and species. *P. primaevus* has been known from the Rexroad and Sand Draw faunas. Thus, the presence of *P. primaevus* in the III Ranch section is probably the latest record of the species.

Thus, the present study on small mammal fossils from the III Ranch area gives a more precise and expanded knowledge than that in Galuska et al. (1984), but requires no changes on their conclusions. Galuska et al. (1984) clearly showed that there is no faunal distinction between the "Flat Tire" and "Tusker" faunas. I agree with them, but there is a minor faunal change in small mammals between the lower-middle and upper part of the section: species composition of *Baiomys* and *Reithrodontomys* were changed and *Calomys* (*Bensonomys*) arizonae might have disappeared (Table 5). This may indicate that the entire section of the III Ranch area represents a greater length of the time than just below and above of the Gauss-Matuyama chron boundary.
SYSTEMATICS

Class MAMMALIA Linnaeus, 1758

Order INSECTIVORA Cuvier, 1817

Classification of so-called insectivores in higher hierarchy had received little attention between the time of Simpson (1945) classification until Van Valen (1966, 1967) created a new order, Deltatheridia, to include the Deltatherioidea, Tenrecoidea, and Chrysochloroidea that had previously been classified among the Insectivora (of Simpson, 1945). Butler (1972) later proposed a new classification, and raised to ordinal rank all the Cretaceous to Oligocene non-Lipotyphla (his ordinal name = Insectivora s.s.) "insectivores" as Proteutheria, and elephant shrews as Macroscelidia, restricting the order to include Erinaceomorpha, Soricomorpha, Tenrecmorpha, and Chrysochlorida, although Butler used the term Lipotyphla (rather than Insectivora) as the ordinal name. Butler's separation of Proteutheria and Insectivora was followed by Novacek (1976), though Novacek used Insectivora as the ordinal name. Since then, the distinction between Proteutheria and Insectivora has generally been followed (Kielan-Jaworowska, Bown, and Lillegraven, 1979; and many references in Novacek, Bown, and Schankler, 1985), and the order Deltatheridia had usually been abandoned. I follow Novacek et al. (1985) on their most recent concept of the order Insectivora.
Family SORICIDAE Vacq'd'Azyr, 1792
Subfamily SORICINAE Fisher von Waldheim, 1817
  Notiosorex Baird, 1877
  Notiosorex sp.
  (Fig. 11A; Table 6)

REFERRED MATERIAL: UALP no. 14185, right 1^1 and 14172, right dentary fragment with M_2-3, both from UA loc. 7937, Duncan, at about 10 m level of the Duncan section, Gila Conglomerate, southern Arizona.

AGE: Middle Blancan (late Pliocene).

DESCRIPTION: 1^1 is relatively thick laterally, with no small cuspule on the medial side of the anterior cusp (non-bifid); posterior cusp is relatively low. M_2 has primitive tribosphenic tooth pattern with 6 basic cusps; the metaconid bends medially (this is obvious in anterior view). Although the entoconid is well worn, it seems rather small and is located slightly anterior to the posterointernal corner of the tooth so that the hypoconid appears more separated from it. M_3 has a reduced talonid with no entoconid; the V-shaped ridge of the hypoconid is absent, a medial anteroposterior ridge joins the hypoconid and metaconid; a very low and short entoconid crest is present. Labial cingulum is present on both M_2 and M_3. In lingual view, the basal edge of the crown forms an arc rather than a straight line in both teeth.

COMPARISONS AND DISCUSSION: Three species of Notiosorex are presently known: modern N. crawfordi, N. jacksoni from the Rexroad fauna (Hibbard, 1950) and the Beck Ranch fauna (Dalquest, 1978), and
Figure 11. Soricidae, Chiroptera, Sciuridae, Heteromyidae, and Cricetidae

A: *Notiosorex* sp., UALP 14172, right dentary with $M_2$-$M_3$.
B: *Sorex* sp., UALP 14173, right $M^1$.
C-D: Chiroptera
   C, UALP 13912, right $M_2$(?); D, UALP 15249, right $M^3$.
E: *Spermophilus* cf. *bensoni*, UALP 10337, left dentary with $P_4$-$M_3$.
F-I: *Perognathus gidleyi*
   F, UALP 14206, left $P_4$; G, UALP 14204, left $P^4$;
   H, UALP 15949, right $P^4$; I, UALP 1008, right dentary fragment with $P_4$-$M_3$.
J-L: *Onychomys pedroensis*
   J, UALP 13947, right $M^1$; K, UALP 14006, left $M_3$;
   L, UALP 13963, left $M_1$.
M-N: *Calomys* (Bensonomyx) *arizonae*
   M, UALP 1048, left dentary fragment with $M_1$-$M_3$;
   N, UALP 14126, left $M_1$.
O: ? *Calomys* (Bensonomyx) sp., UALP 14209, right $M_1$.

Short scale bar represents 1 mm for Figure 1 and M;
long scale bar represents 5 mm for Figure 3. For all other figures, long scale bar represents 1 mm.
Figure 11. Soricidae, Chiroptera, Sciuridae, Heteromyidae, and Cricetidae
Table 6. Measurements of Soricidae

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Notiosorex n. sp. from the Concha fauna of Mexico (Lindsay and Jacobs, in press). The new species from Mexico is much larger in size and has molar trigonids anteroposteriorly shorter. N. jacksoni is also larger than UALP 14172. UALP 14172 is about the same size, or slightly smaller than N. crawfordi; it is morphologically similar also; however, the entoconid is larger and placed more anterior in N. crawfordi. Notiosorex sp." from the Hemphillian White Cone fauna (Baskin, 1979) is similar in size to UALP 14172, but differs slightly in length of the trigonid and development of the M₃ talonid. The longer appearance of trigonids in UALP 14172 may be due to the wear. More and better specimens are needed for a more secure identification.

Sorex Linnaeus, 1758

Sorex sp.
(Fig. 11B; Table 6)

REFERRED MATERIAL: UALP nos. 14183-14184, 14186, I¹'s; 14173, M¹; 14174, 14180-14181, M²'s; 14175, I₂; 14176-14178, M₁'s; 14179, M₂; 14182, edentulous jaw, all from UA loc. 7937, Duncan, at about 10 m level of the Duncan section, Gila Conglomerate, southern Arizona.

AGE: Middle Blancan (late Pliocene).

DESCRIPTION: I¹ has a tiny cuspule on the medial side of the anterior cusp (bifid); it has a single root with a groove on the labial side. Upper molars are similar to those of most soricines in general morphology. M¹ is wider than long, with strong posterior emargination
of the hypoconal flange; a short ridge joins the metaconule and the metacone, forming a small triple junction of crest. $M^2$ is similar to $M^1$, but it is wider than long; posterior V of the W-shaped ectoloph is larger than the anterior V, though not as greatly as in $M^1$. UALP 14181 retains a maxillary fragment that includes part of the zygoma (zygomatic process) that extends posteriorly from the posterolabial corner of $M^2$. $I_1$ is relatively long and nearly straight, with two poorly developed "scalloped cusp" (Repkening, 1967) on the cutting edge. The entoconid of $M_{1-2}$ is prominent, and a low entoconid crest connects the entoconid and metaconid. Posterior, the transverse ridge of the V-shaped hypoconid joins the weak lingual cingulum at the posterolingual corner of the tooth, but does not connect with the entoconid. In lingual view, the basal edge of the crown forms a nearly straight line in both $M_1$ and $M_2$. No $M_3$ is known.

COMPARISONS AND DISCUSSION: $M^{1-2}$ described above are similar to those of Notiosorex in greater width relative to the length and great concavity in posterior outline, but Notiosorex has wider $M^{1-2}$ and does not have a zygomatic process on maxilla. Some Old World Sorex have less wide $M^{1-2}$, but have the zygomatic process as in UALP 14181. $I_1$ of Sorex sp. differs from that of Notiosorex in having slightly bifid anterior cusp. An edentulous jaw (UALP 14182) has mental foramen below the middle part of $M_1$, with a weak depression anterior to it, and thus is tentatively referred to Sorex sp., though lacking any characteristic teeth.
Soricidae gen. and sp. indet.

(Table 6)

REFERRED MATERIAL: Two $i^1$'s, one $p^4$, five $M^1$'s, two $M^2$'s, five $M_1$'s, and one $M_2$, from UA loc. 7933, at about 85 m level of the III Ranch composite section, Gila Conglomerate, southern Arizona.

AGE: Late Blancan (latest Pliocene).

DISCUSSION: The specimens referred to this taxon are isolated, and some are fragmentary. They are similar to *Sorex* in some respects, but are lacking diagnostic characters, and further identification is insecure without more better specimens. They might represent more than a single taxon because some specimens (e.g., UALP 13906) differ from other specimens in size and general outline. They are smaller than *Sorex* sp. described above.

Order CHIROPTERA Blumenbach, 1779

(Fig. 11C-D)

Eleven isolated teeth (7 $M_1$ or $M_2$'s and single specimen of $M^3$, $C_1$, $P_4$, and $M_3$) from the UA locality 7933, at about 85 m level of the III Ranch composite section, are identified as Chiroptera. Basis of this identification is small size, presence of well developed basal cingula, presence of well developed entostylids on lower molars, and dissimilarity with other specimens from the same locality. Most of the specimens probably belong to a single taxon, but two other taxa
may be distinguishable based on the differences in size and general morphology.

Order LAGOMORPHA Brandt, 1855
Family LEPORIDAE Gray, 1821
Notolagus Wilson, 1937
Notolagus lepusculus (Hibbard, 1939)
(Fig. 12A; Table 7)

REFERRED MATERIAL: UALP no. 14169, left dentary fragment with P3-4 M1-3, from UA loc. 8056.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA loc. 8056, at about 8 m level of the Country Club section, Gila Conglomerate, southern Arizona; Wolf Ranch local fauna, St. David Fm., southern Arizona; Rexroad local fauna, Rexroad Fm., Kansas.

AGE: Blancan (late Pliocene).

DESCRIPTION: P3 is trapezoidal in outline, narrow anteriorly. Anteroexternal reentrant is wide and shallow. Posteroexternal reentrant extends lingually less than halfway across the occlusal surface, and the posterior enamel border has no crenulations. Anterointernal reentrant is deep, with complex enamel crenulations, extends labially and posteriorly to reach about halfway across the occlusal surface. Posterointernal reentrant is absent but the posterointernal border of the tooth is slightly concave.
Figure 12. Leporidae

A: *Notolagus lepusculus*, UALP 14169, left P₃.

B-C: *Hypolagus arizonensis*
   B, UALP 1013b, left P₃; C, UALP 1013a, right P₃-₄.

D-K: *Hypolagus virginiae*
   D, UALP 10339, left P₃-₄; E, UALP 13892, left P₃;
   F, UALP 10340, right P₃; G, UALP 1372, left P₃-₄,
   15 mm below occlusal surface (mirror image);
   H, UALP 1372, left P₃-₄; I, UALP 1382, left P₃,
   holotype; J, UALP 10341, left P²-₃; K, UALP 10335,
   right P².


M-P: *Hypolagus sp.*
   M, UALP 1133, left P₃; N, UALP 14188, right P₃;
   O, UALP 1132, right P₃, occlusal surface;
   P, UALP 1132, right P₃, 5.5 mm below occlusal sur-
   face, mirror image.

Q: Leporinae, gen. and sp. indet., UALP 15975, right P₃.

R: *Sylvilagus* or *Lepus* sp., UALP 10338, right P₃.
Figure 12. Leporidae
Table 7. Measurements of *Notolagus* and *Hypolagus*

<table>
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<th>UALP No.</th>
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<td>1133 L P/3</td>
<td>1.96</td>
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External reentrant of $P_4$ through $M_2$ extends lingually completely across the crown of the tooth with no crenulations of enamel. Width of the posterior column of these teeth is 15-29% shorter than that of anterior.

**COMPARISONS:** *Notolagus velox* known in the Yepomera local fauna in Mexico (Wilson, 1937; Lindsay and Jacobs, in press) usually has $P_3$ with anterointernal reentrant connected with anteroexternal reentrant, forming two columns. The $P_3$ of *N. velox* usually has enamel borders somewhat more crenulate than that of *N. lepusculus*, described in the Rexroad local fauna in Kansas by Hibbard (1939). The size of *N. velox* is usually slightly larger than *N. lepusculus*. UALP 14169 is about the same size as *N. lepusculus*, and posterior enamel borders of both posteroexternal reentrant of $P_3$ and the external reentrant of $P_4-M_2$ are not crenulated as in *N. lepusculus*.

**Hypolagus Dice, 1917**

*Hypolagus arizonensis* Downey, 1962

(Fig. 12B-C; Table 7)


**HOLOTYPE:** UALP 1013a, right dentary fragment with $I_1P_3-4$, from UA loc. 15-10.

**STRATIGRAPHIC AND GEOGRAPHIC RANGE:** UA loc. 15-10, at approx. 40 m level of the 111 Ranch composite section, Gila Conglomerate, southern Arizona.
AGE: Late Blancan (latest Pliocene).

DISCUSSION: *H. arizonensis* was described by Downey in 1962 based on two dentary fragments, both including P3. No additional material referable to this species has been collected since 1962. However, Downey's (1962) characterization of this species needs a few revisions, particularly the illustrations and measurements, as given below.

The paratype, UALP 1013b does not contain P4. In his diagnosis, the sentence "P3 wide anteroposteriorly" should be omitted, because it is almost as wide as long, as in most species of the genus (Fig. 12B-C; Table 7). The illustration (Downey, 1962, text-Fig. 1A) seems expanded obliquely and does not illustrate the specimen correctly, and thus should be replaced with the one provided here (Fig. 12C). The obliqueness of both P3 and P4 in original illustration distorts the true shape of the teeth. Also in P4 the illustrated thickness of anterior and posterior enamel walls on anterior and posterior columns is much thinner on the specimen. There is no other species of *Hypolagus* whose P4 has such thick enamel wall on those positions. Measurements of these teeth are given in Table 7.

AMENDED DIAGNOSIS: Size about the same as or slightly smaller than *H. furlongi* or *H. limnetus*. P3 rounded triangle in outline with deep posteroexternal reentrant extending lingually two thirds of the distance across the occlusal surface. Anteroexternal reentrant of P3 relatively deep, extending lingually almost 1/2 across occlusal surface, narrow and non crenulate internally, wide near external margin.
Hypolagus virginiae (Downey), 1970
(Fig. 12D-K; Table 8)


HOLOTYPE: UALP 1382, left dentary fragment with P₃, from UA loc. 25-2, Curtis Ranch, San Pedro Valley, southeastern Arizona.

REFERRED MATERIAL: UALP no. 10355, right maxillary fragment with P²-M³, from UA loc. 7608. UALP nos. 10399, left dentary fragment with P₃-M₃; 10340, right dentary fragment with P₃-M₃; 10341, partial skull with right P²-M³, left P²-M², and basal portions of other teeth; 13892 left P₃; 15907, left Mₓ; 15909, right P⁴(?); 15910, left M²(?), from UA loc. 7706. UALP no. 15821, palate fragment with right P³-4, from UA loc. 7805.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA locs. 25-2 from St. David Fm., Curtis Ranch, San Pedro Valley; 7608, 7706, 7805 from Gila Conglomerate, San Simon Power Line, southern Arizona.

AGE: Late Blancan (latest Pliocene) to early Irvingtonian (earliest Pleistocene).

AMENDED DIAGNOSIS: Small species of the genus, size near that of H. furlongi or H. arizonensis. P₃ is rounded triangular in outline. The posteroexternal reentrant is deep, extending lingually about three-fourth of width of the occlusal surface to near the lingual edge of the tooth. It is constricted near the middle of the tooth, and the lingual half expands anteriorly. Anteroexternal reentrant is wide and
Table 8. Measurements of *Hypolagus virginiae*

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shallow, with depth from one-fifth to one-fourth across the occlusal surface with some enamel crenulation. $P^2$ with deep anterior reentrant located slightly more lingual than median line of the tooth, and with shallow, weak anteroexternal groove.

**DESCRIPTION:** The skull has a shorter rostrum relative to the length of tooth series, as in *H. limnetus* (Gazin, 1934). Anterior palatine foramina are relatively longer and extend posteriorly to the midline of $P^2$, so that the anteroposterior length of the bony palate is somewhat short, in comparison with those in *H. limnetus*.

Base of $I^1$ is preserved on UALP 10341. The anterior reentrant is a relatively shallow and narrow groove, located one-third the distance from the internal surface.

$P^2$ has a deep anterior reentrant with smooth or slight enamel crenulation on the posterior border, located slightly lingual relative to median line, and a shallow anteroexternal groove. One slightly worn specimen (UALP 10355) has a shallow groove on the enamel border at anteriointernal corner of the tooth.

Depth of the internal hypostra of $P^3-M^2$ is about two-thirds of the width of the occlusal surface. The plication count of the anterior enamel border is from 7 to 10, tending toward reduction in number and in depth in more posterior teeth. Plication count of posterior border varies from 4 to zero, and again tends toward reduced in number and straighter in more posterior teeth.

$P_3$ is triangular in outline, with the length about equal to width. Anteroexternal reentrant is wide and varies in depth from
one-fifth to one-fourth the width of the occlusal surface, with a slightly crenulated, thin enamel border. Depth of the posteroexternal reentrant extends from about three-fourths to four-fifths the width of the occlusal surface. It is constricted near its middle with the lingual half expanded anteriorly. In one specimen (UALP 13892) the antero-internal expansion of the posteroexternal reentrant shows a more complicated enamel border (Fig. 12E) than others. In another specimen (UALP 10339) there is a lingual enamel lake with thin wall at the posterointernal position of the tooth.

P₄-M₃ show the enamel pattern characteristic of the genus with smooth enamel on the anterior border of posterior column.

Isolated cheek teeth and associated P₃-₄ are referred to this species based on the similarity in size and/or enamel pattern. The size range overlaps with, but the enamel pattern is different from that of Sylvilagus or Lepus sp., another leporid known from the same general area.

COMPARISONS: H. virginiae is readily distinguished from all of the known species of the genus except for H. arizonensis by the greater depth of the posteroexternal reentrant of P₃. P₃ of H. arizonensis differs from that of H. virginiae in that the posteroexternal reentrant is straighter and its enamel border is simpler, plus the anteroexternal reentrant is deeper, with no enamel crenulation. P₃ of H. virginiae has the most complicated enamel crenulation within the known species of the genus.
Specimens of *Hypolagus* from the Borchers fauna in Kansas (Hibbard, 1969, p. 88-90, Fig. 3c, 3c') are very similar to *H. virginiae*, especially to those specimens from UA loco. 7706, San Simon Valley. The difference of these taxa is that the enamel crenulation on both the antero- and posteroexternal reentrants of *P₃* is less complex in the specimen from the Borchers fauna. The Borchers specimen is probably conspecific with *H. virginiae*.

*H. virginiae* differs from *Aluralagus bensonensis* in having the following characters: (1) in *P₃* the enamel border of the posteroexternal reentrant is much less crenulated and the anteroexternal reentrant is much more shallow and its enamel border is less crenulated, (2) *P²* with deep anterior and very shallow anteroexternal reentrants; and (3) *P₄-M₂* with no enamel crenulation on the anterior border of the posterior column of the teeth (see next section for detail).

**DISCUSSION:** *P₃* from Borchers fauna in Kansas that has been referred to *Hypolagus* sp. (Hibbard, 1969, Fig. 3C) is obviously *Hypolagus*, although it has the deepest posteroexternal reentrant within known species of the genus. *P₃* 's from the San Simon Power Line described here should also be referred to the genus *Hypolagus* because they are similar to that from the Borchers fauna although enamel crenulation of the posteroexternal reentrant is slightly more complicated in specimens from San Simon. Characters of *P²* and *P₄-M₂* are also consistent with reference to the genus *Hypolagus*. Thus, although it expands the concept of the genus, the specimens described here can most parsimoniously be referred to the genus *Hypolagus*. 
Downey (1970) described "Aluralagus" virginiae based mainly on the characters of three P₃'s from Curtis Ranch, San Pedro Valley, Arizona. Compared to the genotypic species, A. bensonensis, P₃ of "A." virginiae from the San Pedro Valley has the following characters:

1) posteroexternal reentrant usually does not extend lingually across the tooth as far as in A. bensonensis, and its posterior enamel border is much smoother (and may lack crenulation) than in A. bensonensis;
2) anteroexternal reentrant is much shallower, and its enamel border is less crenulate. The illustration of the holotype by Downey (1970, p. 8134, Fig. 3b) does not show these characters. It shows enamel crenulation more complicated than seen on the specimen (compared with Fig. 12I).

On the other hand, isolated P₃'s from San Simon area are very similar to those of "A." virginiae from Curtis Ranch. For instance, UALP 13892 from San Simon is almost identical with the holotype of "A." virginiae, UALP 1382 from Curtis Ranch. I consider these two samples are conspecific based on the characters of the P₃.

Another characteristic feature of Aluralagus is the complicated enamel crenulation of the posterior border of the external reentrant in P₄-M₂. If the lower molariform teeth of "A." virginiae show that character, original assignment of this species to the genus Aluralagus is probably valid. Although one of the paratypes (UALP 1372) has the P₄ preserved, Downey (1970) did not mention it. Reexamination of this specimen (Fig. 12G) shows that the posterior enamel border of the external reentrant is smooth which contradicts its assignment to the genus Aluralagus. Other specimens of P₄-M₂ from San Simon assigned to "A."
virginiae do not show crenulation of the posterior enamel border of the external reentrant; enamel border is very smooth.

The $p^2$ specimen that Downey referred to ? Aluralagus virginiae (Downey, 1970, Fig. 3h) does not have 3 anterior reentrant angles. Downey mentioned (1970, p. B135) that $p^2$ assigned to A. bensonensis (Downey, 1968, Fig. 2c) may later prove not to be A. bensonensis, but may be of Nekrolagus. Additional material of A. bensonensis was subsequently collected from UALP loc. 47-9, approximately 1.5 km south and stratigraphically about 5 m below loc. 47-1 (Lammers, 1970) from which most of the material described by Downey (1968) were collected. The specimens from loc. 47-9 include 3 $p_3$'s, 5 $p^2$'s, and numerous other cheek teeth. All $p_3$'s are obviously Aluralagus bensonensis. Seven isolated lower molariform teeth have a well crenulated posterior enamel border on the external reentrant. But, none of the lower cheek teeth can be referred to any genus other than Aluralagus. Therefore, all isolated $p^2$'s very probably belong to A. bensonensis too, and they all have 3 anterior reentrants and are very similar to $p^2$ illustrated by Downey (1968). Thus, $p^2$ of Aluralagus should have 3 anterior reentrants, as originally diagnosed in Downey (1968). If so, the $p^2$ (UALP 1376) that was referred to ? "A." virginiae by Downey (1970, Fig. 3h) should not be Aluralagus. Because of the co-occurrence of UALP 1376 with $p_3$'s of "A." virginiae, and because both are similar to the same teeth from San Simon, UALP 1376 very likely belongs to the same species as $p_3$'s.

Thus, morphologic criteria from three different cheek teeth, that is $p_3$, $p_4$-$M_2$, and $p^2$, argue that "A." virginiae should not be
assigned to Aluralagus, and that samples from San Simon Power Line and Curtis Ranch are conspecific. Thus, specimens from San Simon as well as those referred to "A." virginiae from Curtis Ranch are identified as Hypolagus virginiae.

RELATIONSHIPS BETWEEN H. VIRGINIAE AND ALURALAGUS BENSONENSIS:

As Downey (1968) suggested, Aluralagus bensonensis may be derived from Pratilepus kansasensis or a similar species in which the P₃ connection of posteroexternal reentrant and posterointernal enamel lake is common, although the P² anterior reentrant of A. bensonensis is unique. In fact, some specimens of P. kansasensis have P₃ very similar to A. bensonensis (Hibbard, 1969, Fig. 5H).

On the other hand, although the ancestor of H. virginiae is not known, one of the general trends in the evolution of P₃ in Hypolagus is deepening of the antero- and posteroexternal reentrants and complication of their enamel borders. The result of this trend culminates, I believe, in H. virginiae.

General similarity in P₃ enamel pattern between A. bensonensis and H. virginiae is real, as determined by the original assignment of the latter species to the genus Aluralagus (Downey, 1970). But, as described and discussed above, H. virginiae is an advanced species of the genus Hypolagus. I believe the similarity in P₃ characters discussed above is one of the examples of convergent evolution. It is interesting, however, that although P₃ is very similar to each other, P² and P₄-M₂ show no similarity at all but show their different ancestral characters.
? Hypolagus virginiae (Downey), 1970
(Fig. 12L)

REFERRED MATERIAL: UALP no. 52, isolated left P₃, from UA loc. 15-24, 111 Ranch.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA loc. 15-24, at about 40 m level of 111 Ranch composite section, Gila Conglomerate, San Simon Valley, southern Arizona.

AGE: Late Blancan (latest Pliocene).

DESCRIPTION: Size about that of Hypolagus virginiae: length and width are 2.30 and 2.26 mm, respectively. P₃ is triangular in outline with two external reentrants. Anteroexternal reentrant extends lingually about halfway across the occlusal surface, and its enamel border is deeply and complexly crenulate as seen in Aluralagus bensonensis. Its external margin is as wide as H. virginiae. The posteroexternal reentrant extends lingually about two-thirds across the occlusal surface. Its posterior enamel border has some shallow folds but is essentially smooth. Its anterior enamel border has a large deep fold at about two-thirds the distance from the labial margin.

COMPARISONS: UALP 52 that I refer to ? Hypolagus virginiae is similar in enamel pattern and in size to both H. virginiae and Aluralagus bensonensis. The enamel pattern of the anteroexternal reentrant is very similar to A. bensonensis, much complex than H. virginiae. The posteroexternal reentrant does not extend lingually as deep as A. bensonensis, and its posterior enamel border is essentially smooth whereas
it is very crenulate in *A. bensonensis*. The similar fold of the posteroexternal reentrant formed by the large enamel fold is seen in *H. virginiae*, but the direction of the fold is posterolabial rather than posterolingual. UALP 52 does not have the anterior expansion of posteroexternal reentrant in its lingual half, as seen in *H. virginiae*. UALP 52 is also somewhat similar to *H. arizonensis* in depth and narrowness of the posteroexternal reentrant, but the anteroexternal reentrant is totally different.

**DISCUSSION:** As mentioned above UALP 52 is similar in some respect to those three species, but cannot be referred to any of them with confidence. UALP 52 may represent a new species, but more material is needed to establish characteristics of this taxon with confidence. For the present I questionably refer it to *H. virginiae* because it seems more similar to this species.

*Hypolagus sp.*

(Fig. 12M-P; Table 7)

**REFERRED MATERIAL:** UALP no. 14188, right dentary fragment with *M*₁ and *M*₃, and fragments of *P*₃₋₄, *M*₂, from UA loco. 7937. UALP nos. 30, 1132, 1133, *P*₃'s, 1192, *P*², from UA loco. 15-24.

**STRATIGRAPHIC AND GEOGRAPHIC RANGE:** UA loco. 7937, south of Duncan, at about 10 m level of the Duncan section, and UA loco. 15-24, at about 40 m level of the 111 Ranch composite section, Gila Conglomerate, southern Arizona.
AGE: Blancan (late Pliocene).

DESCRIPTION: Small in overall size. $P_3$ of UALP 14188 is nearly rectangular in outline and longer anteroposteriorly. Posteroexternal reentrant extends lingually nearly two thirds across the occlusal width and the enamel border is simple. Anteroexternal reentrant is moderately deep but not so deep as in $H. \text{arizonensis}$, and opens widely externally. Other cheek teeth show a simple enamel pattern. For the specimens from UA loc. 15-24, see discussion section below.

COMPARISONS AND DISCUSSION: Posteroexternal reentrant within known species of the genus Hypolagus extends lingually more than halfway across the occlusal surface in four species: $H. \text{regalis}$, $H. \text{arizonensis}$, $H. \text{mexicanus}$, and $H. \text{virginiae}$. $H. \text{regalis}$ is much larger than UALP 14188. $P_3$ of $H. \text{arizonensis}$ has narrower and deeper anteroexternal reentrant, and its lingual border is more rounded. $H. \text{mexicanus}$ is larger, and the anteroexternal reentrant is much deeper, with a crenulated posterior enamel border. $P_3$ of $H. \text{virginiae}$ has a deeper and more complicated posteroexternal reentrant and is triangular in outline. UALP 14188 is similar to other $P_3$'s referred to $H. \text{sp.}$ here, but it is slightly different in the depth of the posteroexternal reentrant.

Materials from UA loc. 15-24 have been described by Downey (1962), and no additional specimens have been obtained from there. His description and comparison are followed here, but a few comments are added. Two of his illustrations are inaccurate: exaggerated antero-posteriorly in UALP 1132 (Fig. 1H of Downey, 1962) and thickness and crenulation of enamel wall in UALP 1192 (Fig. 1J of Downey, 1962).
UALP 1132 is re-illustrated here (Fig. 120-P). UALP 1192 is a juvenile right p2. It is slightly corroded and broken and about half of the enamel is missing on the occlusal surface. Re-measurements of those teeth are given in Table 7.

In UALP 1132, a slightly worn P3, the enamel pattern of the occlusal surface resembles the genus *Nekrolagus*, but the enamel pattern at the middle of the tooth indicates assignment of the specimen should be with the genus *Hypolagus* (Fig. 120-P). A cementum-filled anterior reentrant is shallow and narrow on the occlusal surface, and becomes indistinct with wear. A cementum-filled anterointernal reentrant is shallow and disappears at 5.5 mm below the occlusal surface, prior to disappearance of the anterior reentrant.

UALP 32, upper molariform tooth, was assigned to this species by Downey (1962) and there are at least two more upper molariform teeth (UALP 15976, 15977) with slight crenulation on enamel border of the re-entrant.

Leporinae gen. and sp.

(Fig. 12Q)

REFERRED MATERIAL: UALP 15975 right P3 from UA loc. 15-24.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA loc. 15-24, at about 40 m level in the 111 Ranch composite section, Gila Conglomerate, southern Arizona.

AGE: Late Blancan (latest Pliocene).
DISCUSSION: According to Alisa J. Winkler at the University of Texas (pers. comm. January 16, 1984), similar, if not the same, form of rabbit to UALP 15975 is known from Fyllan Cave, Travis Co., Texas, and they are under study now assuming they represent a new genus and new species.

UALP 15975 (L. 2.04, W. 1.92 mm) is similar in the general enamel pattern to the holotype of Pliopentalagus dietrichi from Czechoslovakia and Austria (Fejfar, 1961; Daxner and Fejfar, 1967). But, UALP 15975 is extremely smaller in size and possesses an enamel lake at the posterolinguinal portion of the tooth rather than a posterointernal re-entrant as in Pliopentalagus. UALP 15975 is also somewhat similar to the specimen, IGCL 4266 known from the late Pliocene of Mexico that is referred to Pratilepus ? kansasensis by Miller and Carranza (1982), which I believe not to belong to the genus Pratilepus. At any rate, more specimens, including especially Mx, are needed to place this taxon in correct position, similar to the relationship between Aluralagus and Hypolagus virginiae described above.

Sylvilagus and/or Lepus spp.
(Fig. 12R; Table 9)


REFERRED MATERIAL: UALP nos. 953a, 953b, 15980, P2's; 904, palate fragment with partiary broken P³-M²; 31, 1131, 1193, P3's; 1014,
Table 9. Measurements of *Sylvilagus* or *Lepus* sp.

<table>
<thead>
<tr>
<th>UALP No.</th>
<th>Length</th>
<th>Width</th>
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<tr>
<td>Loc. 15-24</td>
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<td></td>
</tr>
<tr>
<td>953a</td>
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<td>3.44</td>
</tr>
<tr>
<td>953b</td>
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<td></td>
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<td>4.40</td>
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</tr>
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<td>at 5 mm below occl. surf.</td>
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</tr>
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</tr>
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<td></td>
<td>at 7 mm below occl. surf.</td>
<td></td>
</tr>
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<td></td>
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<td>2.12</td>
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<tr>
<td>13893</td>
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</table>
dentary fragment with $M_1^3$, from UA loc. 15-24. UALP nos. 13895, $P^3$; 13894, $P^4$?; 15911, maxillary fragment with $M^{2-3}$; 10338, dentary fragment with $P_3^1-M_1^1$; 13893, $M_3^1$ from UA loc. 7706.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA loc. 15-24 at about 40 m level of the Illi Ranch composite section, and UA loc. 7706 at the San Simon Power Line area, Gila Conglomerate, southern Arizona.

AGE: Late Blancan (latest Pliocene).

DESCRIPTION: $p_2^2$ has three anterior reentrants, the labial reentrant is most shallow. Labial edge of the tooth is rather pointed in contrast to the rounded lingual edge. Upper molariform teeth are relatively large in size and have complicated enamel crenulation on the lingual reentrant. The palate is moderately short anteroposteriorly relative to its width; the ratio of minimum length/distance between left and right $p^3$ alveoli is about 0.57 in UALP 904.

$P_3^3$'s from UA loc. 15-24 (Illi Ranch) are all small relative to the size of the upper and lower molariform teeth from the same locality. Although UALP 31 and 1193 are young individuals and the measurements increase toward the base of the tooth, these specimens are still small. $P_3^3$'s from Illi Ranch have a simple anterior reentrant, a wide but shallow anteroexternal reentrant, and a posteroexternal reentrant that extends nearly to the lingual edge of the tooth with enamel crenulation. $P_3^3$ from UA loc. 7706 (San Simon Power Line area) is large in size, wider than long, and has the same three reentrants, but the enamel walls are more crenulated. The lower molariform teeth from Illi Ranch (UALP 1014) are very large in size; posterior column has no
enamel crenulation on the anterior border, and is distinctly narrower than the anterior column. \( P_4 \) and \( M_1 \) from UA loc. 7706 (UALP 10338) have enamel crenulation on the anterior border of the posterior column; the posterior column is narrower than the anterior column, but not as narrow as in UALP 1014.

COMPARISONS AND DISCUSSION: Downey (1962) identified the specimens from 111 Ranch as \textit{Lepus} near \textit{L. californicus} based on the size and enamel pattern of \( P_2 \) and \( P_3 \). However, it is not possible to distinguish the genera \textit{Lepus} and \textit{Sylvilagus} by the enamel pattern of \( P_2 \) and \( P_3 \) alone (Hibbard, 1963; Dalquest, 1979), especially when the size of these genera overlap.

Comparisons were made with a few recent specimens of each of the following species: \textit{Lepus alleni}, \textit{L. californicus eremicus}, \textit{L. californicus deserticola}, \textit{L. americanus}, \textit{Sylvilagus aquaticus}, \textit{S. cunicularis}, and \textit{S. floridanus} in the Mammal Collection of University of Arizona. Measurements of representative specimens are given in Table 10. The largest species of \textit{Sylvilagus} are \textit{S. cunicularus} and \textit{S. aquaticus}, and both species have size range about the same as \textit{Lepus californicus}. \( P_3 \)'s from 111 Ranch are smaller than any of these three species and are rather closer to the size of \textit{L. americanus} and \textit{S. floridanus}. The pointed labial edge of \( P_2 \) is more common in \textit{Sylvilagus} (Lindsay, pers. commun., 1985). Size of \( P_2 \) is not well correlative with the size of the animal; \( P_2 \) of \textit{S. floridanus} is even larger than that of \textit{L. californicus} in some specimens.
Table 10. Measurements of recent species of *Lepus* and *Sylvilagus* and UALP 904

<table>
<thead>
<tr>
<th>Species</th>
<th>P3</th>
<th>P4</th>
<th>P2</th>
<th>P3</th>
<th>Palate*</th>
<th>Ratio**</th>
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<tbody>
<tr>
<td><em>Lepus alleni</em> (UA 21258)</td>
<td>L</td>
<td>4.75</td>
<td>3.67</td>
<td>2.42</td>
<td>2.96</td>
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<tr>
<td></td>
<td>W</td>
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<td>3.75</td>
<td>4.25</td>
<td>5.50</td>
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<td>3.58</td>
<td>2.75</td>
<td>1.80</td>
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<td>3.25</td>
<td>3.42</td>
<td>4.42</td>
<td>11.7</td>
</tr>
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<td><em>L. californicus deserticola</em> (UA 17899)</td>
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<td>3.83</td>
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<td><em>L. americanus</em> (UA 14140)</td>
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<td>W</td>
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<td>3.75</td>
<td>5.08</td>
<td>10.3</td>
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<td><em>S. floridanus</em> (UA 20488)</td>
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<td>3.17</td>
<td>2.58</td>
<td>1.92</td>
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<td>3.50</td>
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<td>9.5</td>
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<tr>
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<td>W</td>
<td>4.92</td>
<td>10.8</td>
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</table>

*Length is minimum; width is the distance between left and right P3 alveoli.*

**Length/width of palate.*
UALP 904, palate with molariform teeth, is comparable in tooth size with *L. californicus*, *S. cunicularis*, and *S. aquaticus*. However, *S. cunicularis* and *S. aquaticus* have an anteroposteriorly long palate, whereas *L. californicus* has a rather short palate to its width (Table 10). UALP 904 has a palate with moderate length but is closer to *Lepus californicus*. Lower molars (UALP 1014) from III Ranch are slightly larger than *L. californicus* and *S. cunicularis* and is rather closer in size to *L. alleni*, the largest species of the genus in North America. *S. cunicularis*, *S. aquaticus*, and *L. alleni* all have rather strong crenulations on the anterior enamel border of the posterior column in the lower molariform teeth. In this character, UALP 1014 is most similar to *L. californicus* (which has no enamel crenulation on the lower molariform teeth) with slightly larger size. Thus, it is possible that the III Ranch specimens represent both genera, *Sylvilagus* (smaller specimens, p2's and P3's) and *Lepus* (larger specimens, palate and jaw), but secure identification cannot be made without better specimens, especially with skull roof.

The specimens from the San Simon Power Line area probably belong to a single taxon based on their relative size, and are comparable to *L. californicus*, *S. cunicularis*, and *S. aquaticus* in size. UALP 10338 has crenulation on the anterior border of the posterior column on P4–M1; *L. californicus* does not have them. Most species of *Lepus* and *Sylvilagus* have P3 longer than wide, whereas *S. cunicularis* has P3 nearly as long as wide. Thus, UALP 10338 is most similar to *S. cunicularis*, in P3 outline and enamel crenulation of lower molariform teeth, among the
modern species, and probably represents different taxon from the 111 Ranch specimens. Again, more material is needed for secure identification with the knowledge of range of variation in these characters.

Order RODENTIA Bowdich, 1821
Family SCIURIDAE Gray, 1821
Subfamily SCIURINAE Baird, 1857
Spermophilus Cuvier, 1825
Spermophilus sp. cf. S. bensoni (Gidley, 1922)
(Fig. 11E; Table 11)

REFERRED MATERIAL: UALP no. 10337, left dentary fragment with $P_4-M_3$, from UA loco. 7706, San Simon Power Line area, and UALP no. 14001, $M^1$, from UA loco. 7933, at about 85 m level of the 111 Ranch composite section, Gila Conglomerate, southern Arizona.

AGE: Late Blancan (latest Pliocene).

DESCRIPTION: Cheek teeth of squirrels are usually very conservative and similar to each other with subtle differences characterizing taxa. Thus, identification of fossil squirrels is very difficult. In spite of this difficulty, description follows (terminology follows Black, 1963). Size is relatively large. Lower cheek teeth have cusps relatively tall, especially the trigonid; lower cheek teeth tend to increase in size posteriorly, and are slightly compressed anteroposteriorly, especially the trigonid. The protoconid and hypoconid are relatively close in position, and the valley between them is deep in
Table 11. Measurements of Sciuridae

<table>
<thead>
<tr>
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<th>Length</th>
<th>Width</th>
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<td><strong>Spermophilus cf. bensoni</strong></td>
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</tr>
<tr>
<td>M1/ ?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Spermophilus sp.</strong></td>
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</tr>
<tr>
<td>UALP 15981</td>
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<td>2.36</td>
</tr>
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</tr>
<tr>
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</tr>
<tr>
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<td>2.16</td>
</tr>
<tr>
<td>UALP 15982</td>
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<td></td>
</tr>
<tr>
<td>M/2 ?</td>
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</table>
all four teeth. The entoconid is indistinct with a gently rounded posterolinguual corner. Entolophid is continuous, narrow, straight, and low. In P4 the protoconid and metaconid are tall, separate distally, joined broadly in mid height to form a heavy trigonid. The trigonid is narrower relative to the talonid width in P4. The talonid basin is broad, shallow, and opens by a notch in lingual cingulum posterior to the metaconid. M1 and M2 are anteroposteriorly compressed. Size of M3 is slightly larger than M2. In these characters, as well as the size, UALP 10337 is very similar to S. bensoni, although it differs slightly in that P4 is slightly larger relative to M1 and size of M3 is also slightly larger than S. bensoni specimen (USNM 10533).

M1? (UALP 14001) is an unworn tooth. Three distinct, nearly parallel, transverse lophs (anterior cingulum, protoloph, metaloph) are present labially, whereas the anteroposteriorly elongated protocone is present lingually. The protoloph joins protocone, whereas the metaloph (that consists of weakly connected metacone and metaconule) is separated from the protocone. The protocone is continuous with the low posterior cingulum. Although isolated upper molars of sciurids are more difficult to identify, UALP 14001 is here referred to S. cf. bensoni simply because of similarity in general morphology and size.
Spermophilus sp.

REFERRED MATERIAL: UALP nos. 1086, left dentary fragment with $P_4$, $M_1$; 15981, $M_1$; 15982, $M_2$ from UA loc. 15-24, at about 40 m level of the 111 Ranch composite section, Gila Conglomerate, southern Arizona.

AGE: Late Blancan (latest Pliocene).

DISCUSSION: UALP 1086, 15981, and 15982 are comparable in size and probably belong to single species of Spermophilus smaller than S. bensoni (Table 11). In addition to smaller size, lower molars seem less compressed anteroposteriorly, the "entoconid cingulum" seems higher and slightly more angular, and the metalophid is more distinct.

Family GEOMYIDAE Gill, 1872

Geomys Rafinesque, 1817

Geomys (Nerterogeomys) Gazin, 1942

Geomys (Neterogeomys) cf. persimilis (Gazin, 1942)

(Fig. 13; Tables 12-13)

REFERRED MATERIAL: UALP nos. 942, 943, rostral portions of skull; 15988, 15990, $I_1'$s; 1228, 15985-15987, $P_4$'s; 15994-15995, $M_1$'s; 15992, 15996-15997, $M_2$'s; 937, 1015-1016, 15983, fragmentary mandibles; 956, 1272, 14983, 15999, $P_4$'s; 13867, 15951, 15991, 15998, $M_1$'s; 16053-16055, $M_3$'s; 16002, $dP_4$; from UA loc. 15-24, 111 Ranch. UALP nos. 1269-1271, fragmentary mandibles from UA loc. 15-26, 111 Ranch. UALP no. 13924, fragmentary mandible from UA loc. 7933, 111 Ranch. UALP nos. 13889, $M_1$, 13890, $M_2$, from UA loc. 7706; 15307, rostral portion of
Figure 13. *Geomys* cf. *persimilis* and *G. persimilis*

A and K, UALP 15817, skull and left $P^4-M^3$; B and M, UALP 1271, right mandible and $P_4-M_3$; C-E, UALP 1223, right $P^4$; F-G, UALP 1272, right $P_4$; H-J, UALP 956, left $P_4$; L, UALP 943, right $P^4-M^3$; N-O, UALP 6548 from the Curtis Ranch locality (UA loc. 25-3), right $P^4-M^3$ and right $P_4-M_3$; P-R, UALP 16053, right $M_3$; S-U, UALP 12867, right $M_1$; V-W, UALP 16002, left $dP_4$.

A, dorsal view; B, labial view; C,F,H,K-O,P,S,V, occlusal view; D,G,U,W, lingual view; E, posterior view; I,Q,T, anterior view; J, labial view. Scale bar (1) for A,B; (2) for C,F,H,P,S,V,W; (3) for D-E, G,I-O,Q-R,T-U.
Figure 13. Geomys cf. persimilis and G. persimilis
Table 12. Measurements of Geomys cf. persimilis

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<tr>
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<th>S.D.</th>
<th>C.V.</th>
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Table 13. Cranial and mandibular measurements of Geomys cf. persimilis and topotypic G. persimilis

<table>
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<tr>
<th>Description</th>
<th>15817</th>
<th>15307</th>
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<td>ca.8</td>
<td>ca.8</td>
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<td>P4/-M3/</td>
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<td></td>
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<tr>
<td>L. upper</td>
<td>C</td>
<td>15.4</td>
<td>ca.14</td>
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<td>ca.6</td>
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<tr>
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<td>ca.8</td>
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</tr>
<tr>
<td>P4/-M3/</td>
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</tr>
<tr>
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<td>Ment. for.</td>
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<td>8.7</td>
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</tr>
<tr>
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<td>2.32</td>
<td>2.16</td>
<td>2.56</td>
<td>2.20</td>
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</tbody>
</table>

Measurement items are as in Becker and White (1981), though some items are omitted here.
*This measurement differs from the length of P4 in the table because the latter represents the length at occlusal surface.
skull from UA loc. 8134. UALP nos. 15817, skull from UA loc. 8417; 15818, jaw fragment from UA loc. 8418. UALP no. 72, fragmentary mandible from UA loc. 31, Duncan general.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA locs. 15-24 and 15-26 at about 40 m level, and UA loc. 7933 at about 85 m level of the Illi Ranch composite section; UA locs. 7706 and 8134 at the San Simon Power Line; UA locs. 8417 and 8418 at about 3 m and 10 m level, respectively, of Pearson Mesa section; UA loc. 31 of Duncan general; all Gila Conglomerate, southern Arizona.

AGE: Middle to late Blancan (late Pliocene).

DESCRIPTION: This species is a rather small geomyid, represented by several partial skulls, jaws, and number of isolated teeth.

Cranium: Supraorbital ridges are discernible with a shallow depression between them, but the sagittal crest is absent. Supraorbital constriction is relatively narrow. The skull table is flat and the rostrum slopes anteroventrally. The nasals are widened anteriorly, truncated posteriorly, and nearly parallel in their posterior one-half. Anterior extremity of premaxillary is about the same or even slightly anterior to the anterior end of nasals, both of which extend anterior to the anterior surface of the upper incisors. Rostrum is comparatively long and is approximately as deep as wide. The ventral part of the rostrum is distinctly narrow in contrast to that of other species in comparable size (breadth of rostrum at infraorbital canal, Table 14). The auditory meatus is a tubelike structure extending from the tympanic bulla dorsolaterally, in
contrast to *G. bursarius* in which the tube extends anterodorsally. The external opening is widely open, measuring 2.8 mm in diameter in UALP 15817. The maxillary tooth row diverge posteriorly.

**Mandible:** The mandibular ramus is relatively robust. The mental foramen is ventral and slightly anterior to the anterior extremity of the masseteric crest. The ventral branch of the masseteric crest is well developed, but there is no dorsal branch of the crest. The temporal fossa between M₃ and ascending ramus is moderately deep.

I₁: Bisulcate as in other species of the genus.

P₄: There is an enamel cap in unworn teeth; UALP 1223 (Fig. 13C-E) and 15985 represent this condition. The crown consists of the protoloph, metaloph, and posterior cingulum, all of which are capped by a number of tiny unidentifiable cusplets. Protoloph and metaloph are wider than long, with metaloph wider than protoloph. The two lophs are joined before wear by a loph directed anterolabially from the lingual metaloph, that contacts the protoloph lingual to the midline initially and moves toward the midline of the protoloph with wear. The enamel wall of the posterior surface of the metaloph has an irregular base and extends from 1.32–2.48 mm in depth from the unworn surface (about 60–120% of tooth width) of UALP 1223 (Fig. 13C-E). The dentine tracts are developed at both the labial and lingual edges of both the protoloph and metaloph, higher on the metaloph. Anterolinguinal tract is the lowest and ends at 2.4 mm below the occlusal surface. When worn, reentrant angels are nearly parallel.
walled with square corners and are filled with cementum (Fig. 13K-L); the isthmus connecting the two lophs becomes narrow; and the posterior enamel plate disappears.

Upper molars: $M^1$ and $M^2$ are nearly ellipsoidal with slightly wider lingual border in occlusal outline. Anterior enamel plate always wider, deeper, and more persistent than posterior enamel plate. $M^2$ is slightly longer than $M^1$. $M^3$ is rounded triangular in outline with no posterolabial reentrant. Enamel patterns of the upper molars are as in other species of the genus.

$P_4$: When unworn, $P_4$ is also completely enveloped by an enamel cap as in $p^4$. Unworn surface of the much narrower protolophid and wider metalophid capped by numerous unidentified tiny cusplets (Fig. 13F). Both lophids are connected by a narrow loph near the midpoint. The dentine tracts are slightly higher on both labial and lingual side of metalophid relative to protolophid. The anterolingual tract (on the protolophid) is the lowest and extends 2.3 mm (about 120% of tooth width) below the unworn surface. Reentrant angles are open and V-shaped in early stage of wear (Fig. 13H) but become U-shaped with nearly square corners when worn (Fig. 13M). Anterolinguinal enamel plate of the protolophid tends to be thicker, more persistent than anterolabial enamel plate.

Lower molars: Crown of unworn lower molars is bilophodont and is completely enveloped by enamel cap. The unworn cusp pattern is similar to that of *Dipodomys hibbardi* described below, but it is more lophate, and cusps are much elongated laterally. In $M_1$ (UALP
13867; Fig. 13S-U) the metalophid is slightly higher than the hypolophid. Metalophid consists of the protoconid, metaconid, anterior cingulum, and indistinct protostylid. The hypolophid is very narrow, with transversely elongated entoconid, hypoconid, and indistinguishable hypostylid. Unlike Dipodomys, both the protostylid and hypostylid in Geomys are not distinguishable. In UALP 13867 enamel disappears from the anterior surface of the tooth at 1.6 mm below the top of the slightly worn crown. In M_3 (and M_2?) the hypolophid is much lower than the metalophid. In M_3 (UALP 16053-16055: possibly M_2) it is hard to identify the essential cusps on both lophids. The anterior cingulum is distinguishable. Transverse valley separates the two lophids and continues to a shallow groove on the lingual side of the tooth. The enamel of the anterior surface of the tooth disappears at 1.4 mm, 1.6 mm, and 1.0 mm respectively below the top of the slightly worn crown. When worn, the lower molars are all flattened ellipsoidal with widened labial side in occlusal outline. Enamel plate is present only on the posterior surface. M_3 is slightly smaller than M_1 and M_2 in size.

DP_4: Represented by a single specimen, UALP 16002, slightly worn left dP_4 (Fig. 13V-W). The cusp terminology of Rensberger (1971, p. 110) is followed for this specimen. The tooth is brachylophodont, anteroposteriorly long, and narrow anteriorly. The length/width ratio is 1.52. The posterior cingulum is a distinct ridge that is isolated from other occlusal structures at present wear, but it would be connected with the entoconid in late wear. The entoconid
and hypoconid form a nearly straight ridge which is oblique to the
tooth axis. The metaconid forms a ridge anterior to the entoconid
that joins the hypoconid slightly labial to the midline of the tooth;
the valley between the metaconid and entoconid is very deep. There
are two more ridges anterior to the metaconid on the lingual half of
the tooth; these are identified as cingulum cusp and anterior cingu-
lum, separated by a shallow valley. The anterior cingulum is con-
ected to the protostylid by a prominent anterolabial loph, and to
the protoconid by a very narrow loph that closes a deep, oval-shaped
depression between the cingulum cusp and anterior cingulum. All the
lophs, except for the posterior cingulum, are connected to each other
by a longitudinal, sinuous loph.

COMPARISONS: The masseteric crest that extends dorsal to the
mental foramen distinguishes G. cf. persimilis from all the species
of subgenus Geomys which includes G. jacobi, G. quinni, G. adamsi,
and G. tobinensis among the extinct species, and all modern species.
In addition, P₄'s of all those extinct species of Geomys (Geomys)
possess V-shaped rather than U-shaped reentrant angles.

Geomys (Nerterogeomys) includes six extinct species that have
been described so far. G. minor known from Benson fauna, Arizona and
Rexroad fauna, Kansas is slightly smaller in size, and the mandibular
ramus, especially diastemal region is less robust than G. cf. persi-
milis. G. smithi from the Fox Canyon fauna in Kansas and G. paenebur-
sarius from Texas are both similar in size to G. cf. persimilis
described here, but the mental foramen is located directly ventral or
even somewhat posterior to the anterior extremity of the masseteric crest (Hibbard, 1967; Akersten, 1972).

G. garbanii from Anza-Borrego, California is larger in overall measurements and has more developed auditory bulla. G. anzensis also from Anza-Borrego is similar in size and in general morphology to G. cf. persimilis, except that in G. cf. persimilis the rostrum is slightly narrower and is even somewhat deeper than G. anzensis, although the proportionally deep rostrum is one of the diagnoses of G. anzensis (Becker and White, 1981). The ratio of the rostrum depth over rostrum width is approximately 0.9 in G. anzensis whereas it is approximately 1.0 in G. cf. persimilis (Table 13).

G. cf. persimilis described here are somewhat smaller, especially in tooth measurements, than the specimens of G. persimilis from the Curtis Ranch.

A dP4 (UALP 16002) described above is very similar in morphology to that of G. (N.) cf. minor (UMMP 28414) illustrated in Hibbard (1954, Fig. 5A). UALP 16002 differs, however, from the latter in its larger size and in relatively indistinct development of the protoconid: in UMMP 28414 the protoconid is more conical with no protostylid and no labial junction between the protoconid and anterior cingulum.

DISCUSSION: The genus Nerterogeomys was established based mainly on 1) P4 with enamel across the posterior wall, 2) the narrow protoloph/protolophid of P4/4, 3) mental foramen ventral to the anterior extremity of the masseteric crest, and 4) rostrum more
depressed anteriorly with respect to the plane of cheek teeth. Hibbard (1967) reexamined the holotype of the genotype *N. persimilis* and concluded that *Nerterogeomys* is considered to be of subgeneric rank and is defined only by the relative position of the mental foramen. This is followed by Becker and White (1981). The first and second characters above are obviously due to the juvenility of the holotype (Hibbard, 1967). The depressed rostrum may be related to the shortness of the rostrum, which is also probably due to the juvenility. In *Geomys arenarius* the upper diastemal length is the most variable with age among the various cranial measurements (Williams and Genoways, 1978, p. 547).

Although Hibbard (1967) revealed that the nearly complete enamel pattern of $P^4$ is due to juvenility of the specimen, mentioning the presence of the dentine tracts at all four edges, he did not deny or mention the presence of the enamel plate on the posterior surface. However, the topotypic adult specimen from the Curtis Ranch locality (UALP 6548; anterior portion of skull and both left and right jaws, Fig. 13N-O) has $P^4$ with no posterior enamel plate. Harrison (1978) referred UALP 4169 from the Wolf Ranch local fauna, near Curtis Ranch, to $P^4$ of *G. persimilis* and cited the presence of the posterior enamel plate for that identification. However, reexamination of UALP 4169 reveals that it is a fragmental $P_4$ rather than $P^4$. Among the advanced, non-rooted geomyids *Thomomys* is the only genus that has $P^4$ with a full posterior enamel plate. *Zygogeomys* and *Orthogeomys* also have $P^4$ with a posterior enamel plate, but it is restricted to the
lingual half (Russell, 1968a). All of these three genera are distinctly different from Geomys not only in enamel of P₄ but also in many other characters, such as grooves on I¹ and outline of M³ among the dental characters, whereas "Nerterogeomys" is very similar to Geomys. All five other species of G. (Nerterogeomys) do not possess the enamel plate on the posterior surface of P₄. Thus, although I have had no opportunity to examine the holotype of N. persimilis (USNM 10492), it is most likely that the posterior enamel plate on P₄ is absent in G. (Nerterogeomys) persimilis in adult stage.

Wood, P. A. (1962) described a "new" species of Geomys based on the skulls and mandibles from UA locs. 15-24 and 15-26, which are included in this taxon here. He diagnosed the "new" species as follows: 1) about the size of G. arenarius, 2) bisulcate I¹, 3) M³ lacking well developed heel, 4) cheek teeth all rootless, 5) P₄ much longer than P₄ in contrast to all other species of the genus, and 6) rostral depth relative to the palato-frontal depth is greater than in any living species of the genus. Of these, 2, 3, and 4 are part of the generic characters of the genus Geomys, and the size of G. arenarius is common among the species of the genus. The length of P₄ and P₄ should be compared between the teeth of same individuals or at least between the teeth of a large sample. His sample includes two skulls and five mandibles which are all different individuals. And, four of the five P₄'s are among the largest in all P₄'s described here. Thus, number 5) above should not be considered. Although I do not have much data on living species, the ratio of the
rostral depth over the palato-frontal depth is 0.51 in average in *G. arenarius* (Becker and White, 1981) whereas that of the skull from III Ranch (UALP 943) is approximately 0.55 (UALP 942 is too poorly preserved to obtain even an approximate measurement of the palato-frontal depth). Among the extinct species of the genus this ratio averages 0.55 in *G. garbanii*, 0.54 in *G. anzensis* (Becker and White, 1981), 0.53 in UALP 6548 (a toptype specimen of *G. persimilis*), and approximately 0.54 in the holotype of *G. quinni*. Thus, although the value 0.55 may be exceeded in the recent species, it is common value among the extinct species. Thus, Wood's new species is not valid, and in fact all specimens he referred are included here in *G. cf. persimilis*.

Although it is most likely that *G. persimilis* has $P^4$ lacking a posterior enamel plate in adult as mentioned above, the thorough reexamination of all specimens from the Curtis Ranch is essential before redefining the species. Also, it is necessary to distinguish *G. anzensis* from *G. persimilis* because they are quite similar to each other, especially if *G. persimilis* has $P^4$ lacking a posterior enamel plate. However, Becker and White (1981) did not make this comparison, and instead they distinguished *G. anzensis* from *G. minor* based on the presence of the posterior enamel plate on $P^4$ in the latter, but $P^4$ has not been known in *G. minor* to my knowledge. Thus, until the comparisons can be made and the relationships among these species become clear, it is difficult to securely identify the species described here.
Referring to "Geomys and cf. Geomys spp.

(Table 14)

REFERRED MATERIAL: UALP nos. 15989, $I^1$ fragment; 15993, right $M^1$; 955, left $P_4$, from UA loco. 15-24, Illi Ranch. UALP no. 14198, left $M^1$, from UA loco. 7937, Duncan. UALP nos. 14165, rostrum with fragmentary $I^1$'s and right $P_4$; 14166, fragmentary snout with left and right $I^1$'s, from UA loco. 8042, Country Club.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA loco. 15-24, at about 40 m level of the Illi Ranch composite section; loco. 7937, at about 10 m level of the Duncan section; loco. 8042, at about 12 m level of the Country Club section; all in the Gila Conglomerate, southern Arizona.

AGE: Middle-late Blancan (late Pliocene).

DESCRIPTION: Upper incisor fragment from Illi Ranch, UALP 15989, possesses two grooves on the anterior surface of the tooth; the deep groove is located somewhat labial to the midline whereas the shallow groove is along the lingual edge of the tooth, like in Geomys. $M^1$'s from Illi Ranch and Duncan are both ellipsoidal in outline and have enamel plates on both anterior and posterior surfaces, like many members of Tribe Geomyini. The enamel pattern of $P_4$ (UALP 955) is essentially as in the members of Tribe Geomyini. Reentrant angles are V-shaped and open. The two rostrum fragments from Country Club possess bisulcate upper incisors and one of them (UALP 14165) has $P_4$ with no enamel plate on the posterior surface, typical in Geomys.

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DISCUSSION: UALP 14165 from Country Club is referable to the genus Geomys on the basis of the characters of $I^1$ and $P^4$. UALP 14165 is similar in size to G. persimilis described above but lacks characters reliable on the species identification. Other specimens are all distinctly smaller than G. persimilis described above. The upper incisors, UALP 15989 from I1 Ranch and 14166 from Country Club, are probably referable to the genus Geomys based on the grooves and their smaller size, but other isolated $M^1$'s and $P_4$ are referred temporarily to Geomys based only on their enamel pattern (though common with most members of the Tribe Geomyini) and their smaller size.

Pappogeomys Merriam, 1895

Pappogeomys (Cratogeomys) Merriam, 1895

Cratogeomys have often been given the generic rank, especially in the field of paleontology, but I here follow Russell (1968a, 1968b) and give it the subgeneric rank. Other geomyid genera with nonrooted cheek teeth can be distinguished by the characters of the upper inciser grooves and the posterior enamel plate of $P^4$ only, but both of these characters are common between Pappogeomys and Crato-geomys.
**Pappogeomys (Cratogeomys) sansimonensis,** n. sp.

*(Fig. 14; Table 15)*

**HOLOTYPE:** UALP no. 10344, a partial skeleton including anterior portion of skull with right \( I^1_p^4-M^2 \) and left \( I^1_p^4 \), right mandible with all teeth, left \( I_1 \), fragmental pelvis and sacrum, and right femur.

**TYPE LOCALITY:** UA loco. 7809, San Simon Power Line, San Simon Valley, southern Arizona.

**HYPODIGM:** The holotype; UALP nos. 10343, a partial skeleton from UA loc. 7808; 15820, a rostrum with all teeth but right \( I_1 \) from loc. 7605; 10329, right dentary with \( I_1 \) from loc. 7704; 13896, left dentary with \( I_1 \) and \( M_2 \) from loc. 8060; all at the San Simon Power Line area.

**STRATIGRAPHIC AND GEOGRAPHIC RANGE:** UA locs. 7605, 7704, 7808, 7809, and 8060 all at San Simon Power Line, Gila Conglomerate, San Simon Valley, southern Arizona.

**AGE:** Late Blancan (latest Pliocene).

**DIAGNOSIS:** Size about that of *Pappogeomys castanops*; \( p^4 \) with or without narrow enamel plate posterolingually and \( M_{1-2} \) with narrow enamel plates posterolabially; mental foramen anterior but slightly ventral to the anterior extremity of the masseteric crest that is well expanded labially.

**DESCRIPTION:** Cranium: Supraorbital ridges are barely discernible with very shallow depression between them; they raise their
Figure 14. *Pappogeomys sansimonensis* n. sp.

A, D-G: UALP 10344, holotype, A, right mandible, D, right I, E, right P₄-M₂, F, left P₄, G, right P₃-M₃.

B: UALP 10329, right mandible with no cheek teeth.


I: UALP 15820, right P₄-M₃.

A-B, labial view; C, dorsal view; D, cross section; E-I, occlusal view.
Figure 14. *Pappogeomys sansimonensis* n. sp.
Table 15. Measurements of *Pappogeomys sansimonensis* n. sp.

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height slightly and converge posteriorly. Although not observable because of the breakage, they would unite to form the sagittal crest further posteriorly (Fig. 14C). The anterior angles of zygomata are enlarged into platelike expansions. Ventral portion of the rostrum is relatively narrow.

Mandible: The mandible is robust, and the angular process is widely expanded labially. The mental foramen is anterior but slightly ventral to the anterior extremity of the masseteric crest. The temporal fossa is markedly deep, reaching labial to the inciser.

Postcranial skeleton: The holotype includes fragmental pelvis and sacrum and right femur, and UALP 10343 includes six lumbar vertebrae, pelvis and part of sacrum, and left femur and tibiofibula. Five vertebrae are united in forming the sacrum. The postcranial skeleton, as far as preserved parts are concerned, is essentially as in other recent geomyine genera, and I do not see any diagnostic features except for the size.

I\(^1\): There is a groove on the anterior surface at almost exactly medial line. Close examination indicates a slight depression along the inner edge, but it is not as deep as the inner groove of Geomys incisors.

P\(^4\): The width of the protoloph is slightly narrower than that of the metaloph. The isthmus between them is narrow, cement filled, and located slightly medial to the midline of the tooth. Re-entrant valleys have square corners; the lingual valley is narrower and shallower than the labial. P\(^4\) of the holotype, but not two other
specimens, has a narrow and thin, deep enamel plate at the posterolingual side of the metaloph.

\( M^{1-2} \): Occlusal surface is nearly ellipsoidal in outline, with thick enamel plate across entire anterior surface. All three specimens have narrow and thin, deep enamel plates, about one-fourth of the width of the tooth, on the posterolabial side.

\( M^3 \): Occlusal surface is sub-triangular in outline and is about as long as wide. An enamel plate is present along each side of triangle. The anterior plate is much thicker than the other two which are about the same thickness and size. \( M^3 \) is similar to that of sub-genus *Pappogeomys*.

Lower dentition: The enamel pattern of the lower dentition is comparable to all other species of the Tribe Geomyini. In \( P_4 \) proto­lophid is slightly narrower than the matlophid, reentrant angles are cement filled, not as square as \( P^4 \), but the anterior and posterior walls are nearly parallel to each other. The isthmus is on or near the midline of the tooth in contrast to \( P^4 \). The molars are oval, much wider than long, in occlusal outline with a thick, wide, and deep enamel plate on the posterior surface. \( M_2 \) is slightly larger than \( M_1 \), and \( M_3 \) is smaller than \( M_1 \).

COMPARISONS: The medially unisulcate upper incisers and the absence or near absence of the enamel plate on the posterior surface of \( P^4 \) warrant the referral of this species to the genus *Pappogeomys*. The presence of weak sagittal crest (as expected by the confluence of the supraorbital ridges) and the platelike anterior face of zygomata
and the absence of enamel plates on the posterior surface of $M^{1-2}$ make this species referrable to the subgenus *Cratogeomys*.

The holotype of *"Crataogeomys" bensoni* is a left dentary with all teeth included, which is not reliable for the generic identification. The referral of this species to *Cratogeomys* is based solely on an isolated upper incisor which is still not reliable to the subgeneric identification. At any rate, *P. (Cratogeomys) sansimonensis* differs from *"C." bensoni* in having the mental foramen anterior and only slightly ventral to the anterior margin of the masseteric crest, and in having a robust and laterally expanded masseteric crest.

*P. sansimonensis* differs from all the recent species of the subgenus *Cratogeomys* in having $M^{1-2}$ with narrow and thin enamel plates on the posterolabial surface.

**DISCUSSION:** As pointed out above, *P. sansimonensis* is referrable to the subgenus *Cratogeomys* on the basis of the presence of the sagittal crest and platelike anterior angle of zygomata. Recent species of the subgenus *Cratogeomys* all lack enamel plates on the posterior surfaces of $P^4$-$M^{1-2}$. *P. sansimonensis*, however, retains narrow, thin enamel plates on posterolabial surfaces of $M^{1-2}$ in all three specimens and on the posterolingual surface of $P^4$ in one specimen (holotype). The posterolingual enamel plate on the right $P^4$ of the holotype is thinner and narrower than that of the left, and two other specimens do not have such enamel plate. Individual variation in reduction of enamel of $P^4$ may suggest that the tooth was
undergoing evolutionary changes and that loss of enamel had not become stabilized by late Blancan time.

The presence of \textit{P. sansimonensis} in the late Blancan time suggests that differentiation of the subgenus \textit{Cratogeomys} had occurred before that time, retaining such primitive characters as the remnant posterior enamel plates on $M_{1-2}$ and $M_3$ with the occlusal surface of simple triangle in outline. \textit{P. sansimonensis} could have given rise to all recent species of the subgenus \textit{Cratogeomys} with the further loss of the posterior enamel plates of $P_4M_{1-2}$ and the specialization of $M_3$.

"\textit{Cratogeomys" bensoni} was temporarily referred to the subgenus \textit{Pappogeomys} by Russell (1968a, 1968b) based on a primitive feature (minute lateral inflection: 1968a, p. 533) on $M_3$ (which I cannot see) and its older geologic age, assuming that specialized \textit{Cratogeomys} had not arisen by that time (Russell, 1968b, p. 617). However, subgenus \textit{Cratogeomys} was distinct by late Blancan; therefore, subgeneric assignment of "\textit{Cratogeomys" bensoni} is virtually impossible without reference to the upper dentition and/or skull.

cf. \textit{Pappogeomys} spp.

REferred \textbf{MATERIAL:} UALP no. 5739, isolated right $I_1$ from UA loc. 15-11, 111 Ranch; no. 15928, left dentary fragment with $I_1$ from loc. 7323, 111 Ranch; no. 15664, associated left and right $I_1$ from loc. 8210, Country Club.
STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA loc. 15-111, lll Ranch general; loc. 7323, at approx. 35 m level of the lll Ranch composite section; UA loc. 8210, at approx. 15 m level of the Country Club section; Gila Conglomerate, southern Arizona.

AGE: Middle-late Blancan (late Pliocene).

DESCRIPTION: Upper incisor (UALP 5739) possesses a deep groove medially on the anterior surface as in the genus Pappogeomys, not like that of Geomys in which the median groove is slightly labial to the midline of the tooth. A very shallow depression is present along the inner edge of the tooth, but it is faint and much shallower than that of Geomys species. UALP 5739 is much smaller in size than P. sansimonensis; width is 2.20 mm. Two lower incisor specimens (UALP 15928, 15664) are both similar in size to P. sansimonensis; width is 3.20 and 3.52 mm, respectively. The anterolabial edge of the tooth is smooth and somewhat rounded as in Pappogeomys in contrast to that of Geomys in which the edge is much sharper and is as sharp as lingual edge.

Family HETEROMYIDAE Allen and Chapman, 1893

Subfamily PEROGNATHINAE Wood, 1935

Perognathus Wied-Neuwied, 1839

Perognathus gidleyi Hibbard, 1941

(Fig. 11F-I; Table 16)

REFERRED MATERIAL: UALP nos. 14204, P⁴; 14199, M¹; 14200-14203, M²'s; 14205-14206, P₄'s; 14207, M₁, from UA loc. 7937. UALP
Table 16. Measurements of *Perognathus gidleyi*

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
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<th>Width</th>
<th></th>
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<td></td>
<td>N</td>
<td>O.R.</td>
<td>Mean</td>
<td>N</td>
</tr>
<tr>
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<td>4</td>
<td>0.90-1.16</td>
<td>1.03</td>
<td>4</td>
</tr>
<tr>
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<td>2</td>
<td>0.88-0.90</td>
<td>0.89</td>
<td>2</td>
</tr>
<tr>
<td>M2/</td>
<td>5</td>
<td>0.74-0.82</td>
<td>0.79</td>
<td>5</td>
</tr>
<tr>
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<td>0.76-0.84</td>
<td>0.81</td>
<td>3</td>
</tr>
<tr>
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<td>0.94-0.96</td>
<td>0.95</td>
<td>2</td>
</tr>
<tr>
<td>M/2</td>
<td>1</td>
<td>0.92</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>M/3</td>
<td>1</td>
<td>0.68</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>
no. 1008, right dentary with $P_4$–$M_3$, from UA loc. 15-24. UALP nos. 15948–15950, $P^4$'s; 15947, $M^1$; 5746, $M^2$, from UA loc. 15-5.

**STRATIGRAPHIC AND GEOGRAPHIC RANGE:** UA loc. 7937 at about 10 m level of the Duncan section, UA locs. 15-24 and 15-5 both at about 40 m level of the 111 Ranch composite section, Gila Conglomerate, southern Arizona; Wolf Ranch local fauna, St. David Fm., southern Arizona; Rexroad local fauna, Rexroad Fm., and Borchers local fauna, Crooked Creek Fm., Kansas.

**AGE:** Blancan (late Pliocene)

**DESCRIPTION:** Cheek teeth are brachylophodont with cusps distinct at their apices, but united below the apices into transverse lophs. Upper cheek teeth possess three distinct (i.e., not fused) roots, and lowers with two distinct roots, except for $M_3$ on which root is not observable.

$P^4$: Four-cusped. Protoloph consists of a columnar protocone, uniting medially to submedially with the metaloph after moderate wear. Two specimens out of four have the basal part of the protocone expanded anteriorly and more robust than the remainder. The metaloph is three-cusped. Hypostyle is elongated anteroposteriorly and joins into hypocone by weak posterior cingulum. The base of the crown is lower on protoloph.

$M^1$: Bilophodont with the protoloph slightly wider than the metaloph. Transverse valley is closed lingually by union of proto- style and hypostyle, forming U-shaped occlusal outline. The protoloph consists of three cusps arranged in a straight line, and anterior
cingulum is continuous, low, and anterior to the protocone as on UALP 14199, or it is weak and discontinuous as on UALP 15947. The metaloph consists of three cusps, of which hypostyle is anteroposteriorly elongated, and the cusps are united by a low posterior cingulum.

\( M_2 \): Similar to \( M_1 \) but smaller. Anterior cingulum is continuous on two specimens and is discontinuous on two other specimens (one is too worn to evaluate this character).

\( P_4 \): Subquadrate in occlusal outline and quadricuspidate. Lingual cusps are slightly larger than labial cusps on each lophid. Protolophid and metalophid are united medially to submedially by a low, narrow ridge on two specimens, or there is no such ridge but the protoconid and protostylid are somewhat swollen posteromedially as on UALP 14206. The base of crown is slightly lower on the protolophid.

\( M_1 \): Consists of the metalophid and hypolophid which are subequal and the latter is slightly lower than the former. Anterior cingulum connects the protoconid and protostylid with sub-angular flexure at anterolabial corner of the tooth. Transverse valley is deep, slightly curved or nearly straight, and is open at both ends. Connection of the lophids is very weak, and thus H-pattern is formed at very late stage of wear.

\( M_2 \): Similar to \( M_1 \) but slightly shorter anteroposteriorly. Hypolophid is nearly straight and is slightly shorter than the metalophid. \( M_3 \) is smaller than \( M_2 \) and is about same size as \( P_4 \). Hypolophid is much shorter than the metalophid on \( M_3 \) as a result of the lack of hypostylid and reduced hypoconid.
COMPARISONS: In size, \( P. \) gidleyi is similar to \( P. \)
rexroadensis, \( P. \) maldei, \( P. \) mclaughlini, \( P. \) stevei, and \( P. \) furlongi.
\( P. \) rexroadensis differs from \( P. \) gidleyi in having slightly larger size
and \( P_4 \) with shallow anterior groove and weak external reentrant angle,
indicating labially inclined lophid connection (Hibbard, 1950). \( P. \)
maldei differs from \( P. \) gidleyi in having molars lower crowned, with
stronger H-pattern (Zakrzewski, 1969). \( P. \) mclaughlini differs from \( P. \)
gidleyi in having molars lower crowned, with stronger H-pattern (Zakr-
zewski, 1969). \( P. \) mclaughlini differs from \( P. \) gidleyi in having \( P_4 \)
with a very shallow external reentrant angle and with initial union
of lophids between the protoconid and hypoconid (Hibbard, 1949a;
Jacobs, 1977). \( P. \) stevei has a stronger H-pattern on \( M_{1-2} \) than \( P. \)
gidleyi, and has a \( P_4 \) with frequent occurrence of an anteroconid and
hypostylid, which never occur in \( P. \) gidleyi (Martin, 1984). \( P. \) fur-
longi has a more cuspat e and more brachydont dentition than \( P. \) gidleyi
and has \( M_1 \) with the transverse valley open lingually (Wood, 1935;
Lindsay, 1972). \( P. \) gidleyi is larger than \( P. \) pearlettensis, \( P. \) dunk-
lei, \( P. \) henryredfieldi and \( P. \) minutus, and is smaller than \( P. \) car-
penteri.

Among the extant species, \( P. \) baileyi is similar in size to \( P. \)
gidleyi but has a higher crowned and more lophate dentition. \( P. \)
peniscillatus is similar to \( P. \) gidleyi in having a relatively cuspat e
dentition with moderately deep transverse valley, but it is smaller
and has still shallower transverse valley on molars.
DISCUSSION: Two large species, "P." sargenti and "P." magnus, were recently removed from Perognathus and were referred to the genus Oregonomys (Martin, 1984). Although Martin (1984) has left within Perognathus, Korth (1979) referred "P." saskatchewanensis to the genus Cupidinimus.

Sample from Duncan (UA loc. 7937) is slightly higher crowned than that from 111 Ranch, especially the lower part of the crown below the base of the transverse valley. Two specimens of $P^4$ (UALP 15948 and 15949) from 111 Ranch are slightly larger and more robust than UALP 14199 from Duncan, but another specimen from 111 Ranch sample (UALP 15950) is nearly identical with UALP 14199. All other characters are very similar in both samples, and they are here treated as same species.

Perognathus sp.

REFERRED MATERIAL: UALP no. 15253, left $M_3$ from UA loc. 7933, at about 85 m level of the 111 Ranch composite section, Gila Conglomerase, southern Arizona.

AGE: Late Blancan (latest Pliocene).

DESCRIPTION AND COMPARISONS: UALP 15253 is a six-cusped, brachylophodont, and single rooted $M_3$. Although moderately worn, protostylid and hypostylid are identifiable, and the transverse valley is slightly closed lingually by very low union of these stylids. Length and width are 0.76 mm and 0.96 mm, respectively.
UALP 15253 is similar in size to P. gidleyi described above but differs in having a wider hypolophid with a minute hypostylid. It is similar in both size and cusp pattern to M₃ of P. mclaughlini, but the latter has two well separated roots.

Subfamily DIPODOMYINAE Coues, 1875

Prodipodomys Hibbard, 1939

Prodipodomys sp.

REFERRED MATERIAL: UALP no. 16046, isolated left M₂, from UA loc. 15-24, at about 40 m level of the Ill Ranch composite section, Gila Conglomerate, San Simon Valley, southern Arizona.

AGE: Late Blancan (latest Pliocene).

DESCRIPTION: The tooth is hypsolophodont with cusps distinct at their apices. The metalophid is nearly straight and consists of the metaconid, protoconid, anteroposteriorly elongated protostylid, and anterior cingulum that unites protostylid and the anterolabial corner of the metaconid. Anterior expansion of the anterior cingulum is weak in contrast to that of D. hibbardi described below. The hypolophid is straight and consists of three conical cusps, the hypoconid being largest and the hypostylid being smallest and lower than two other cusps. The transverse valley is shallower medially, and the tooth would form an H-pattern with moderate wear. The dentine tract is not present, though the base of enamel is irregular. Two roots are distinct and well developed, though the anterior is broken.
The posterior root curves posteriorly. Length 1.08 mm, width 1.44 mm, and height of the crown 1.98 cm.

DISCUSSION: Because of the posteriorly curved posterior root, this tooth should not be an M\textsubscript{1}. The well developed and separated roots and absence of the dentine tract indicate a rather primitive condition within the genus. But, a single isolated M\textsubscript{2} is not sufficient for more specific identification.

*Dipodomys* Gray, 1841

*Dipodomys hibbardi* Zakrzewski, 1981

(Figs. 15A-R, Table 17)

REFERRED MATERIAL: UALP nos. 1005, 1006, 1009, 16014, associated upper dentitions; 13864-13866, 16005-16009, 16012-16013, P\textsuperscript{4}'s; 13869-13870, 16015, 16017-16018, 16020-16021, M\textsuperscript{1}'s; 16022-16024, M\textsuperscript{2}'s; 1050-1052, 1054-1055, 1098, 1103, 5057-5058, 5060, fragmentary mandibles with one or more teeth or associated lower dentitions; 13861-13863, 16026, 16028-16042, P\textsubscript{4}'s; 16000, 16016, 16019, 16043, 16045, M\textsubscript{1}'s; 16044, 16047-16052, M\textsubscript{2}'s, all from UA loc. 15-24. UALP no. 5747, isolated M\textsubscript{1} from UA loc. 15-5. UALP no. 14116, isolated dP\textsubscript{4}, from UA loc. 7914. UALP nos. 13932, P\textsuperscript{4}; 13930, M\textsuperscript{1}; 13931, 15251, M\textsuperscript{3}'s; 13925-13926, P\textsubscript{4}'s; 13933, M\textsubscript{1}; 13934-13935, M\textsubscript{2}'s; 13927-13928, M\textsubscript{3}'s from UA loc. 7933. UALP no. 13891, isolated M\textsubscript{1}, from UA loc. 7706.

STRATIGRAPHIC AND GEOGRAPHIC RANGES: UA loc. 7914 at about 30 m level, UA locs. 15-24 and 15-5 at about 40 m level, and UA loc. 7933 at about 85 m level of the 111 Ranch composite section, and UA loc. 7706.
Figure 15. *Dipodomys hibbardi* and *D. sp. cf. D. gidleyi*.

A-R: *Dipodomys hibbardi*.
- A-B, UALP 13932, left P₄; C-D, UALP 16006, right P₄.
- E, UALP 1103, right dentary fragment with P₄-M₂.
- F, UALP 5060, left dentary fragment with I₁P₄.
- G-H, UALP 16014, left M₁-2; I-J, UALP 16012, left P₄; K-L, UALP 16029, left P₄; M-N, UALP 13925, right P₄; O-P, UALP 5058, right M₁-3; Q-R, UALP 14116, right dP₄.
- A, C, G, I, K, M, O, Q: occlusal views;
- B, J, L, P, R: lingual views; D, E, F, H, N: labial views.

S-W: *Dipodomys sp. cf. D. gidleyi*.
- S-T, UALP 16027, left P₄; U-V, UALP 16011, right P₄.
- W, UALP 1053, left dentary fragment with I₁P₄M₁-2.
- S, U: occlusal view; T, W: labial views; V: lingual view.
Figure 15. *Dipodomys hibbardi* and *D. sp. cf. D. gidleyi*
Table 17. Measurements of *Dipodomys hibbardi*

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>O.R.</th>
<th>Mean</th>
<th>S.D.</th>
<th>C.V.</th>
</tr>
</thead>
<tbody>
<tr>
<td>P/4</td>
<td>L</td>
<td>29</td>
<td>1.04-1.36</td>
<td>1.18</td>
<td>0.074</td>
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<tr>
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<td>1.28-1.56</td>
<td>1.39</td>
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<td>16.42</td>
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<td>0.73</td>
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<td>0.92-1.20</td>
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<td>*H/DT</td>
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<td>0.060</td>
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<td>23.64</td>
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</tr>
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<td>0.320</td>
<td>32.00</td>
</tr>
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<td>L</td>
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<td>W</td>
<td>2</td>
<td>1.12-1.40</td>
<td>1.26</td>
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</tbody>
</table>

Measurements with asterisks (*) are taken at nearest 0.2 mm because of the inaccuracy due to the curvature of the tooth. H/T: tooth height above the base enamel; H/DT: dentine tract height above the base of enamel.
at San Simon Power Line, Gila Conglomerate, San Simon Valley, southern Arizona; Crooked Creek Fm., Borchers local fauna, Kansas.

AGE: Late Blancan (latest Pliocene).

DESCRIPTION: The posterior portion of the lower jaw is missing in all specimens. The mandible is shallower relative to the length than the modern species of the genus. The mental foramen is higher in position. The masseteric crest is well developed. The cheek teeth are hypsodont and possess the dentine tracts on both the labial and lingual sides. The height of dentine tracts is moderate but varies with individual tooth (Table 17). They tend to be slightly higher at the labial side on the lower and lingual side on upper teeth. The tracts are slightly observable above the edge of the ramus whereas they are less developed on the premolars and are hardly observable above the edge. Roots of the cheek teeth are fused in various degrees, the lesser on the more anterior tooth. Roots are better developed in old individuals but poorer in young; they are much shorter on molars than premolars; and they are not formed on un-worn or little-worn teeth.

P⁴: The protoloph consists of a prominent subcircular protocone, and the base of the protoloph expands anteriorly. The protocone is connected with the metacone first in early stage of wear. The vertical grooves at the union of the protoloph and metaloph extend to the base of the tooth on lingual side but do not extend on the labial side in most specimens. The metaloph consists of three cusps; the hypocone is slightly posterior relative to the metacone, and the hypostyle is anterolingular to the hypocone. The posterior cingulum connects the
hypostyle to the posterior margin of the hypocone, but it is not so distinctive. The base of enamel is obviously lower on the protoloph, but the height of the dentine tracts and enamel crown are measured at the enamel base of the metaloph (Table 17). The dentine tracts are on both the labial and lingual sides of the metaloph, and extend approx. one third to half way up to the tooth height in young individuals. In old individuals a large, anteroposteriorly elongated root lies at the base of the protoloph, and a transversely elongated but distally separated root lies at the base of the metaloph. Both roots are fused at the base, forming a T-pattern.

\[ M^1: \] The nearly straight protoloph consists of transversely elongated paracone and protocone, and the protostyle. On the metaloph the rounded metacone and hypocone are arranged nearly parallel to the protoloph, and the posterior margin of the hypocone is connected by the posterior cingulum with the nearly anteroposteriorly elongated hypostyle. The metaloph is shorter than the protoloph, and both are connected completely at their lingual margins. These cusps disappear in early stage of wear, and the lophs form a U-shape. Further wear unites the lophs and the occlusal surface becomes semi-oval in shape. The dentine tracts occur on both the labial and lingual sides, the former is broader than the latter. The height varies but extends approx. a little over half of the tooth height in a majority of the young individuals (Table 17). The roots are short and well fused at the bases; main root is anterolabial-to-lingually elongated and another is located at the posterolabial corner of the tooth base. They are fused
lingually, forming a V-shape, open labially. The molar roots are less distinct than in P^4.

M^2: It is similar to but smaller than M^1 in overall measurements. M^2 curves (concave posteriorly) in contrast to the nearly straight in M^1, and the roots are well fused to become a short, single root with shallow groove on the labial side.

M^3: This tooth is represented by only two specimens. M^3 is distinctly smaller than other cheek teeth. The nearly straight protoloph consists of three closely appressed cusps; the anterior cingulum is incomplete, it projects labially from the protostyle anterior to the protocone. Three cusps are barely distinguishable on the metaloph which is much shorter than the protoloph. The protostyle and hypostyle join at their bases, but the tips are separated by the extension of the transverse valley. The occlusal pattern of the worn tooth is semi-circular. Low dentine tracts occur on both the labial and lingual sides. Roots are well fused, with or without a weak vertical groove posterolabially.

P^4: The protolophid consists of two cusps joined medially and has a shallow anterior groove. The protostylid (labial cusp) has an anterolabial cuspule on one of 13 slightly worn specimens (Fig. 15 M-N). The metalophid consists of three cusps and is wider than the protolophid. The two lophids are joined in an early stage of wear by a distinct bridge between the midpoint of the protolophid and the hypoconid of the metalophid. The lingual groove between the two lophids is deeper than the labial groove and continues to the base of the enamel, where
it becomes indistinct; the labial groove disappears above the base of
the enamel. The labial dentine tract is wider and higher than the
lingual. The dentine tracts develop only on the metalophid and extend
one third to one half the height of the enamel in young individuals.
A long, anteroposteriorly elongated root is present at the base of the
protolophid and a transversely elongated root is present at the base of
the metalophid; they are fused at their bases but are separated through
most of their length.

$M_1$: The metalophid is three cusped with a subequal metaconid
and protoconid and a smaller protostylid. These cusps are nearly
straight; the anterior cingulum extends anteriorly from the protostylid
near the anteroexternal corner of the tooth, curves lingually, and
joins the anterior margin of the metaconid. Therefore, the occlusal
pattern at worn stage is somewhat oblique to the axis. The hypolophid
is nearly straight or slightly convex posteriorly and consists of three
cusps: transversely elongated entoconid, rounded hypoconid, and smaller
hypostylid. The transverse valley is shallower medially, and thus the
two lophids join medially after moderate wear, forming an H-pattern.
The dentine tracts are better developed than on any other tooth, and
extend approx. two thirds of the tooth height in slightly worn teeth.
The labial dentine tract is wider and slightly higher than the lingual.
Roots are broken in most specimens, but a few specimens indicate that
the roots are short and almost completely fused into a single root,
posterior half of which is wider than lingual (forming rounded tri-
gle), with or without a shallow, labial groove.
M₂: Very similar to and is only slightly smaller than M₁, though lower in height. Roots are fused into a single, transversely elongated root.

M₃: Distinctly smaller than M₂. The metalophid consists of the metaconid, protoconid, and anterior cingulum; a separate protostylid is indistinguishable. The anterior cingulum is distinctly lower in position and projects from the metaconid to the position of the protostylid anterior to the protoconid. The hypolophid is represented by a small isolated entoconid, distinctly lower than the metalophid. Roots are fused into a single, transversely elongated root.

DP₄: Two deciduous premolars are referred to this taxon. The lower molar cusp terminology or dP₄ cusp terminology of Rensberger (1971, p. 110) is employed here. The tooth is very brachydont; lophodonty is weak. The hypolophid consists of three cusps, the hypostylid being much smaller, and is oblique to the tooth axis. The metalophid also consists of three cusps perpendicular to the axis. The protoconid and protostylid are anteroposteriorly elongated. Transverse valley between these lophids is moderately deep lingually, shallow medially; these two lophids form an H-pattern after moderate wear. The anterior cingulum forms a semi-circle anterior to the metalophid. It joins to the protostylid but does not join to the metaconid. Although the detail of the anterior cingulum is not observable because of breakage, there would have been three cingulum cusps (stylistal cusps) distributed in nearly equal distance. Two roots are observable on UALP 1055,
but both the posterior surface of the anterior root and the anterior surface of the posterior root are being resorbed.

COMPARISONS AND DISCUSSION: I follow Zakrzewski (1981) on the definitions of the genera Prodipodomys and Dipodomys. D. hibbardi from 111 Ranch is distinguished from any species of the genus Prodipodomys by having more hypsodont cheek teeth with the higher dentine tracts and by less developed roots, especially those of molars. D. hibbardi is distinguished from D. gidleyi in its smaller size and in having P\textsubscript{4} with an anterior groove and cheek teeth less hypsodont with lower dentine tracts. All other forms of the genus are more advanced than D. gidleyi.

When he synonymized Etadonomys with Prodipodomys, Zakrzewski (1981) diagnosed P. tiheni as most advanced species of the genus in hypsodonty and the height of the dentine tracts. He mentioned that the dentine tracts in Prodipodomys seldom exceed 0.7 mm in height whereas those in Dipodomys are generally greater than 1.0 mm. If so, he should have discussed the contradiction that P. idahoensis has much higher dentine tracts than P. tiheni. That is, the dentine tracts of M\textsubscript{1}'s of P. idahoensis are 1.59 and 1.38 mm in height (Zakrzewski, 1969), well within the range of D. hibbardi from 111 Ranch (which has the same ranges on P\textsubscript{4}/\textsubscript{4} as D. hibbardi from Borchers) (Table 17). Also, the dentine tracts of the holotype of P. idahoensis is observable above the edge of the ramus, which, I believe, indicates that the dentine tracts are quite high like in D. hibbardi.

It is probably true that P. idahoensis is another advanced species of the genus Prodipodomys, but the relationships between
P. idahoensis' and P. tiheni and between P. idahoensis and D. hibbardi still remain obscure. P. idahoensis may be in need of review, especially in view of the presence of more than one kind of kangaroo rats as in the Borchers local fauna and in 111 Ranch.

The kangaroo rat from Wolf Ranch, Arizona is very similar to 111 Ranch specimens described here and probably represents D. hibbardi rather than P. idahoensis as referred by Harrison (1978). More precise examination is needed as in the Hagerman kangaroo rats.

**Dipodomys sp. cf. D. gidleyi** Wood, 1935
(Fig. 15S-W; Table 18)

REFERRED MATERIAL: UALP nos. 1053, left dentary with broken $I_1$ and $P_4$'s; 16010-16011, $P_4$'s; 16001, $M_1$; 16025, 16027, $P_4$'s; 13868, $M_2$, from UA loc. 15-24. UALP nos. 15952, $M_2$ and 15953, $M_2$ from UA loc. 15-5, 111 Ranch.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA locs. 15-24 and 15-5, both about 40 m level of the 111 Ranch composite section, Gila Conglomerate, San Simon Valley, southern Arizona.

AGE: Late Blancan (latest Pliocene).

DESCRIPTION: The mandible is deeper relative to the length, and the mental foramen is more ventral than in **Dipodomys hibbardi** (Fig. 15W). The masseteric crest is well developed and is close to the alveolar ridge. The cheek teeth are all very hypsodont and possess high dentine tracts on both the labial and lingual sides. The dentine tracts are observable above the edge of the alveolus. The roots are not formed in
Table 18. Measurements of Dipodomys cf. gidleyi

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young individuals. In old individuals, the roots are fused and are poorly developed. All the specimens show slight but apparent decrease in width toward the base of the tooth. The width is greatest approx. at the point where the transverse valley disappears.

\( \text{P}^4 \): The cusp pattern is nearly identical with that of Dipodomys hibbardi described above. The anteroposterior length is slightly shorter relative to the width, and the anterior expansion of the proto-loph toward the base of the tooth is very weak. The dentine tracts are more than two thirds the height of the tooth on slightly worn teeth. The roots are fused into a tubular root, slightly triangular in cross-section.

\( \text{M}^1 \) and \( \text{M}^2 \): Both teeth are very worn; the oval shaped enamel pattern is almost interrupted by the dentine tracts on \( \text{M}^1 \) and is interrupted on \( \text{M}^2 \). Root is short and tubular. \( \text{M}^2 \) is slightly smaller than \( \text{M}^1 \) and is curved, concave posteriorly.

\( \text{P}_4 \): All cusps are indistinguishable by wear, but a cusp pattern similar to the \textit{D. hibbardi} can be inferred from a moderately worn tooth. The anterior groove between the protoconid and protostyloid is not present. The lingual groove between the protolophid and metalophid becomes indistinguishable toward the base of the tooth as in the labial groove. The labial dentine tract is higher than the lingual and extends over three fourths of the tooth height. Roots are fused into a tubular root which is anteroposteriorly elongated to become triangular in cross-section. Length is greater than in \( \text{P}^4 \).
M₂: The cusp morphology is similar to that of D. hibbardi, but each cusp is more transversely elongated (or less rounded) relative to D. hibbardi. Dentine tracts extend over three fourths of the tooth height in slightly worn teeth. Roots are open on two slightly worn teeth. One specimen possesses a short, small, tubular root, though it is broken.

COMPARISONS: This taxon is somewhat larger in size than D. hibbardi. The teeth are more hypsodont with much higher dentine tracts, and roots are more reduced than in D. hibbardi (Table 18). In a few moderately worn P₄'s of D. hibbardi (e.g. UALP 1051 and 1054), the anterior groove between the protoconid and protostylid is observable, whereas the groove is less obvious (probably may not be present) in D. cf. gidleyi. Recent species possess more hypsodont teeth with higher dentine tracts, and many of them have less developed roots and anteroposteriorly shorter P₄ than the specimens described here. Many recent species also possess P₄ with dentine tracts on both the proto-lophid and metalophid.

DISCUSSION: Dipodomys gidleyi is probably one of the less well known species of the genus. Wood (1935) described this species based on a fragmentary lower jaw with P₄-M₃. Although Wood said that the enamel is complete throughout life, this is not true. The dentine tracts are observable above the alveolar edge on both sides of P₄ and on the lingual side of M₁ (labial is broken), as in UALP 1053. The peculiar occlusal pattern (except for the absence of the anterior groove) of P₄ is simply due to its early stage of wear, as Gazin
(1942) pointed out. Gazin (1942) also pointed out that AM 27790, a jaw with $P_4$-$M_1$, very probably belongs to $D. \text{gidleyi}$, rather than $P. \text{minor}$ as assigned by Wood. The teeth of AM 27790 possess high dentine tracts that are observable above the alveolar edge. Thus, among the characters of $D. \text{gidleyi}$ that Wood described, the only valid characters are the anterior surface of $P_4$ not being grooved and $M_3$ not so reduced, in addition to the size.

III Ranch specimens described here agree well in size with those two specimens of $D. \text{gidleyi}$ including tooth height, in the development of the dentine tracts, and in $P_4$ lacking an anterior groove. But, I hesitate to conclude that the III Ranch specimens described here are definitely $D. \text{gidleyi}$ without reviewing the original American Museum specimens and additional toptotypic specimens.

Family CRICETIDAE Rochebrune, 1883

The family Cricetidae are represented by 8 genera and 15 species in the present study area. Of which 5 genera and 10 species are smaller forms with brachydont cheek teeth, one genus one species ($\text{Sigmodon}$) is medium size with brachydont teeth, and 2 genera with 4 species ($\text{Neotoma, Repomys}$) are larger forms with hypsodont cheek teeth.

Those small, brachydont cricetines are similar to each other in general morphology. Following are some of the diagnostic characters that distinguish each genus from other genera.
**Onychomys**: Largest in size within these genera; anterocone of M\(^1\) narrow, located near the labial edge; individual cusps of cheek teeth are very steep with flexi and flexids relatively wide and deep.

**Peromyscus**: Medium in size, anterocone of M\(^1\) is centered slightly labial to the midline; labial cusps of M\(^1-2\) and lingual cusps of M\(_{1-2}\) are relatively rounded and conical; flexi and flexids are relatively narrow; M\(^3\) is very reduced.

**Calomys (Bensonomys)**: Medium in size; anterocone of M\(^1\) is wide, centrally located, and distinctly bilobed with deep anteromedian flexus; individual cusps are rather sharp, very low, and gently sloping.

**Reithrodontomys**: Small in size; anterocone/antroconid are wide, and laterally elongated single cusps or indistinctly bilobed; labial cusps of upper molars and lingual cusps of lower molars have a relatively rounded, conical appearance.

**Baiomys**: Small to very small in size; anterocone of M\(^1\) is relatively centrally located, and distinctly bilobed with a relatively wide anteromedian flexus and conical conules; anteroconid of M\(_{1}\) is placed very close to the metaconid.

Cusp terminology of cricetid molars and their homology with the tribosphenic molars has been a subject to which a number of vertebrate paleontologists have paid attention (Wood and Wilson, 1936; Hershkovitz, 1962; and many others cited by Reig, 1977). However, since cricetines recognized in this study have rather simple cusp and fold pattern and since the terminology of Wood and Wilson (1936) or Lindsay (1972) is widely used for those cricetines, I first intended to follow them with
the additional terms (striae, striids) for the hypsodont teeth provided by Stirton (1935). However, it was recognized that the direct application of Stirton's (1935) terms to Wood and Wilson (1936) was difficult mainly because the cusp homology between cricetids and castorids was slightly different and terms of the folds between upper and lower teeth were not consistent in Stirton (1935). Reig (1977) reviewed all available terminology since 1925, and proposed a unified nomenclature of cusps, lophs, and folds of cricetid molars. I agree with his discussions, and his terminology is acceptable. However, since cricetines described below do not have complicated pattern, especially the portion of the procingulum (Reig's term), I slightly simplified his nomenclature and used in this paper as illustrated in Fig. 16. Grooves on the side walls of the hypsodont tooth (as in Neotoma and Repomys) are named (striae and striids) after the names of corresponding flexi and flexids, though they are not illustrated in Fig. 16.

**Onychomys Baird, 1858**

**Onychomys pedroensis** Gidley, 1922

*(Fig. 11J-L; Table 19)*

REFERRED MATERIAL: UALP nos. 13946-13947, 15255-15256, M1's; 13948-13949, M2's; 14007, M3; 13963, 15274, M1's 13988, M2; 14006, M3, from UA loc. 7933.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA loc. 7933, Dry Mt. East, at approx. 85 m level of the Ill Ranch composite section, Gila
Figure 16. Cusp and fold terminology of Cricetidae used in this paper, slightly changed after Reig (1977)
Table 19. Measurements of *Onychomys pedroensis*

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Conglomerate, southern Arizona; Borchers fauna, Crooked Creek Formation, Kansas; White Rock local fauna, Belleville Fm., Kansas; Jinglebob and Cragin Quarry local faunas, Kindsdown Fm., Kansas; Sandahl local fauna, McPherson Fm., Kansas.

AGE: Late Blancan (latest Pliocene)- Rancholabrean (late Pleistocene).

DESCRIPTION: Cheek teeth are brachydont with relatively high and steep cusps; lingual cusps slightly alternating (anterior) relative to the labial cusps; alternation of cusps more pronounced in lower molars than in upper molars.

M1: Occlusal outline is a rounded rectangle with the anterolingual corner cut off, longer than wide. The anterocone is situated labial to the midline, transversely narrow, and moderately bilobed. The anterolabial conule of the anterocone is higher, slightly larger, and slightly anterior relative to the lingual conule. The anteromedian flexus is broad and shallow, and disappears with advanced wear. The anterolingual conule joins the anterior arm of the protocone near the midpoint of the tooth. The protocone has a low anterior arm, nearly parallel to the long axis of the tooth, and a short, posterior arm directed posterolabially that joins the paracone. The labial cusps have obliquely elongated occlusal wear surfaces that face posterolingually. The hypocone has a low anterior arm, nearly parallel to the tooth axis, and a short, strong posterior arm that is directed obliquely, joining the posterolingual corner of the metacone. A short posterior cingulum extends labially from the junction of the
hypocone and metacone. The flexi are very deep and wide; they are all partially closed by low cingula in two of four specimens and some of them are open in two other specimens. Three distinct roots are present.

\( M^2 \): Occlusal outline is oval, wider anteriorly, with a nearly straight anterior margin and a rounded, posterior margin. Major cusps and lophs are similar to \( M^1 \) except that the anterocone is absent and a long anterior cingulum crosses the front of the tooth. The short anterior arm of the protocone extends anteriorly and joins the anterior cingulum at its high point near the midline of the tooth. A minute "parastyle" is present at the labial end of the anterior cingulum. The major cusps are nearly opposite, less alternating, than in \( M^1 \). The hypoflexus and metaflexus are slightly closed by low cingula. Three distinct roots are present.

\( M^3 \): This tooth is very small relative to \( M^{1-2} \). Occlusal outline is a subcircle. Three distinct cusps (protocone, paracone, and hypocone) are present; the protocone and paracone are transversely opposed, while the smaller hypocone is near the midline of the tooth. The anterior arm of the protocone joins the anterior cingulum near the midline; anterior cingulum extends labially to the anterior base of the paracone; anterior cingulum is indistinct lingual to the midline.

\( M^1 \): Occlusal outline is a rounded, elongated subtriangle. The anteroconid is single cusped, small, and narrow, situated labial to the midline; the anterior cingulum is indistinct. The anteroconid is close to the metaconid and joins it near the midline of the tooth. The cusps are distinctly alternating. The metaconid and entoconid are
slightly elongated obliquely, with their wear surfaces facing anterolabially. The posterior arm of the protoconid is confluent with the anterior arm of the entoconid in 1 of 2 specimens. There is a very weak, low, and short mesolophid extending anterolingually from the protoconid-entoconid junction (Fig. 11L). A posterior cingulum is moderately thick, but transversely short and low; it joins the hypo­conid after moderate wear. The metaflexid is very narrow and shallow, closed by the union of the anteroconid and metaconid after moderate wear. Other flexids are deep and wide; protoflexid and hypoflexid are slightly closed by very low anterior and labial cingula, respectively. Anterior and posterior roots are present with no indication of accessory rootlets.

M₂: Occlusal outline is a rounded subrectangle, longer than wide. Major cusps and lophs are similar to M₁, except that the anteroconid is absent. Cusps alternate as in M₁. The anterior arm of the protoconid and the short metalophid join the anterior cingulum near the midline of the tooth. The low posterior cingulum is transversely short and expands near the midline of the tooth, forming a small pos­teroconid. The labial flexids and entoflexid are as in M₁; the postero­flexid is partly closed by union of the posterior cingulum and the base of the entoconid. Two distinct roots are present.

M₃: Occlusal outline is a rounded triangle, wider anteriorly. Oppositely placed metaconid and protoconid form the trigonid; the talonid consists of a large medially located cusp (hypoconid) and a small lingual cuspule (entoconid). A short lingual anterior cingulum
is relatively high anterior to the metaconid. The entoflexid is wide but shallow, whereas the hypoflexid is wide and deep. Two distinct roots are present.

COMPARISONS: Carleton and Eshelman (1979) reviewed and revised the classification of fossil species of the genus Onychomys, and I follow their taxonomic framework. *O. pedroensis* is distinguished from *O. bensoni*, *O. hollisteri*, and *O. torridus* by its distinctly larger size. *O. pedroensis* is similar to *O. leucogaster* in size, but is distinguished by having a relatively larger (less reduced) M3/3. *O. pedroensis* is distinguished from *O. gidleyi* by its slightly larger size, a relatively smaller M3 with slightly more reduced talonid, and by more hypsodont cheek teeth.

The specimens described here are slightly smaller than the holotype and topotypic specimens from the Curtis Ranch, but are well within the assumed size range. The specimens described here also exhibit hyp sodonty similar to that in *O. pedroensis*, which is more hypsodont than *O. gidleyi*. Relative size of M3 is closer to *O. pedroensis* than in *O. gidleyi* (see discussion below).

DISCUSSION: Measurements by Carleton and Eshelman (1979) seem slightly larger because my measurements of the Curtis Ranch specimens are slightly smaller than theirs, although mine are made on the epoxy casts (Table 19).

Since the specimens described here are all isolated teeth, it seems likely that the ratios of the length of any two lower molars do not reflect precise value. However, UALP nos. 13963 (M1), 13988 (M2),
14006 (M₃) seem very likely to belong to a same individual because of their stage of wear, their color, and they are the only left lower molars present. The ratios of M₂/M₁, M₃/M₁, and M₃/M₂ in length are 82.2, 61.1, and 74.3 respectively. These values match most closely to those of O. pedroensis (Carleton and Eshelman, 1979, p. 63) and the ratio of M₃/M₁ (61.1) is nearly identical with that (61.5) of the holotype, USNM 10506.

Peromyscus Gloger, 1841

Peromyscus hagermanensis Hibbard, 1962

(Fig. 17A-D; Table 20)

REFERRED MATERIAL: UALP nos. 14266, left maxillary fragment with M₁-₃ somewhat corroded; 14267-14272, M₁'s; 14273-14278, M₂'s, of which 14275 with maxillary fragment; 14279-14280, M₃'s; 14208, left dentary with I₁M₁-₂; 14281-14286, M₁'s; 14210, 14262-14263, 14288-14291, M₂'s; 14292-14297, M₃'s, from UA loc. 7937. UALP nos. 13936-13940, M₁'s; 13941-13945, 15261-15263, M₂'s; 15270-15271, M₃'s; 13965-13966, 13968, 13979-13981, M₁'s; 13964, 13967, 13984-13987, 15276-15277, M₂'s; 14004-14005, M₃'s, from UA loc. 7933.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA locs. 7937 at about 10 m level of the Duncan section, and 7933 at about 85 m level of the Ill Ranch composite section, Gila Conglomerate, southern Arizona; Hagerman local fauna, Glens Ferry Fm., Idaho.

AGE: Blancan (late Pliocene).
Figure 17. *Peromyscus*, *Baiomys*, and *Reithrodontomys*

A-D: *Peromyscus hagermanensis*
A, UALP 14270, left M\(_1\); B, UALP 15271, right M\(_2\);
C, UALP 14284, left M\(_1\); D, UALP 14293, left M\(_3\).

E-F: *Baiomys minimus*
E, UALP 14239, left M\(_1\); F, UALP 14216, right M\(_1\).

G: *Baiomys* sp., UALP 14117, left maxillary fragment with M\(_1-3\).

H-I: *Baiomys* cf. *brachygnathus*
H, UALP 13953, right M\(_1\); I, UALP 13974, left M\(_1\).

J-L: *Reithrodontomys rexroadensis*
J, UALP 14254, left M\(_1\);
K, UALP 14256, left maxillary fragment with M\(_2-3\);
L, UALP 14260, left dentary fragment with M\(_1-3\).

M-O: *Reithrodontomys galushai* n. sp.
M, UALP 13962, left M\(_1\); N, UALP 15283, right M\(_3\);
O, UALP 13975, right M\(_1\), holotype.

Short scale bar represents 1 mm for figures G and L;
long scale bar represents 1 mm for all other figures.
Figure 17. *Peromyscus*, *Baiomys*, and *Reithrodontomys*
Table 20. Measurements of *Peromyscus hagermanensis*

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<th>S.D.</th>
<th>C.V.</th>
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<td>0.76-0.82</td>
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DESCRIPTION: Dentary is moderately deep. Mental foramen is located near the border of the labial and dorsal surfaces of the dentary, immediately anterior to the $M_1$ root. Masseteric crest is well developed; its anterior margin is labial to the anterior root of $M_1$ and is higher in position than the mental foramen.

$M^1$: Occlusal outline is oval. The anterocone is located relatively labial to the midline of the tooth; it is subequally bilobed in 3 of 4 specimens, laterally elongated, single cusped in one specimen from UA loc. 7937, and bilobed in 2 of 4 specimens, single cusped in 2 specimens from UA loc. 7933. The anterior mure is rather short. The protocone and hypocone have a long, anterior arm directed anterolabially and a short posterior arm directed postero-labially. The paracone and metacone are rounded and conical. A posterior cingulum is absent. Mesoloph is present in all 12 specimens, and reaches to a minute mesostyle in 8 specimens. Mesostyle is present in 3 of 4 specimens (absent in UALP 14268) that do not possess a complete mesoloph. A lophate (rather than conical) parastyle is moderately to well developed, closing the paraflexus in all specimens. The anteroloph is absent in most specimens, except for UALP 14270 (Fig. 17A) in which a short anteroloph does not reach the parastyle. Lingual flexi are nearly open or partially closed by low cingula, except for 2 specimens (UALP 14269, 14270; Fig. 17A) that possess a minute protostyle. There are three distinct roots in all specimens, plus a small rootlet below the paracone in 5 of 6
specimens from UA loc. 7937, and only a tiny bump in 2 of 3 specimens from UA loc. 7933.

M\textsuperscript{2}: Occlusal outline is oval, wider anteriorly, with nearly straight anterior and labial margin. Cusps and lopes are similar to M\textsuperscript{1} except that the anterocone is absent and a thick labial anterior cingulum is present, which join the paracone anterolabially, closing the paraflexus. Development of the mesoloph and mesostyle is similar to those in M\textsuperscript{1}. There are three distinct roots with no indication of accessory rootlets.

M\textsuperscript{3}: Occlusal outline is a subcircle. M\textsuperscript{3} is very reduced in size relative to M\textsuperscript{1-2}. The paracone, protocone, and smaller hypocone are distinct, enclosing an anteroposteriorly elongated central basin. A cingulum extending from the hypocone to posterior face of the paracone encloses another small basin which is probably comparable with the mesoflexus of M\textsuperscript{1} and M\textsuperscript{2}. A thin anterior cingulum is present as in M\textsuperscript{2}. Three distinct roots are present.

M\textsubscript{1}: Occlusal outline is a long oval, narrow anteriorly, with a wide, nearly straight posterior margin. The anteroconid is indistinctly (5 of 8 specimens) or moderately distinctly bilobed (with a short anteromedian flexid) in Duncan (UA loc. 7937) specimens, whereas it is indistinctly bilobed (4 of 6) or single cusped (2 of 6 specimens: UALP 13965, 13968) in 111 Ranch (UA loc. 7933) specimens. Anterior murid is relatively short and joins the anteroconid and the short anterior arm of the protoconid near the midline of the tooth. The metaconid and entoconid are rounded and conical, and
join respectively the short anterior arm and the long, posterior arm (directed posterolingually) of the protoconid; the protoconid-entoconid junction is slightly offset and forms a straight line in late wear. The hypoconid is similar to the protoconid; its posterior arm broadly joins the posterior cingulum that joins the posterior base of the entoconid, partially closing the postero-flexid. A short mesolophid that extends from the entolophid and a small mesostylid are present in 6 of 13 specimens, whereas the entoflexid is narrow but open in the rest of the specimens. The proto-flexid is partially closed by a well developed anterior cingulum in all specimens. The hypoflexid is also partially closed by a cingulum (cingular ridge in most specimens; UALP 14284 (Fig. 17C) possesses a low ectolophid and a small ectostylid. There are two distinct roots with no accessory rootlets; except for UALP 14284 that possesses a small rootlet that branches anteroventrally from the anterior side of the posterior root.

\[M_2\]: Occlusal outline is a rectangle, longer than wide, with a rounded posterior margin. Cusps and lophs are similar in \[M_1\], except that the anteroconid is absent and the posterior cingulum expands more posteriorly from a constricted, narrow junction with the hypoconid. The lingual flexids are shallower than the labial flexids; entoflexid is partially closed by a low cingulum (in two thirds of the specimens) or a minute mesostylid (in one third of the specimens). Similarly, the hypoflexid is partially closed by
a minute ectostylid or a low cingulum. There is no mesolophid nor ectolophid. Two distinct roots are present.

$M_3$: Occlusal outline is a slightly elongated, rounded triangle with broadly rounded posterior margin. The protoconid and hypoconid are subequal and the metaconid is slightly smaller. Entoconid is indistinct except for one specimen (UALP 14292) with a very small entoconid; in other specimens a sinuous loph joins the protoconid and hypoconid in the position of the entoconid. The entoflexid is much shallower than the hypoflexid and is directed anterolabially, whereas the hypoflexid is deep and is directed lingually, perpendicular to the tooth axis. Both flexids are partially closed by low cingula (cingular ridges) rather than stylids. Two distinct roots are present.

COMPARISONS: Development of the mesoloph, mesostyle, and parastyle in $M_1$ and/or $M_2$ places the specimen described here as $P. $hagermanensis$ in the subgenus $P.$ (Peromyscus) (Hooper, 1957). $P. $hagermanensis$ is similar to $P. $maniculatus$ among modern species both in size and in general morphology, but differs from the latter in $M_1$ with relatively narrower and relatively poorly bilobed anterocone and in $M_3$ with completely enclosed, deep central basin. Extinct Blancan and Irvingtonian species from Kansas ($P. $kansasensis$, $P. $baumgartneri$, and $P. $cragini$) are members of subgenus $P.$ (Haplomyalomys); $P. $irvingtonensis$ from california is also a member of $P.$ (Haplomyalomys) and is much larger in size.
P. hagermanensis from Idaho (Hibbard, 1962; Zakrzewski, 1969) and P. nosher known from the White Bluffs local fauna in Washington (Gustafson, 1978) are the only known members of the sub-genus P. (Peromyscus) during the Blancan and Irvingtonian.

P. nosher differs from P. hagermanensis material described here in having \( M_1 \) with the parastyle small and "cuspoid" rather than large and "lophoid", in having \( M_1 \) with the anteroconid more strongly bilobed, and in having \( M_2 \) with smooth and broad connection between the hypoconid and posterior cingulum (Gustafson, 1978). Casts of five of the seven known specimens of P. hagermanensis from the Hagerman local fauna were available for comparisons. The direct comparisons with these casts indicates that the Hagerman specimens are within the ranges of the Duncan and 111 Ranch samples in most measurements and morphological variations. Length of \( M^2 \) of UMMP 53448 is slightly shorter than the range of Arizona specimens, but it is probably due to its extreme wear.

DISCUSSION: The samples from UA loc. 7937, south of Duncan, and UA loc. 7933, 111 Ranch, are very similar to each other both in size and in morphology. In size these two samples are nearly identical both in average and in observed range of most measurements (Table 20). Differences in morphology include: bilobed anterocone of \( M^1 \) is less developed, bilobation of anteroconid of \( M_1 \) is weak, and single-cusped anteroconid of \( M_1 \) is narrower in the sample from UA loc. 7933. UALP 13965 and 13968 from UA loc. 7933 possess narrow, single-cusped anteroconid and are slightly smaller in size than
other M₁ specimens; thus, they might represent a different taxon, but they are tentatively included here mainly because of their similarity in other general morphology. These differences (possibly except for the narrow anteroconid of UALP 13965 and 13968) are rather minor relative to other nearly identical characters, and here considered as the same species with some wide variation, although the geologic time gap between these two localities is relatively wide (ca. 1 Ma).

Peromyscus differs from extinct genus Copemys in alignment of the entolophid and the posterior arm of the protoconid (Lindsay, 1972, p. 75). In M₁-2 material described here as P. hagermanensis, the protoconid-entoconid junction is slightly offset in relatively unworn specimens (though form a straight line in late wear). Similar slight offset is also observed in P. eremicus among the modern species (Lindsay, pers. commun., 1985). Thus, P. hagermanensis and P. eremicus may be more closely related to the extinct genus Copemys than to modern Peromyscus.

Peromyscus and cf. Peromyscus spp.

REFERRED MATERIAL: UALP nos. 15669, rostrum with broken incisors, left and right M₁'s, from UA Loc. 8210. UALP nos. 1046, left dentary with M₁, 16004, isolated M₁, from UA loc. 15-24.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA loc. 8210, exact position in the Country Club section is not known, but at about
10-15 m level; UA loc. 15-24, about 40 m level of the Ill Ranch composite section, Gila Conglomerate, southern Arizona.

AGE: Blancan (late Pliocene).

DESCRIPTION AND DISCUSSION: UALP 15669 is a rostrum about the size of *Peromyscus maniculatus*; anterior face of the incisor is flat as in *Peromyscus*. Both M1's are very worn, and none of the occlusal structure is preserved. Occlusal outline of the tooth and the relative position of the wide anterocone resembles *Peromyscus*. Length and width of M1 are 1.60 and 1.10 mm, respectively.

UALP 16004 has cusp pattern and size similar to those of *Peromyscus*. However, the metaflexid is very narrow, accessory lophids and stylids are absent, anteroconid is wide and single cusped, and cusps slope slightly anteriorly. Length and width are 1.62 and 1.00 mm, respectively.

M1 of UALP 1046 is also similar to *Peromyscus* in general morphology. However, it has 1) more triangular occlusal outline, 2) much wider hypoflexid and entoflexid, and 3) more gently sloping anterior surface of the protoconid and hypoconid. These features give this tooth an *Onychomys*-like appearance. Thus, UALP 1046 is questionably assigned to the genus *Peromyscus*. Length and width are 1.54 and 1.02 mm, respectively.
Baiomys True, 1894

Baiomys minimus (Gidley, 1922)

(Fig. 17E-F; Table 21)

REFERRED MATERIAL: UALP nos. 14215, 14218, 14220-14221, M₁'s with maxillary fragment; 14214, 14216-14217, 14219, 14222-14226, M₁'s; 14227-14233, M₂'s; 14298-14300, M₃'s with maxillary fragment; 14235-14244, M₁'s; 14247, left M₁-2 with dentary fragment; 14248, left dentary fragment with I₁, M₂; 14245-14246, 14249-14250, M₂'s, all from UA loc. 7937.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA loc. 7937, south of Duncan, at approx. 10 m level of the Duncan section, Gila Conglomerate, southern Arizona; Benson fauna, St. David Fm., southern Arizona.

AGE: Middle Blancan (late Pliocene).

DESCRIPTION: Very small cricetine with brachydont cheek teeth. The posterior margin of the incisive foramen is medial to the anterior margin of the protocone of M₁. Small knob present on maxilla anterior to M₁ and medial to zygomatic plate, presumably for insertion of M. masseter superficialis. Dorsal and ventral ridges of the masseteric crest are distinct, joining at the anterior margin of the crest which is labial to the anterior root of M₁. The mental foramen is located at the border of the dorsal and labial sides of the dentary, anterior to M₁. Length of the M₁-3 alveolus is 2.76 mm in UALP 14248.
Table 21. Measurements of *Baiomys minimus* and *Baiomys sp.*

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<td>4.47</td>
</tr>
<tr>
<td>M/1 W</td>
<td>9</td>
<td>0.68-0.80</td>
<td>0.75</td>
<td>0.045</td>
<td>6.00</td>
</tr>
<tr>
<td>M/2 L</td>
<td>6</td>
<td>0.84-0.90</td>
<td>0.86</td>
<td>0.029</td>
<td>3.37</td>
</tr>
<tr>
<td>M/2 W</td>
<td>6</td>
<td>0.70-0.78</td>
<td>0.73</td>
<td>0.033</td>
<td>4.52</td>
</tr>
<tr>
<td>M/3 L</td>
<td>2</td>
<td>0.68-0.72</td>
<td>0.70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M/3 W</td>
<td>2</td>
<td>0.54-0.62</td>
<td>0.58</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Baiomys sp.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M1/ L</td>
<td>4</td>
<td>1.26-1.30</td>
<td>1.29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M1/ W</td>
<td>4</td>
<td>0.72-0.76</td>
<td>0.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M2/ L</td>
<td>2</td>
<td>0.80-0.90</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M2/ W</td>
<td>2</td>
<td>0.70</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M3/ L</td>
<td>1</td>
<td>0.54</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M3/ W</td>
<td>1</td>
<td>0.56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M1-3/ L</td>
<td></td>
<td>2.64</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
M^1: Occlusal outline is oval. The anterocone is relatively wide, subequally bilobed with labial conule slightly higher; the anteromedian flexus is moderately deep. A low transverse cingulum is located anterior or anterolabial to the deep anteromedian flexus in 5 of 13 specimens, and tends to ascend the labial lobe of the anterocone. The protocone and hypocone have long, anteriorly-oriented anterior arms and short, nearly transversely-oriented posterior arms. The anterior arm of the protocone joins the anterocone either in the midline of the two conules or very slightly lingual to the midline. The paracone and metacone are transversely elongated and join the posterior arms of the protocone and hypocone, respectively. Lingual and labial flexi are relatively wide and all are closed by well developed cingula (termed cingular ridges by Packard, 1960). In some specimens (e.g., UALP 14214, 14224), those cingular ridges form minute styles, especially on lingual side of teeth. The posterior cingulum is absent. There are three distinct roots with no indication of accessory rootlets.

M^2: Occlusal outline is oval, with nearly straight anterior and labial margins and a relatively narrow, rounded posterior margin. Cusps and lophs are similar to those of M^1, except that the anterocone is absent, and a long and high labial anterior cingulum is present. The labial anterior cingulum joins the anterolabial base of the paracone, enclosing the paraflexus. The lingual anterior cingulum is low, short, and indistinct.
The metaflexus and hypoflexus are relatively wide valleys and are closed by well developed (but less than in $M^1$) cingular ridges, except for one specimen (UALP 14231) in which the hypoflexus is nearly open. Three roots are present.

$M^3$: Occlusal outline is a rounded triangle. Three cusps (protocone, paracone, and hypocone) are prominent. The labial anterior cingulum extends from the protocone to the anterolabial base of the paracone. The narrow valley posterior to the paracone ("metaflexus") extends about half way across the tooth; it is slightly closed by a low cingulum in two specimens or is completely closed by well developed cingular ridge in one specimen (UALP 14300), forming a central basin. Three distinct roots are present.

$M_1$: Occlusal outline is an elongate oval, with a narrow, rounded anterior margin and a relatively straight, wide posterior margin. The anteroconid is relatively wide, slightly bilobed (3 of 9 specimens) or indistinctly bilobed (6 of 9 specimens). The anterolingual conulid of the bilobed anteroconid is larger, higher, and located slightly anterior in relation to the labial conulid; the anteromedian flexid is very shallow. The protoconid, metaconid, hypoconid, and entoconid have straight, nearly vertical anterior sides, and slightly sloping posterior sides. A very short anterior murid joins the anteroconid and the short anterior arm of the protoconid near the midline of the tooth. The metalophid and entolophid are short, joining respectively the anterior arm and relatively long posterior arm of the protoconid. The posterior arm of the hypoconid
is expanded near the midline of the tooth, forming a small cuspule (posteroconulid) slightly lingual to the midline; when worn, however, the posteroconulid disappears, and a thick normal posterior cingulum is formed. The metaflexid is very shallow and narrow, except for one specimen (UALP 14244) which has a relatively deep metaflexid; other flexids are deep and wide. The protoflexid and hypoflexid are wider than lingual flexids and partially closed by well developed cingular ridges; the cingular ridge at the hypoflexid develops a small ectostylid in some specimens. The entoflexid is open in 8 of 10 specimens, slightly closed by a low cingulum in 2 specimens, and the posteroflexid is partially closed by the posterior cingulum in 5 of 10 specimens. Two distinct roots are present.

\( M_2 \): Occlusal outline is a rounded subrectangle, longer than wide. Cusps and lophs are as in \( M_1 \), except the anteroconid is absent. The distinct anterior cingulum extends labially from the junction of the anterior arm of the protoconid with the metalophid; it joins the anterolingual base of the protoconid, closing the narrow but deep protoflexid. The posteroconulid and posterior cingulum are as in \( M_1 \), though the latter is slightly shorter in some specimens, which causes the posteroflexid to be open posterolingually. The hypoflexid is partially closed by a well developed cingular ridge, whereas the entoflexid is open in most specimens. Two roots are present.

\( M_3 \): Occlusal outline is oval to rounded triangular, narrowing posteriorly with relatively straight anterior and broadly rounded posterior margins. The protoconid, metaconid, and hypoconid are
distinct, and the entoconid is absent. A thin anterior cingulum is present anterior to the protoconid, but is closer to the latter than in M₂. The hypoflexid is deep, partially closed by a cingular ridge, and extends perpendicular to the tooth axis more than half way across the tooth, whereas the "entoflexid" is shallow, directing slightly posterolabially, and disappears after moderate wear. Two roots are present.

**COMPARISONS:** *Baiomys minimus* differs from *B. kolbi* and *B. cf. brachygnathus* described below in its smaller size and relatively brachydont cheek teeth. *B. minimus* is also smaller than *B. intermedius* and *B. musculus*. *B. minimus* is similar in size to *B. rexroadi*, *B. brachygnathus*, and *B. taylori*, but differs from them in having relatively brachydont cheek teeth with well developed cingular ridges and styles/stylids. *B. aquilonius* is slightly smaller than *B. minimus* and differs from the latter in having M₁ with an anteromedian stylid and expanded anteroconid, and greatly reduced M₃. *B. minimus* is similar to *B. sawrockensis* in size and brachydonty, but differs from it in having M₁ larger relative to the size of other molars with better developed cingular ridges.

UALP 14240 is slightly larger in size and has very narrow metaflexid compared to other M₁ specimens. It may represent a similar but different taxon. But, until other similar specimens are found and are distinguished from the rest of the specimens, UALP 14240 is considered here to be *B. minimus*. 
DISCUSSION: *Baiomys minimus* is one of the most poorly known species of the genus; it is originally known only by the holotype. The holotype (USNM 10500) possesses an $M_1$ with bilobed anteroconid with anteromedian flexid. Two of three specimens (UALP 14236, 14243) that possess bilobed anteroconid are similar to the holotype, though two thirds of $M_1$ sample is single cusped. The size of individual teeth and relative size of each tooth (except for $M_3$ which is slightly larger) are both comparable to those of the holotype. Mental foramen of the holotype is located at the border of the dorsal and labial surfaces of the dentary and is similar to that of UALP 14248 which is the only specimen from UA loc. 7937 preserving the mental foramen. Although *B. minimus* is originally diagnosed as having bilobed anteroconid, I refer the specimens described here to *B. minimus*.

*Baiomys sp. cf. B. brachygnathus* (Gidley, 1922)

(Fig. 17H-I; Table 22)

REFERRED MATERIAL: UALP nos. 13950-13953, 15247-15260, $M_1$'s; 15265-15268, $M_2$'s; 13969, 13973-13974, 13982, 15272, 15275, $M_1$'s; 13990-13993, 13996, 15280, $M_2$'s; 13999-14000, 15284, $M_3$'s, from UA loc. 7933. UALP nos. 14154, 16313, $M_1$'s; 14153, right dentary with $I_1 M_1-2$; 14155-14156, $M_1$'s; 14157-14158, 16314, $M_2$'s; 14159, $M_3$, from UA loc. 8051.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA locs. 7933 and 8051 at approx. 85 m and 90 m levels, respectively, of the lll Ranch composite section, Gila Conglomerate, southern Arizona.
Table 22. Measurements of *Baiomys cf. brachygnathus*

<table>
<thead>
<tr>
<th>Location</th>
<th>Size</th>
<th>O.R.</th>
<th>Mean</th>
<th>S.D.</th>
<th>C.V.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loc. 7933</td>
<td>M1 L</td>
<td>7</td>
<td>1.42-1.50</td>
<td>1.47</td>
<td>0.030</td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>7</td>
<td>0.86-1.00</td>
<td>0.93</td>
<td>0.054</td>
</tr>
<tr>
<td></td>
<td>M2 L</td>
<td>4</td>
<td>0.98-1.02</td>
<td>0.99</td>
<td></td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>4</td>
<td>0.88-0.94</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M/1 L</td>
<td>5</td>
<td>1.18-1.30</td>
<td>1.26</td>
<td>0.047</td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>5</td>
<td>0.74-0.82</td>
<td>0.79</td>
<td>0.030</td>
</tr>
<tr>
<td></td>
<td>M/2 L</td>
<td>6</td>
<td>0.94-1.00</td>
<td>0.99</td>
<td>0.055</td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>6</td>
<td>0.76-0.86</td>
<td>0.80</td>
<td>0.034</td>
</tr>
<tr>
<td></td>
<td>M/3 L</td>
<td>3</td>
<td>0.78-0.82</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>3</td>
<td>0.66-0.68</td>
<td>0.67</td>
<td></td>
</tr>
<tr>
<td>Loc. 8051</td>
<td>M1 L</td>
<td>2</td>
<td>1.40-1.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>2</td>
<td>0.92-0.94</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M/1 L</td>
<td>2</td>
<td>1.34-1.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>2</td>
<td>0.86-0.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M/2 L</td>
<td>4</td>
<td>0.98-1.06</td>
<td>1.02</td>
<td></td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>4</td>
<td>0.82-0.84</td>
<td>0.83</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M/3 L</td>
<td>1</td>
<td>0.76</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>1</td>
<td>0.62</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
AGE: Late Blancan (latest Pliocene).

DESCRIPTION: Except for its larger size and relatively hypsodont cheek teeth, B. cf. brachygnathus is very similar to B. minimus described above. For this reason, a complete description of each tooth of B. cf. brachygnathus is not given, but instead the characters that separate B. cf. brachygnathus from B. minimus are discussed. For characters not discussed, B. cf. brachygnathus is considered morphologically identical with B. minimus.

M\textsuperscript{1}: The anterocone is unequally bilobed with the labial conule higher and larger than and is positioned posterior relative to the lingual conule. There is no loph descending anteriorly from the labial conule of the anterocone. When worn, the labial and lingual conules become nearly equal in size. The anterior arm of the protocone joins the anterocone at the posterolinguai corner of the labial conule; when worn, the junction is approximately at the midline of the anterocone. The anteromedian flexus is slightly shallower, and the transverse cingulum anterior to the anteromedian flexus is absent. The cingular ridges located at the mouths of flexi are less developed, especially in lingual ridges, and never form styles. A short posterior cingulum is discernible prior to middle wear, distinct on 3 of 8 specimens because of wear but causing a posterior expansion of the metacone after moderate wear. Three distinct roots are present; a minute tubercle is present below the paracone in one (UALP 15260) of three specimens that preserve roots.
M\(^2\): Occlusal outline is wider and shorter than in *B. minimus*, and is rather a short rectangle with relatively narrow, rounded posterior margin. The labial and lingual cusps are less alternating (more opposite) in position.

M\(_1\): The anteroconid is single cusped with the highest and most anterior projection slightly lingual to the midline of the tooth. The anteromedian flexid is absent. A short anterior murid joins the anteroconid approx. at the midline of the tooth in 6 of 8 specimens labial to the midline of the tooth in 2 specimens. The metaflexid is narrow but moderately deep, and is open. The labial flexids are partially closed as in *B. minimus*. The entoflexid is open in all 7 specimens, whereas the posteroflexid is partially closed by the posterior cingulum in 5 of 7 specimens.

M\(_2\): Occlusal outline is a rounded subrectangle as in *B. minimus*, but it is slightly longer relative to the width. The anterior cingulum is close to the protoconid. The posteroconid is slightly more posteriorly located than in *B. minimus*, and a low posterior cingulum continues and joins to the posterolingual base of the entoconid, partially closing the posteroflexid. The entoflexid is open in 4 of 6 specimens, partially closed in 2 specimens.

M\(_3\): Occlusal outline is a rather slightly elongated, rounded triangle with a relatively straight anterior and broad, rounded posterior margins. The hypoflexid and "entoflexid" are nearly opposing and with wear form a two-lophed appearance, the metaconid and protoconid forming the anterior loph, the hypoconid forming the posterior loph.
COMPARISONS AND DISCUSSION: B. cf. brachygnathus differs from B. sawrockensis, B. minimus, B. rexroadi, B. aquilonius, and B. taylori in its larger size. B. cf. brachygnathus is similar to B. musculus in size but differs in having cheek teeth relatively hypsodont. B. cf. brachygnathus is similar in overall size and relatively large size of M₃ to B. kolbi, but B. kolbi is slightly less hypsodont and has M₂ slightly shorter relative to the width.

The holotype of B. brachygnathus (USNM 10501, the only specimen known when described) is very worn and difficult to compare in detail. B. cf. brachygnathus is similar to the holotype in size and general morphology in M₁-₂. However, M₃ of the holotype is very reduced and much smaller than the M₃ described here. M₃'s of B. cf. brachygnathus are rather similar to that of B. kolbi. Harrison (1978) reported the occurrence of B. brachygnathus from the Wolf Ranch local fauna which is approx. 0.6 Ma older in age than the Curtis Ranch, the type locality of the species (Johnson et al., 1975). Although her sample does not include any M₃, a few M₁ specimens that I could examine are similar to the specimens described here, especially M₁ is nearly identical. Thus, I tentatively identified the specimens from UA locs. 7933 and 8051 described here as B. cf. brachygnathus.

Baiomys sp.
(Fig. 17G; Table 21)

REFERRED MATERIAL: UALP nos. 14117, left maxillary fragment with M₁-₃; 14118-14120, M₁'s, 14121, M₂; all from UA loc. 7914.
STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA loc. 7914, at approx. 30 m level of the Illi Ranch composite section, Gila Conglomerate, southern Arizona.

AGE: Late Blancan (latest Pliocene).

DESCRIPTION: As with B. cf. brachygnathus, a complete description of the teeth is not given, but the contrasts between Baiomys sp. and the two previously described species are discussed. Baiomys sp. is slightly smaller than B. minimus; its teeth are about as long as those of the latter but are narrower. Cheek teeth are relatively hypsodont for the genus. Cusp morphology is more similar to B. cf. brachygnathus than B. minimus.

M^1: The anterocone is slightly unequally bilobed with the labial conule slightly larger and positioned posterior relative to the lingual conule, as in B. cf. brachygnathus. The anterior arm of the protocone joins the anterocone at about the midline of the two conules. The anteromedian flexus is relatively shallow with no cingulum anterior to it. The cingular ridges at the labial flexi are relatively well developed (with no styles), but the lingual cingular ridges are barely developed. A very short posterior cingulum is present on slightly worn specimens. There is no indication of extra roots.

M^2: Occlusal outline is ovate with a relatively straight anterior and labial margin; relatively longer than B. minimus, with narrow, rounded posterior margin. A short, indistinct posterior cingulum is present on two slightly worn specimens.
M<sup>3</sup>: This tooth is represented by a single specimen. Occlusal outline is a rounded triangle as in B. minimus, but is relatively longer. The paracone, protocone, and hypocone are present and join to enclose a central basin. An anterior cingulum joins the paracone higher than in B. minimus, forming a shallow, narrow basin anterior to the paracone.

COMPARISONS AND DISCUSSION: Baiomys sp. described here is represented only by the upper teeth, but it differs from B. kolbi, B. brachygnathus, and B. musculus in its much smaller size. In size B. sp. is similar to species other than above three species, but it differs from B. minimus described above in having relatively hypsodont and narrow cheek teeth; similarly it differs from B. sawrockensis. The rest of the species (B. rexroadi, B. aquilonius, and B. taylori) are similar to B. sp. in size and relative hypsodonty, but the specific identification of the Baiomys material described here is difficult without lower cheek teeth.

Reithrodontomys Giglioli, 1894

Reithrodontomys rexroadensis Hibbard, 1952

(Fig. 17J-L; Table 23)

REFERRED MATERIAL: UALP nos. 14213, 14253-14254, M<sup>1</sup>'s; 14256, maxillary fragment with M<sup>2-3</sup>; 14234, 14257-14259, M<sup>2</sup>'s; 14260, dentary fragment with M<sub>1-3</sub>; 14261, 14287, M<sub>1</sub>'s; 14251, dentary fragment with M<sub>2</sub>; 14264, M<sub>3</sub>, from UA loc. 7937. UALP nos. 16003, I<sup>1</sup> fragment; 1043, dentary fragment with I<sub>1</sub>M<sub>1-3</sub>, from UA loc. 15-24.
Table 23. Measurements of Reithrodontomys species

<table>
<thead>
<tr>
<th>N.</th>
<th>O.R. Mean</th>
<th>S.D.</th>
<th>C.V.</th>
</tr>
</thead>
</table>
| **Reithrodontomys galushai n. sp.**
Loc. 7933 | | | |
M1/ L 6 | 1.26-1.50 | 1.37 | 0.120 | 8.76 |
W 7 | 0.82-0.90 | 0.85 | 0.025 | 2.94 |
M2/ L 6 | 0.92-1.02 | 0.96 | 0.043 | 4.48 |
W 4 | 0.80-0.82 | 0.81 | | |
M/1 L 8 | 1.28-1.44 | 1.36 | 0.045 | 3.31 |
W 8 | 0.74-0.86 | 0.83 | 0.037 | 4.46 |
M/2 L 6 | 0.96-1.06 | 1.03 | 0.037 | 3.59 |
W 7 | 0.78-0.84 | 0.81 | 0.022 | 2.72 |
M/3 L 1 | 0.80 | | | |
W 1 | 0.70 | | | |
| **Reithrodontomys rexroadensis**
Loc. 7937 | | | |
M1/ L 2 | 1.36-1.44 | 1.40 | | |
W 3 | 0.88-0.90 | 0.89 | | |
M2/ L 5 | 0.92-1.04 | 0.98 | 0.052 | 5.31 |
W 5 | 0.82-0.90 | 0.85 | 0.030 | 3.53 |
M3/ L 1 | 0.56 | | | |
W 1 | 0.58 | | | |
M/1 L 3 | 1.28-1.30 | 1.29 | | |
W 3 | 0.82-0.84 | 0.83 | | |
M/2 L 2 | 1.00-1.02 | 1.01 | | |
W 2 | 0.84 | | | |
M/3 L 2 | 0.72-0.80 | 0.76 | | |
W 2 | 0.64-0.70 | 0.67 | | |
M/1-3 L 1 | 3.08 | | | |
Loc. 15-24
M1 L 1 | 1.26 | | | |
W 1 | 0.86 | | | |
M2 L 1 | 0.98 | | | |
W 1 | 0.86 | | | |
M3 L 1 | 0.78 | | | |
W 1 | 0.68 | | | |
M/1-3 L 1 | 3.16 | | | |
STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA loc. 7937 at about 10 m level of the Duncan section, and UA loc. 15-24 at about 40 m level of the Illi Ranch composite section, Gila Conglomerate, southern Arizona; Fox Canyon local fauna, Rexroad Rm., Kansas.

AGE: Blancan (late Pliocene).

DESCRIPTION: Relatively small in size for the genus. Dentary is rather deep with a deep diastemal region. The mental foramen is high on the labial side, near the border of the dorsal surface at diastema. Masseteric crest is well developed; anterior margin is labial to the anterior root of M₁, and higher relative to the mental foramen. I₁ is deeply notched, rather than a deep groove, and it looks like two steps of a stairway in cross section. Cheek teeth are relatively slender with the labial cusps of the upper molars and the lingual cusps of lower molars slightly compressed anteroposteriorly.

M₁: Occlusal outline is an oval. The anterocone is wide and lingually elongated, single cusped with a rounded labial margin and a narrow, pointed lingual margin. The protocone and hypocone have a longer anterior arm directed anterolabially and a short posterior arm directed nearly labially. The paracone and metacone are slightly laterally elongated, located slightly posterior relative to the lingual cusps, and join respectively the posterior arms of the protocone and hypocone. Posterior cingulum is absent. The protoflexus and hypoflexus are partially closed by a very low anterior cingulum and a lingual cingulum, respectively; labial flexi are open in 2 of 4 specimens. A short, incipient mesoloph is present in 2 of 4 specimens. There are
three distinct roots plus a small bump below the paracone in specimens with roots preserved.

**M₂**: Occlusal outline is shortened oval with broad, nearly straight anterior labial margins and a narrow, rounded posterior margin. Cusps and lophs are similar to those of M₁ except that the anterocone is absent. A thick labial anterior cingulum joins the anterior arm of the protocone, and continues to the anterolabial base of the paracone where it expands as a parastyle in 4 of 5 specimens, partially closing the paraflexus. Mesoloph is absent in 4 of 5 specimens; a very short, incipient mesoloph is represented by UALP 14258. The metaflexus is slightly closed. The hypoflexus is partially closed by a moderately or poorly developed cingulum in all five specimens. Three distinct roots are present with no indication of an accessory rootlet.

**M₃**: Represented by a single specimen (UALP 14256). Occlusal outline is a rounded triangle with a widely rounded posterior margin. Occlusal enamel pattern is transitional between E-shaped and C-shaped pattern (Hooper, 1952, p. 28): the paraflexus is shallow but long, and extends about halfway across the tooth; the paracone joins the protocone centrally and a short hypoflexus is present.

**M₁**: Occlusal outline is an oval with a pointed anterior margin and nearly straight posterior margin. The anteroconid is laterally elongate, single cusped with rounded lingual and pointed labial margins; apex of the anteroconid is lingual to the midline of the tooth. A short anterior murid joins anteroconid with the anterior arm of the protoconid and the metalophid slightly labial to the midline of the tooth. The
metaconid and entoconid are transversely elongated, less rounded. The labial cusps are slightly posterior relative to the lingual cusps, with longer posterior arms. The posterior arm of the hypoconid is continuous with the posterior cingulum that extends from the midline of the tooth to the posterolingual base of the entoconid, partially closing the posteroflexid. The metaflexid is narrow and shallow; the entoflexid is open. The hypoflexid is partially closed by a small ectostylid or moderately developed cingulum in all specimens, though it is broken in UALP 14260 (Fig. 17L). There are two distinct roots with no indication of accessory rootlets.

M2: Occlusal outline is a rounded rectangle with a widely rounded posterior margin. The cusps and lophs are similar to M1 except that the antercone is absent and an anterior cingulum is present anterior to the protoconid. Posterior cingulum is slightly shorter and directed slightly more posteriorly than in M1. Entoflexid is open, and hypoflexid is partially closed by a low cingulum as in M1. Two distinct roots are present.

M3: Occlusal outline is a rounded triangle, and the enamel wear pattern is S-shaped (Hooper, 1952, p. 29). The metaconid, protoconid, and hypoconid are distinct, and about equal in size. The entoconid is indistinct and forms a continuous, sinuous loph from the protoconid to the hypoconid. The anterior cingulum extends labially from the junction of the anterior arm of the protoconid and metaconid at the midline of the tooth, and encloses a narrow, deep protoflexid. Posterior cingulum is absent. "Entoflexid" is shallower than the
hypoflexid but extends anterolabially and reaches the protoconid-metaconid junction. Hypoflexid is deep and extends perpendicular to the tooth axis more than half way across the tooth. A minute ectostylid is present in UALP 1043 and 14264. Two distinct roots are present.

COMPARISONS: With the weakly developed mesoloph on M$^{1-2}$ and relatively simple M$^{2/3}$, *R. rexroadensis* obviously belongs to the subgenus *R.* (Reithrodontomyss). Although Hibbard (1952) did not assign *R. rexroadensis* to any species group, M$^3$ with transitional pattern between C-shaped and E-shaped, M$_3$ with a typical S-shaped pattern, and M$_1^3$ with relatively simple anterocone/anteroconid indicate that *R. rexroadensis* is transitional between *R. megalotis* species group and *R. fulvescens* species group.

*R. rexroadensis* described here differs from *R. wetmorei* in its slightly smaller size, in having the molars narrower relative to the length, and the metaconid and entoconid of M$_{1-2}$ less rounded. *R. rexroadensis* differs from *R. moorei* in slightly larger size and in having an S-shaped M$_3$. *R. rexroadensis* differs from the new species described below in having molars slightly wider, M$_1$ with anteroconid narrower and single cusped, M$_1^1$ with less developed extra root, and the labial cusps of M$_{1-2}$ and lingual cusps of M$_{1-2}$ with an anteroposteriorly compressed appearance rather than rounded, conical appearance.

*R. rexroadensis* differs from *R. fulvescens* and *R. hirsutus* in having reduced M$^3$ (transitional between E-shaped and C-shaped pattern), simpler anterocone/anteroconid, and less developed mesoloph of M$^{1-2}$.  
R. rexroadensis differs from the megalotis species group in having typical S-shaped $M_3$ and $M^3$ transitional between E- and C-shaped pattern.

**DISCUSSION:** Although Hibbard (1952) avoided to include any upper teeth in his R. rexroadensis with confidence, isolated upper and lower teeth can be assigned with pretty high confidence to a same species by the similarity in size and general morphology, and proportion of upper and lower teeth found within a single locality. $M^2/2$ of Reithrodontomys and Baiomys are very similar in morphology and are difficult to separate when only mixed $M^2/2$ are found. However, with the help of the co-occurrence of other characteristic teeth (such as $M^1$ and $M_3$ in case of Reithrodontomys and Baiomys) in large number and with the size differences, most of the isolated teeth are grouped into certain number of species with high confidence.

Occurrence of this species from Duncan and Illi Ranch extends its geographic range to west of the Rocky Mts. and geologic age from the early Blancan to late Blancan.

**Reithrodontomys galushai** n. sp.

(Fig. 17M-0; Table 23)

**HOLOTYPE:** UALP no. 13975, isolated right $M_1$, from UA loco. 7933.

**TYPE LOCALITY:** UA loco. 7933, Dry Mt. East, at about 85 m level of the Illi Ranch composite section, Gila Conglomerate, southern Arizona.

**HYPODIGM:** Holotype, and UALP nos. 13954-13955, 13958-13962, 13983, $M^1$s; 13956-13957, 13997-13998, 15264, 15269, $M^2$s; 13970-13972,
13976-13978, 15273, \( M_1 \)'s; 13989, 13994-13995, 15278-15279, 15281-15282, 
\( M_2 \)'s; 15283, \( M_3 \), all from UA loc. 7933.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: Same as for the type locality.

AGE: Late Blancan (latest Pliocene).

ETYMOLOGY: In honor of late Mr. Theodore Galusha who discovered many fossil localities and extensively collected fossils for the Frick Laboratory of the American Museum of Natural History from 1937 to 1978 in the Safford and Duncan area.

DIAGNOSIS: Size is relatively small for the genus and is about that of \( R. \) rexroadensis; \( M_1 \) with the anterocone transversely elongated, single cusped and with weakly developed mesoloph; \( M_1 \) anteroconid indistinctly bilobed; \( M_3 \) with an S-shaped occlusal pattern.

DESCRIPTION: Since \( R. \) galushai is very similar to \( R. \) rexroadensis in general tooth morphology, a complete description of each tooth of \( R. \) galushai is not given, but instead characters that separate it from \( R. \) rexroadensis (and other species of the genus) are discussed. For characters not discussed, \( R. \) galushai is considered morphologically identical with \( R. \) rexroadensis.

Cheek teeth are about the same size as those of \( R. \) rexroadensis, but slightly more slender relative to the width. The labial cusps of the upper molars and lingual cusps of lower molars have a rounded appearance.

\( M_1 \): Oclusal outline is an oval, slightly more elongate than in \( R. \) rexroadensis, especially in UALP 13958. A minute posterior
cingulum is present as in UALP 13961 and 13962, but disappears after early wear. Protoflexus, hypoflexus, and paraflexus are partially closed by very low cingula in approx. 50% of the specimens, whereas the metaflexus is open. A mesoloph is absent in 4 of 6 specimens, short and indistinct in UALP 13961 and 13983. A small bump (an incipient rootlet) is present below the paracone in all 6 specimens that preserve roots.

M²: More slender in occlusal outline, and the labial and lingual cusps are less alternating than *R. rexroadensis*. A short posterior cingulum is present in two slightly worn specimens. Mesoloph is absent. The metaflexus and hypoflexus are partially closed by very low cingula.

M₁: Anterior margin is widely rounded in occlusal outline. The anteroconid is wide, relatively heavy, and distinctly (4 of 8 specimens) or indistinctly bilobed, though the anteromedian flexid is shallow. The metaconid and entoconid are more rounded, conical than in *R. rexroadensis*, and thus, entoflexid is slightly narrower. The entoconid joins the posterior arm of the protoconid anterolabially, forming a straight line between the protoconid and entoconid, rather than offset as in *R. rexroadensis*. A minute mesostylid is present in 4 of 8 specimens; in the rest the entoflexid is nearly open. Ectostylid is absent, but low labial cingulum is present in 6 of 8 specimens. Two distinct roots are present with no indication of an extra rootlet. Length and width of the holotype (UALP 13975) are 1.34 and 0.84 mm, respectively.
M₂: Cusps and lophs are similar to M₁, except that the anteroconid is absent. Entoflexid is slightly closed by the posterior cingulum in 4 of 7 specimens, and the hypoflexid is partially closed by a low labial cingulum in 6 of 7 specimens.

M₃: This tooth is represented by a single specimen (UALP 15283). Occlusal outline and general morphology is similar to *R. rexroadensis*. The metaconid is slightly smaller and the entoconid is slightly more distinct than in *R. rexroadensis*, mainly because of the presence of a shallow lingual flexid between the hypoconid and entoconid. The anterior cingulum and protoflexid are shorter and less developed, whereas the entoflexid is deep and broadly closed by a lingual cingulum, thereby forming a relatively deep anteromedial fossette with wear.

COMPARISONS: Although M₃ is not known, an S-shaped pattern of M₃ and bilobed anteroconid of M₁ suggest close similarity of *R. galushai* to the *fulvescens* species group. However, the single cusped anterocone of M₁ and the less developed mesoloph suggest that *R. galushai* may be closer to the *megalotis* species group within the *fulvescens* species group.

*R. galushai* differs from *R. wetmorei* in having slightly smaller size, narrower molars relative to the width, and M₃ with bilobed anteroconid. *R. galushai* differs from *R. rexroadensis* in having M₁ with a bilobed anteroconid and slightly narrower molars relative to the width. *R. pratincola* is smaller in size and has M₁ with triangular occlusal outline and a small, single cusped anteroconid. *R. galushai* differs
from all species of the megalotis species group including R. moorei (Hibbard, 1944; Paulson, 1961) in having M\textsubscript{3} with an S-shaped occlusal pattern, and M\textsubscript{1} with a bilobed anteroconid. R. galushai differs from R. fulvescens and R. hirsutus in having M\textsuperscript{1} with a single cusped anterocone and M\textsuperscript{1-2} with much less developed mesoloph.

**DISCUSSION:** The earliest known fossil species of the genus are R. wetmorei and R. rexroadensis both from the Fox Canyon local fauna of the early Blancan. Both species are more or less transitional between megalotis species group and fulvescens species group, as they possess a single cusped anteroconid and an S-shaped M\textsubscript{3}.

*R. pratincola* from the Borchers local fauna (Hibbard, 1941b) and White Rock local fauna (Eshelman, 1975) is very likely a member of the megalotis species group, though M\textsuperscript{3/3} are not known. R. galushai as described above is very likely a member of fulvescens species group with some characters that it shares with the megalotis species group. R. moorei from Cudahy local fauna (Hibbard, 1944; Paulson, 1961) of the late Irvingtonian is obviously a member of the megalotis species group based primarily on C-shaped pattern of M\textsuperscript{3/3}.

Thus, although the phylogenetic relationships of each species are poorly known, it may be inferred that the primitive species of Reithrodontomys (more precisely subgenus Reithrodonomys) is characterized by a single-cusped anterocone/anteroconid of M\textsuperscript{1/1}, transitional between C- and E-shaped M\textsuperscript{3}, S-shaped, less reduced M\textsubscript{3}, and M\textsuperscript{1-2} with mesoloph poorly developed or absent. By the late Blancan time, Reithrodontomys species differentiated into the megalotis and fulvescens
species groups, the latter is represented by \textit{R. galushai}. After Blancan the \textit{megalotis} species group and \textit{fulvescens} species group diversified into two directions, characterized by a more simplified and a more complicated tooth pattern, respectively.

\textit{Calomys} Waterhouse, 1837

\textit{Calomys (Bensonomyx)} Gazin, 1942

\textit{Calomys (Bensonomyx) arizonae} (Gidley, 1922)

(Fig. 11M-N; Table 24)

REFERRED MATERIAL: UALP nos. 14126, 14128-14129, M\textsuperscript{1}'s; 14130, M\textsuperscript{2}; 14131, M\textsuperscript{3} with maxillary fragment; 14127, 14132-14133, M\textsubscript{1} fragments; 14135, M\textsubscript{2} with dentary fragment; 14134, 14136, M\textsubscript{2}'s; 14137-14139, M\textsubscript{3}'s, from UA loc. 7914. UALP no. 1048, left dentary fragment with M\textsubscript{1-3}, from UA loc. 15-24.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA locs. 7914 and 15-24, at approx. 30 m and 40 m levels, respectively, of the I11 Ranch composite section, Gila Conglomerate, southern Arizona; Benson fauna (Gazin, 1942) and Wolf Ranch local fauna (Harrison, 1978), St. David Fm., southern Arizona.

AGE: Blancan (late Pliocene).

DESCRIPTION: Cheek teeth are very brachydont, with the cusps gently sloping anteriorly on the upper molars and posteriorly on the lower molars. The cusps are slightly alternating; the lingual cusps anterior to the labial cusps.
Table 24. Measurements of Calomys (Bensonomys) arizonae and ? Calomys (Bensonomys) sp.

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M¹: Occlusal outline is oval, longer than wide and narrow anteriorly. The anterocone is very broad, and is asymmetrically bilobed. Labial conule of the anterocone is higher, larger, and slightly posterior relative to the lingual conule. A small, narrow transverse cingular shelf is present below the deep anteromedian flexus. Posterior side of the major cusps is vertical whereas the anterior side slopes gently. Lingual cusps have short, slightly posterolabially oriented posterior arms and long,anterolabially oriented anterior arms. The posterior arm of the hypocone joins the metacone to form a high posterior tooth margin. The posterior cingulum is short and slopes steeply to the posterior base of the metacone. The flexi are deep and wide. The paraflexus and protoflexus are partly closed by a very small parastyle and anterior cingulum, respectively, in two of three specimens. Three distinct roots are present and a tiny tubercle is present below the paracone in one specimen (UALP 14129).

M²: This tooth is represented by a slightly corroded specimen. Occlusal outline is oval with a near-straight anterior margin. Cusps are similar to M¹ except that the anterocone is absent. Anterior arm of the protocone is short and joins the broad anterior cingulum near the midpoint of the tooth. Labial anterior cingulum is high, and lingual anterior cingulum descends to the anterior base of the protocone. Roots are not preserved.

M³: Occlusal outline is a rounded triangle. Three cusps (paracone, protocone, and hypocone) are prominent; the hypocone is displaced labially, located near the midline of the tooth. Anterior
cingulum is prominent anterior to the paracone. There appears to be a mesoloph closely appressed to the paracone. The metaflexus between the mesoloph and hypocone is deep, extending to the midline of the tooth. Three distinct roots are present.

\( M_1 \): Occlusal outline is an elongated oval, narrowing anteriorly to a rounded anterior margin. The anteroconid is relatively wide and is nearly symmetrical (in 2 of 3 specimens) or slightly asymmetrically (one specimen, UALP 1048) bilobed. The anteromedian flexid is deep and persists until late wear. Major cusps alternate in position. The anterior arm of the protoconid is directed anterolingually and joins the posteriorly directed anterolophid and short metalophid near the midline of the tooth. The posterior cingulum is directed lingually from the posterior arm of the hypoconid; it joins the posterolingual base of the entoconid as UALP 14127 or does not join as in UALP 1048. The posterior cingulum thickens slightly where it joins the hypoconid near the midline of the tooth. The anterior cingulum is directed posterolabially from the labial conulid of the anteroconid and terminates at the base of the protoconid. The metaflexid is narrower and may be shallower than other flexids. The entoflexid is wide, deep, and open lingually. The posteroflexid is wide and partially closed by the posterior cingulum. The labial flexids are wider than lingual flexids, forming a narrow flat shelf, and are partially closed by low cingula. Two distinct roots are present.
M₂: Occlusal outline is a rounded rectangle, longer than wide. Cusps and lophs are similar to M₁ except that the anteroconid is absent. The anterior cingulum extends labially from a high point where the metalophid joins the protoconid and descends to the anterolabial base of the protoconid. The posterior cingulum is expanded near the midline of the tooth forming a distinct "posteroconulid" elongated transversely, joining the hypoconid, and forming a shallow posterolabial sulcus posterior to the hypoconid. Two distinct roots are present.

M₃: Occlusal outline is a rounded triangle, narrow posteriorly. The metaconid, protoconid, and hypoconid are distinct; entoconid is small (UALP 14139) or indistinct (UALP 14137). A low, narrow anterior cingulum is present anterolabial to the protoconid. The hypo-flexid is deep, whereas the "entoflexid" is shallow and partially closed by a low cingulum. Two distinct roots are present.

COMPARISONS: Calomys (Bensonomys) arizonae is much smaller in size than C. stirtoni (Hibbard, 1953) and C. new species from Yepomera (Lindsay and Jacobs, in press). C. yazhi and C. gidleyi from the White Cone local fauna (Baskin, 1978) are smaller in size than C. arizonae. C. yazhi also differs from the latter by having a better developed posterior cingulum on M₁ and by having three-rooted M₂-₃. C. gidleyi also differs from C. arizonae by having a mesoloph on M₁. Calomys eliasi (Hibbard, 1956) and C. meadensis are similar to or slightly smaller in size than C. arizonae, and they differ from
the latter by having more rectangular $M_1$ with the wider anteroconid and narrower trigonid, in contrast to the more triangular $M_1$ of $C. arizonae$.

? *Calomys* (*Bensonomys*) sp.

(Fig. 110; Table 24)

REFERRED MATERIAL: UALP nos. 14211 maxillary fragment with $M_1^{-2}$; 14209, $M_1$; 14252, $M_2$, from UA Loc. 7937.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA loc. 7937, south of Duncan, at 10 m level of the Duncan section, Gila Conglomerate, southern Arizona.

AGE: Middle Blancan (late Pliocene).

DESCRIPTION: Cheek teeth are brachydont, low cusped.

$M_1$: Occlusal outline is an oval, longer than wide. The anterocone is broad, strongly and subequally bilobed, and sloping anteriorly. The lingual conule of the anterocone is slightly lower and smaller than the labial conule; both conules are opposite in position, not alternating. The anteromedian flexus is deep and wide. The lingual cusps are slightly anterior relative to the labial cusps. The anterior surfaces of the cusps are gently sloping. The lingual cusps have long, near-anteriorly oriented anterior arms and short, transversely oriented posterior arms. The anterior arm of the hypocone joins the "protolophule" (loph connecting protocone and paracone) near the midline of the tooth forming a near right angle junction.
A high posterior margin is as in *C. arizonae*. The posterior cingulum is short and narrow. The flexi are broad; labial and lingual flexi are nearly opposite in position. The flexi are very slightly closed by very low cingula. Three distinct roots are present; in addition, a small tubercle is present below the paracone.

**M₂**: Occlusal outline is a rounded rectangle with a rounded, slightly narrow posterior margin. Cusps and lophs are similar to *M₁* except that the anterocone is absent. The low labial anterior cingulum is relatively weak. A weak posterior cingulum is short and narrow. Three distinct roots are present.

**M₁**: Occlusal outline is an elongate oval. The anteroconid is relatively wide, and strongly, subequally bilobed. The antero-median flexid is wide and deep. A distinct anterior cingulum extends posterolabially from the labial conulid of the anteroconid. Long, posteriorly directed anterior murid joins the metalophid and the anterior arm of the protoconid at a point near the midline of the tooth. Labial cusps and lingual cusps are moderately alternate in position. The posterior cingulum is expanded and elongated transversely, forming a "posteroconulid" and a posterolabial sulcus. Flexids are wide and deep except for the posteroflexid that is shallow, and are slightly closed by very low cingula except for the metaflexid that is open. Distinct anterior and posterior roots and a small tubercle between them are present.

**M₂**: Occlusal outline is a rounded rectangle with a rounded posterior margin. Cusps and flexids are similar to *M₁* except that
the anteroconid is absent. Anterior cingulum descends labially from the high junction with the metalophid and the anterior arm of the protoconid near the midline of the tooth.

**COMPARISONS:** The specimens described here as *Calomys* (Bensonomys) sp. are similar in general morphology to *Calomys* (Bensonomys), but differ from the latter in having 1) cheek teeth slightly higher-crowned, 2) tooth cusps less alternating in position, especially in upper dention, 3) wide and more strongly bilobed anterocone and anteroconid of $M^1_1$, 4) $M^1_1$ narrower, and 5) the metaflexid of $M_1$ much wider and deeper than in *Calomys* (Bensonomys) species. They are similar in size to *S. (B.) arizonae* described above and *C. (B.) meadensis*.

*Sigmodon* Say and Ord, 1825

*Sigmodon medius* Gidley, 1922

(Fig. 18; Tables 25-29)


**REFERRED MATERIAL:** Duncan Basin area, UA loc. 8042--UALP nos. 14164, 14167, dentaries with cheek teeth. UA locs. 7934--UALP no. 14171, $M_1$. UA loc. 7937--UALP nos. 14304-14310, maxillary fragments with one or more teeth; 14311-14315, $M^1_1$s; 14302, 14316-14323, $M^2_1$s; 14324-14336, $M^3_1$s; 14337-14339, dentary fragments with more
Figure 18. Variation in tooth measurements of 4 fossil Sigmodon samples
Table 25. Measurements of *Sigmodon medius* from UA localities 7937, 15-24, and 7933

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<td>12</td>
<td>2.00-2.24</td>
<td>2.11</td>
<td>0.075</td>
<td>3.55</td>
</tr>
<tr>
<td>W</td>
<td>12</td>
<td>1.60-1.72</td>
<td>1.67</td>
<td>0.033</td>
<td>1.98</td>
</tr>
<tr>
<td>M2/L</td>
<td>14</td>
<td>1.44-1.56</td>
<td>1.52</td>
<td>0.039</td>
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<td>13</td>
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<td>1.61</td>
<td>0.062</td>
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<td>1.36-1.60</td>
<td>1.49</td>
<td>0.071</td>
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<td>1.28-1.56</td>
<td>1.48</td>
<td>0.074</td>
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<td>1.32-1.52</td>
<td>1.44</td>
<td>0.084</td>
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<td>M2/L</td>
<td>7</td>
<td>1.48-1.64</td>
<td>1.54</td>
<td>0.060</td>
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<tr>
<td>W</td>
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<td>0.083</td>
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<td>M3/L</td>
<td>10</td>
<td>1.52-1.96</td>
<td>1.82</td>
<td>0.131</td>
<td>7.20</td>
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<td>W</td>
<td>10</td>
<td>1.28-1.60</td>
<td>1.51</td>
<td>0.100</td>
<td>6.62</td>
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<tr>
<td>M/1-3L</td>
<td>2</td>
<td>5.67-5.92</td>
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| Loc. 15-24 | M1/L | 113 | 1.80-2.28 | 2.04 | 0.102 | 5.00 |
|            | W    | 121 | 1.36-1.80 | 1.59 | 0.092 | 5.79 |
|            | M2/L | 94  | 1.32-1.64 | 1.44 | 0.064 | 4.44 |
|            | W    | 96  | 1.36-1.92 | 1.58 | 0.094 | 5.95 |
|            | M3/L | 46  | 1.28-1.60 | 1.43 | 0.094 | 6.57 |
|            | W    | 45  | 1.20-1.52 | 1.37 | 0.074 | 5.40 |
|            | M1-3/L | 9  | 4.75-5.75 | 5.43 | 0.278 | 5.12 |
|            | M1/L | 121 | 1.84-2.28 | 2.03 | 0.093 | 4.58 |
|            | W    | 139 | 1.28-1.60 | 1.41 | 0.063 | 4.47 |
|            | M2/L | 149 | 1.40-1.68 | 1.55 | 0.066 | 4.26 |
|            | W    | 150 | 1.36-1.68 | 1.55 | 0.064 | 4.13 |
|            | M3/L | 92  | 1.52-2.08 | 1.79 | 0.118 | 6.59 |
|            | W    | 93  | 1.32-1.72 | 1.48 | 0.083 | 5.61 |
|            | M/1-3L | 25 | 5.31-5.94 | 5.64 | 0.176 | 2.77 |

| Loc. 7933 | M1/L | 8  | 1.92-2.16 | 2.03 | 0.088 | 4.33 |
|           | W    | 9  | 1.52-1.68 | 1.60 | 0.058 | 3.63 |
|           | M2/L | 7  | 1.36-1.52 | 1.42 | 0.051 | 3.59 |
|           | W    | 7  | 1.44-1.68 | 1.58 | 0.086 | 5.44 |
|           | M3/L | 1  | 1.40      |      |       |      |
|           | W    | 2  | 1.32-1.40 | 1.36 |       |      |
|           | M/1 L | 2  | 2.08      |      |       |      |
|           | M/2 L | 2  | 1.32-1.40 | 1.36 |       |      |
|           | W    | 1  | 1.68      |      |       |      |
|           | M/3 L | 4  | 1.76-2.00 | 1.87 |       |      |
|           | W    | 4  | 1.44-1.60 | 1.51 |       |      |
Table 26. Measurements of *Sigmodon medius* from various UA locs.

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<th>M1W</th>
<th>M2L</th>
<th>M2W</th>
<th>M3L</th>
<th>M3W</th>
<th>M1-3L</th>
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<td>Low/ 14164 L</td>
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<td>1.56</td>
<td>1.64</td>
<td>1.96</td>
<td>1.52</td>
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<tr>
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<td>1.68</td>
<td>1.60</td>
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<td>1.60</td>
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<td>1.72</td>
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<td>1.60</td>
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<td>-</td>
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<td>1.56</td>
<td>1.76</td>
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<td>15959 L</td>
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<td>15961 L</td>
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Table 27. Development of roots in *Sigmodon medius* (in %)

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<tr>
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<th>N</th>
<th>Number of Roots</th>
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<td>M₁ 7933 (Dry Mt., 111 Ranch)</td>
<td>11</td>
<td>27</td>
</tr>
<tr>
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<td>71</td>
<td>24</td>
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<tr>
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<td>9</td>
<td>33</td>
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<tr>
<td>M₁ 7933 (Dry Mt., 111 Ranch)</td>
<td>3</td>
<td>-</td>
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<tr>
<td></td>
<td>79</td>
<td>11</td>
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<td>3</td>
<td>33</td>
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Table 28. Development of anterior cingulum in *Sigmodon medius* (in %)

<table>
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<th>Locality</th>
<th>N</th>
<th>None</th>
<th>Weakly developed</th>
<th>Well developed</th>
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<tr>
<td>M₂ 7933 (Dry Mt.)</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>100</td>
</tr>
<tr>
<td>15-24 (111 Ranch)</td>
<td>146</td>
<td>-</td>
<td>8</td>
<td>92</td>
</tr>
<tr>
<td>7937 (Duncan)</td>
<td>7</td>
<td>-</td>
<td>-</td>
<td>100</td>
</tr>
<tr>
<td>M₂ 7933 (Dry Mt.)</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>100</td>
</tr>
<tr>
<td>15-24 (111 Ranch)</td>
<td>82</td>
<td>1</td>
<td>7</td>
<td>92</td>
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<tr>
<td>7937 (Duncan)</td>
<td>9</td>
<td>-</td>
<td>-</td>
<td>100</td>
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Table 29. Statistical comparisons of three samples of *Sigmodon medius* and *S. minor* using student's t-test

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<tr>
<th></th>
<th>vs. 15-24</th>
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<th>vs. 7933</th>
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<th>vs. 25-3</th>
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<td>P</td>
<td>t df</td>
<td>P</td>
<td>t df</td>
<td>P</td>
</tr>
<tr>
<td>7937 M1/ L</td>
<td>2.96 124</td>
<td>&lt;0.01</td>
<td>2.11 19</td>
<td>&lt;0.05</td>
<td>3.96 19</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>W 6.31 132</td>
<td>&lt;0.001</td>
<td>3.25 20</td>
<td>0.01</td>
<td>8.36 19</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>M2/ L</td>
<td>6.48 107</td>
<td>&lt;0.001</td>
<td>4.56 20</td>
<td>&lt;0.001</td>
<td>6.90 19</td>
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<tr>
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<td>W 1.51 108</td>
<td>N.S.</td>
<td>0.82 19</td>
<td>N.S.</td>
<td>4.15 18</td>
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</tr>
<tr>
<td>M3/ L</td>
<td>2.55 59</td>
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<td>W 4.86 58</td>
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<tr>
<td>M/1 L</td>
<td>2.27 126</td>
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<td>N.S.</td>
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<tr>
<td>15-24 M1/ L</td>
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<td>N.S.</td>
<td>2.15 120</td>
<td>&lt;0.05</td>
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<tr>
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<tr>
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<td>4.43 99</td>
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<td>W 0 102</td>
<td>N.S.</td>
<td>3.65 101</td>
<td>&lt;0.001</td>
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<tr>
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<td>N.S.</td>
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<tr>
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<td>N.S.</td>
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<td>&lt;0.05</td>
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than one tooth; 14340-14342, M₁'s; 14343-14346, M₂'s; 14347-14355, M₃'s.

111 Ranch area, UA loc. 15-0--UALP nos. 5751, 16322-16323, M¹'s; 16324, M₁; 16325-16327, M₂'s. UA loc. 15-3--UALP no. 5742, dentary fragment with M₁-3. UA loc. 15-10--UALP no. 5742, dentary fragment with M₁-3. UA loc. 15-10--UALP nos. 5738, maxillary fragment with M₁-2; 15957-15961, dentary fragments with one or more teeth. UA loc. 15-17--UALP no. 5737, dentary fragment with M₃. UA loc. 7914--UALP nos. 14140-14143, M¹'s; 14144-14147, M²'s; 14148-14150, M₂'s; 14151-14152, M₃'s. UA loc. 8051--UALP no. 14160, fragment of M². UA loc. 15-24--UALP nos. 889, 899, 936, partial skulls; 945, 959, 978, 987-993, 995-997, 999-1003, 1019-1020, 1030, 1038, 1041, 1057, 1064, 1067, 1078, 1081, 1094, 1096, 1105, 1114, 2505-2510, 2515, 2983, maxillary fragments with one or more teeth; 2705, 2741, 2763-2834, 2977-2980, 16059, 16209, M¹'s; 2900-2901, 2903-2920, 2922-2924, 2926-2939, 2954-2955, 16186-16208, M²'s; 2877-2899, 2902, 2921, 2925, 2940, 2976, M₃'s; 905, 910, 913-914, 916, 922, 924-925, 927-935, 938-941, 946-948, 966-977, 979-986, 994, 998, 1007, 1017-1018, 1023-1025, 1036-1037, 1039-1040, 1042, 1056, 1059-1063, 1068-1069, 1075, 1077, 1079, 1089-1090, 1100, 1104, 1113, 1118, 2494-2504, 2513-2514, 2519, 2991, 3006, dentary fragments with one or more teeth; 2700-2704, 2706-2741, 2743-2753, 2755-2761, 2981-2982, 3030-3053, 16060, 16210, M₁'s; 2941-2953, 2956-2972, 2974, 2984-2990, 2992-3005, 3007-3029, 16061, M₂'s; 2835-2875, 2973, 2975, 16062, M₃'s.
STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA loc. 8042 at about 12 m level of the Country Club section, UA loc. 7934 and 7937 at 0 m and 10 m levels, respectively, of the Duncan section, and several horizons from 25-90 m level of the III Ranch composite section, Gila Conglomerate southern Arizona; several faunas in the San Pedro Valley, St. David Fm., southern Arizona; the Rexroad, Benders, Sanders, and White Rock faunas, Kansas; Sand Draw fauna, Nebraska; Beck Ranch and Blanco faunas, Texas; Layer Cake and Arroyo Seco faunas, California; Haile XV-A fauna, Florida.

AGE: Blancan (late Pliocene).

DESCRIPTIONS: Relatively small cotton rat with low-crowned cheek teeth. Cusps of cheek teeth are anteroposteriorly compressed and lophate; cusps of upper teeth slope slightly anteriorly, whereas cusps of lower teeth slope slightly posteriorly. Cusps and lophs are relatively inflated almost robust, and correspondingly the flexa and flexids are relatively deep and narrow.

M1: Occlusal outline is a short oval with broadly rounded anterior margin. Anterocone is single-cusped, laterally elongated, and subsymmetrical; anterior arm of the protocone joins the anterocone near the midpoint of its width. The paracone and the anterior arm of the Hypocone form a nearly straight loph that is oblique to the tooth axis, and the posterior arm of the protocone joins this loph at nearly the midpoint of its length. The paracone is slightly posterior relative to the protocone, whereas the metacone and hypocone are opposed in position. Lingual flexi are relatively straight and extend about halfway across the tooth, whereas the labial flexi are
longer, extend more than halfway across the tooth, and are flexed posteriorly medially. About one-fourth of the specimens have three roots, about half have an extra "bump"-like tubercle, and one-fourth have small rootlet (Table 27).

**M²:** Occlusal outline is sub-quadrate with rounded corners. Cusps and lophs are similar to M¹ except that the anterocone is absent and a long labial anterior cingulum joins the protocone at the midline of the tooth. Three roots are present; the lingual root is stout and anteroposteriorly elongated. No indication of an extra rootlet is observed.

**M³:** Occlusal outline is a rounded trapezoid or triangle with wide anterior margin. Cusps and lophs are similar to M², except that the hypocone and metacone are much reduced and thereby the metaflexus is shorter. The protocone and labial anterior cingulum form the longest loph. Three roots are present and not much variation is observed in most specimens, except for the sample from the UA loco. 7937 in Duncan. In 12 Duncan specimens, a small medial rootlet is usually developed posterior to the anterolabial root that may be fused with the anterolabial root (in 3 specimens, e.g., UALP 14325), and complete fusion of the anterolinguial and posterior roots is seen in 2 specimens (e.g., UALP 14330).

**M¹:** Occlusal outline is an elongated oval, narrowing anteriorly with a broadly rounded anterior margin. The anteroconid is wide and single-lobed in most specimens, but the width varies. Also, a weakly bi-lobed anteroconid is seen in some specimens (e.g., UALP
An exceptional three-lobed anteroconid is present on UALP 2501 from loc. 15-24, in which the anterior grooves extend nearly to the base of the crown. The anterior cingulum is present in majority of the specimens, but its development varies widely; the Duncan sample shows more reduced anterior cingulum. The metaconid and entoconid are slightly anterior relative to the protoconid and hypoconid. The anterior arms of the protoconid and hypoconid are short in contrast to their posterior arms. The posterior arm of the hypoconid is continuous with the high, well-developed posterior cingulum that extends nearly to the lingual edge of the tooth. The hypoflexid is either open or slightly closed by a low labial cingulum. In the sample from the UA loc. 15-25 (Ill Ranch), 60% of the 79 specimens have two roots, whereas 29% and 11% of the sample have an extra "bump" and a small rootlet, respectively. The sample from Duncan (loc. 7937) exhibits slightly increased development of the extra bump or rootlet (Table 27).

\[ M_2 \]: Occlusal outline is sub-square with rounded corners. Cusps and lophs are similar to \( M_1 \), except that the anteroconid is absent. The protoconid joins the metaconid more anterolabially, rather than near the midline of the tooth as in \( M_1 \), and correspondingly the entoflexid extends much more deeply than in \( M_1 \). The anterior cingulum is small but distinct in most specimens. Omitting the well worn specimens, 92% of the 146 specimens from loc. 15-24 have a well developed anterior cingulum (Table 28). There are two anterior and one posterior well developed roots; the anterior roots are slightly fused
at the base in some specimens of the 111 Ranch sample and are fused at basal 1/3 to 2/3 of root length in the Duncan sample.

**M3:** Occlusal outline is suboval with wide, nearly straight anterior margin, narrowing posteriorly to the broadly rounded posterior margin. Occlusal enamel pattern is S-shaped formed by continuous union of the laterally elongated metaconid, protoconid, small entoconid, and wide hypoconid. The anterior cingulum is less developed than in M2, but is distinctive in almost 100% of the specimens; one specimen (UALP 971) is exceptional in lacking any indication of an anterior cingulum (Table 28). Two anterior and one posterior roots are present; the anterior roots are slightly fused at their bases, and the posterior root is elongated obliquely to the tooth axis, well developed and stout.

**COMPARISONS AND DISCUSSION:** Martin (1979) is the most recent review of fossil *Sigmodon*, and I follow him regarding the taxonomy. *Sigmodon medius* is distinguished from all species of *hispidus* species group and *leucotis* species group in having M1 with only two well developed roots; *S. medius* also differs from those groups in having lower crowned cheek teeth, less lophate cheek teeth, and its smaller average size.

One of the major samples that Martin (1979) studied was that of Tusker, which is UA loc. 15-24, 111 Ranch area and is included in this study. I measured all the specimens including Martin's material (Table 25). Two other relatively large samples are from UA loc. 7937 in Duncan and UA loc. 7933 at about 85 m level of the 111 Ranch.
section (Dry Mt.; about 45 m above the loc. 15-24). In addition, several specimens of *S. minor* from the Curtis Ranch that have been curated at the UALP were also measured for comparisons (Table 30). This sample of *S. minor* differs from that of Martin (1979), but the measurements are very similar, except for $M_3$ length. This is probably because his and my measurements were made from different points on the tooth. Figure 18 shows the size change of these samples with variations through time; the vertical axis is scaled to the MPTS as in Figure 10, and data points are limited to those that include $N = 5$ or more in Tables 25 and 30 (except for $M_1$ length of *S. minor* which includes 4 specimens). Table 29 shows comparisons of these measurements using the student's "t"-test. Figure 18 suggests a general trend to reduce the size gradually through time, but the student's "t"-test indicates that three samples of *S. medius* (UA locs. 7937, 15-24, and 7933) are more closely related to each other than the *S. minor* sample from the Curtis Ranch, although there are two measurements that are not significantly different between *S. medius* and *S. minor* (N.S. for Table 29). When the data that are based on less than five specimens are added on Figure 18, the results illustrates many zig-zag patterns and does not show any trend. It rather seems that the size had not changed significantly from 7937 sample (Duncan) to 7933 sample (Dry Mt., 111 Ranch), whereas the Curtis Ranch sample (*S. minor*) is statistically smaller than other samples in most measurements (Table 29).
Table 30. Measurements of *Sigmodon minor* from UA loc. 25-3, Curtis Ranch, San Pedro Valley, Arizona

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>O.R.</th>
<th>Mean</th>
<th>S.D.</th>
<th>C.V.</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1/ L</td>
<td>8</td>
<td>1.88-2.04</td>
<td>1.99</td>
<td>0.060</td>
<td>3.02</td>
</tr>
<tr>
<td>W</td>
<td>8</td>
<td>1.48-1.60</td>
<td>1.52</td>
<td>0.043</td>
<td>2.83</td>
</tr>
<tr>
<td>M2/ L</td>
<td>6</td>
<td>1.20-1.40</td>
<td>1.31</td>
<td>0.070</td>
<td>5.34</td>
</tr>
<tr>
<td>W</td>
<td>6</td>
<td>1.28-1.52</td>
<td>1.44</td>
<td>0.091</td>
<td>6.32</td>
</tr>
<tr>
<td>M3/ L</td>
<td>2</td>
<td>1.24-1.36</td>
<td>1.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>2</td>
<td>1.28-1.40</td>
<td>1.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M1-3/ L</td>
<td>1</td>
<td>5.42</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M/1 L</td>
<td>4</td>
<td>1.88-2.12</td>
<td>1.99</td>
<td>0.100</td>
<td>5.03</td>
</tr>
<tr>
<td>W</td>
<td>5</td>
<td>1.28-1.36</td>
<td>1.32</td>
<td>0.040</td>
<td>3.03</td>
</tr>
<tr>
<td>M/2 L</td>
<td>5</td>
<td>1.24-1.44</td>
<td>1.34</td>
<td>0.092</td>
<td>6.72</td>
</tr>
<tr>
<td>W</td>
<td>6</td>
<td>1.32-1.52</td>
<td>1.44</td>
<td>0.080</td>
<td>5.56</td>
</tr>
<tr>
<td>M/3 L</td>
<td>3</td>
<td>1.56-1.68</td>
<td>1.63</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>3</td>
<td>1.28-1.44</td>
<td>1.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M/1-3 L</td>
<td>3</td>
<td>5.08-5.50</td>
<td>5.36</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
S. medius and S. minor were once thought a single species with wide variation (Cantwell, 1969; Harrison, 1978). However, Martin (1979) treated them as two different end species of a single lineage suspecting that new material from Arizona would provide more samples intermediate to Tusker (UA loc. 15-24, Ill Ranch) and Curtis Ranch. The sample from UA loc. 7933 is chronologically intermediate between loc. 15-24 and Curtis Ranch. The measurements from this sample do not show significant change of size, although they do not refute Martin's conclusion. Overall, the data from the samples included in this study support Martin's conclusion.

The anterior two roots of M₂ and M₃ are apparently formed by bifurcation of a single anterior root. Anterior roots of M₃ are almost completely bifurcated in all samples studied. Those of M₂ are partly fused in their bases in the Duncan sample, whereas they are more completely bifurcated in other chronologically younger samples (e.g., loc. 15-24 and loc. 7933 samples). Although Prosigmodon may not be directly ancestral to the genus Sigmodon, the anterior root of M₃ in Prosigmodon n. sp. from Chihuahua (late Hemphillian to early Blancan age) is slightly bifurcated distally, whereas the anterior root of M₂ is complete (e.g., unbifurcated) (Lindsay and Jacobs, in press). Although the S. medius species group may not be directly ancestral to the S. leucotis species group, the better developed accessory rootlet of M₁ appears first in the S. leucotis species group, and the accessory rootlet had always been very poorly developed or absent in S. medius and S. minor. Thus, it is very likely
that the development of extra roots in lower molars of *Sigmodon*
started from the posterior tooth, migrating anteriorly, and $M_1$ de­
veloped two well developed accessory roots in the *S. hispidus* species
group later than in other groups of *Sigmodon*.

**Neotoma** Say and Ord, 1825

**Neotoma (Paraneotoma)** Hibbard, 1967

DISCUSSION: The subgenus *Paraneotoma* was erected by Hibbard
(1967) to include those species, of the genus **Neotoma**, that share the
following characters: shorter crowned cheek teeth with thicker enam­
el; upper molars with better developed roots, of which the posterior
two are not fused; and $M_3$ with distinctive S-shaped occlusal pattern.
Hibbard (1967) assigned three species to this subgenus: *sawrockensis*,
*quadriplicatus*, and *taylori*.

The species of subgenus *Paraneotoma* also share the following
characters: in occlusal view the labial flexi extend posterolingually
with the tips bent further posteriorly whereas the hypoflexus is
nearly perpendicular to the long axis of the tooth in upper $M^{1-2}$;
similarly the lingual flexids extend anterolabially whereas the hypo­
flexid is nearly perpendicular to the long axis of the tooth in $M_{1-2}$;
the labial and lingual flexi or flexids alternate in position, es­
pecially in lower molars.

**Neotoma fossilis** was described by Gidley (1922) from the
Benson fauna based on three teeth ($M^1$, $M_{1-2}$) and an edentulous jaw.
It has been one of the most poorly known species of the genus, and has tentatively been assigned to the subgenus *Neotoma* with poor rationale (Kurten and Anderson, 1980). Its reliable subgeneric assignment is difficult without M₃.

The *Neotoma* specimens from Duncan (UA loc. 7937) referred to *N. fossilis*, as described below, include two M₃'s. Both teeth have an S-shaped occlusal pattern, though not literally typical S-shape throughout the life, and with other characters shared *N. fossilis* is referable to the subgenus *Paraneotoma*. Thus, the faunas studied and dealt with in the present paper included three species of *Neotoma*, and all of them are classified in the subgenus *Paraneotoma*.

The subgenus *Paraneotoma* is distinguished from the subgenus *Parahodomys* by having the molar flexi and flexids oblique to the long axis and M₃ without the posteroflexid; from the subgenus *Hodomys* by having comparatively lower molars with thick enamel and M₃ with shallower striids (Hibbard, 1967); and from all other subgenera by having M₃ with S-shaped occlusal pattern.

*Neotoma (Paraneotoma) fossilis* Gidley, 1922

(Figs. 19A-H, 20; Table 31)

REFERRED MATERIAL: UALP nos. 14536, maxillary fragment with M¹-²; 14357-14358, M¹'s; 14359-14360, 14363, M²'s; 14361-14362, 14364, M³'s; 14365-14370, M₁'s; 14371, M₂; 14372-14373, M₃'s, all from UA loc. 7937.
Figure 19. Occlusal patterns and side views of the cheek teeth of Neotoma (Paraneotoma) species.

A-H: Neotoma fossilis.
A-B, UALP 14357, right M$_1$; C-D, UALP 14358, right M$_1$; E-F, UALP 14368, right M$_1$; G-H, UALP 14372, right M$_3$.

I-J: Neotoma quadriplicatus, UALP 14168, left M$_2$-3.

K-AA: Neotoma taylori.
K-L, UALP 4555, right M$_1$; M, UALP 4549, left M$_1$; N, UALP 16056, left M$_1$; O, UALP 1012, right M$_1$; P, UALP 4553, left M$_1$; Q-R, UALP 898, left M$_1$; S, UALP 4567, left M$_1$; T, UALP 4576, right M$_1$; U, UALP 1033, left M$_1$; V-W, UALP 16311, right M$_3$; X, UALP 14111, right M$_3$; Y, UALP 4642, left M$_3$; Z, UALP 4639, left M$_3$; AA, UALP 4649, left M$_3$. 
Figure 19. Occlusal patterns and side views of the cheek teeth of Neotoma (Paraneotoma) species
Table 31. Measurements of *Neotoma fossilis*

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>O.R.</th>
<th>Mean</th>
<th>S.D.</th>
<th>C.V.</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1/</td>
<td>L</td>
<td>3</td>
<td>3.04-3.16</td>
<td>3.11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>3</td>
<td>2.20-2.28</td>
<td>2.24</td>
<td></td>
</tr>
<tr>
<td>M2/</td>
<td>L</td>
<td>4</td>
<td>2.24-2.56</td>
<td>2.44</td>
<td></td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>4</td>
<td>1.92-2.04</td>
<td>2.00</td>
<td></td>
</tr>
<tr>
<td>M3/</td>
<td>L</td>
<td>2</td>
<td>1.68-1.88</td>
<td>1.74</td>
<td></td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>2</td>
<td>1.64-1.68</td>
<td>1.66</td>
<td></td>
</tr>
<tr>
<td>M/1</td>
<td>L</td>
<td>5</td>
<td>2.64-3.04</td>
<td>2.91</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>6</td>
<td>1.76-1.92</td>
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<td>0.08</td>
</tr>
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<td>M/2</td>
<td>L</td>
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<td>2.76</td>
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<td></td>
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<tr>
<td></td>
<td>W</td>
<td>1</td>
<td>2.00</td>
<td></td>
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</tr>
<tr>
<td>M/3</td>
<td>L</td>
<td>2</td>
<td>2.12-2.16</td>
<td>2.14</td>
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<td></td>
<td>W</td>
<td>2</td>
<td>1.52-1.60</td>
<td>1.56</td>
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</table>
STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA loc. 7937, at approx. 10 m level of the Duncan section, Gila Conglomerate, and the Benson fauna, St. David Formation, both in southern Arizona; and possibly Beck Ranch local fauna, Texas (see discussion section below).

AGE: Middle Blancan (late Pliocene).

DESCRIPTION: *Neotoma fossilis* from Duncan is represented by isolated teeth except for one fragmentary left maxilla with M\(^1\)\(^-2\) (UALP 14356). The posterior end of the incisive foramen is located directly lingual to the anterior edge of the anterior root of M\(^1\). The cheek teeth are relatively lower crowned with thicker enamel than within the genus *Neotoma*, and the side wall of the teeth is curved, giving the teeth a rounded appearance, rather than straight walled as seen in *N. cinerea*.

M\(^1\): Suboval, elongated anteroposteriorly in occlusal outline with five major cusps. The anterocone is slightly bilobed, and the anteromedian stria is very shallow. The protoflexus that separates the protocone from the anterocone is broad, and the protostria is shallow and disappears in late wear. The anterior arm of the protocone becomes confluent with the anterocone after early wear, forming an anterior loph that is oblique to the long axis of the tooth. The posterior arm of the protocone is constricted at the point where it joins the posterior arm of the paracone. The paracone is located slightly posterior relative to the protocone. The posterior arm of the paracone and the anterior arm of the hypocone become broadly confluent after slight wear, forming the middle loph that is nearly
parallel to the anterior loph. The hypocone is slightly larger than
the protocone, whereas the metacone is similar to the paracone both
in size and in occlusal shape. The posterior arm of the hypocone
joins the metacone near the longitudinal axis after early wear.

The paraflexus and metaflexus are directed posterolingually
and their tips are flexed more posteriorly. The hypoflexus (located
in between the two labial flexi) is directed perpendicular to the
long axis of the tooth. Depth of striae is deeper medially, and thus
they would form enamel lakes in very late wear.

Three roots are commonly developed, arranged anterolabial,
posterolabial, and lingual. One extremely worn specimens, UALP 14357
(Fig. 19A-B), possesses a small fourth root, approx. 0.6 mm long,
below the paracone as in M₁ of N. quadriplicatus.

M₂: Similar to M₁ but anteroposteriorly shorter. The anter-
rocone is absent. The labial anterior cingulum is broadly confluent
with the protocone. The paraflexus is nearly straight whereas the
metaflexus is flexed posteriorly as in M₁; the hypoflexus is flexed
slightly posteriorly in early wear but becomes perpendicular to the
long axis of the tooth with wear as in M₁. M₂ possesses three well
developed roots as in M₁; UALP 14363 has the anterior and lingual
roots slightly fused at their bases.

M₃: Reduced in size and is E shaped in occlusal view. Al-
though only three specimens are available, M₃ varies widely. Two
labial flexi are incised across about three-fourths of the occlusal
surface; they retreat lingually with wear; depth of their
corresponding striae varies widely. The lingual flexus is from absent (UALP 14362) to about one-third of the way across the tooth (UALP 14364). UALP 14361 and 14362 possess laterally elongated anterior and small, rounded posterior roots, whereas UALP 14364 has three distinct, nearly equal-sized roots.

$M_1$: Consists of five major cusps and a well developed posterior cingulum. The anteroconid is single cusped; the short anterior cingulum extends anterolabially from the anteroconid. The metaconid is located closely to the anteroconid and is connected anterolabially to the posterolingual side of the latter; there is a shallow basin in slightly worn teeth before the connection becomes confluent. A weak and very shallow metastriid separates these cusps in early stage of wear but disappears with moderate wear. The anterior arm of the protoconid joins the anteroconid, but these two never become widely confluent. The posterior arm of the protoconid becomes confluent with the anterior arm of the entoconid after slight wear, forming a wide loph that is oblique to the long axis of the tooth. The anterior arm of the hypoconid joins the labial side of the entoconid, but the junction is constricted throughout the life. The posterior cingulum is well developed; it extends from the hypoconid to the lingual side of the tooth but not as far as the entoconid.

The entoflexid and posteroflexid are directed anterolabially, and the tip of the former is flexed anteriorly in early wear. Both flexids extend more than halfway across the occlusal surface in early stage of wear but retreat lingually with wear. The depth of the
posterostrid is fairly constant and is slightly shallower than the entostrid. The protoflexid crosses less than one-fourth of the occlusal width of the tooth; the protostrid varies in depth, and its base is nearly the same as or as deep as about 0.6 mm above the base of the hypostrid on the labial surface. The hypoflexid crosses about one-third of the occlusal width of the tooth and is nearly perpendicular to the long axis of the tooth; it extends further lingually and becomes slightly wider anteroposteriorly with wear. M₁ possesses two, anterior and posterior, roots.

M₂: Similar to M₁ but shorter and anteroposteriorly compressed. The anteroconid is absent. The entoflexid extends further labially than in M₁ (maximum about two-thirds across the occlusal surface), whereas the posteroflexid is shallower and extends less than halfway across the occlusal width. Inversely the protoflexid is weaker and shallower whereas the hypoflexid extends further lingually than in M₁. M₂ has two roots as in M₁.

M₃: The occlusal outline is S-shaped. The metaconid is separated from the entoconid by the entoflexid, but both cusps unite at near the mouth of the flexid with moderate wear; the entoflexid becomes an obliquely elongated enamel lake (entofossettid). The shorter anterior cingulum is separated from the protoconid by a short, shallow protoflexid in UALP 14373, but the protoflexid is absent in UALP 14372; whether the absence is due to the moderate wear or is due to the absence in origin is not certain. The hypoflexid is deep and extends nearly perpendicular to the long axis of the tooth as in
The posteroflexid is absent in \( M_3 \). UALP 14373 possesses two distinct roots, but the roots of UALP 14372 are fused at their lingual bases.

**COMPARISONS:** *Neotoma fossilis* from Duncan described above is distinguished from *N. sawrockensis* by its larger size and higher crowned cheek teeth; Duncan *Neotoma* is also distinguished from *N. quadruplicatus* by its distinctly smaller size; it is distinguished from *N. taylori* by its smaller size and the lower crowned cheek teeth (Fig. 19). *Neotoma taylori* from UA loc. 7933, Dry Mt. East, described below is slightly smaller than typical *N. taylori* and is only slightly larger than Duncan species, but both species are distinguished by the degree of hypsodonty and the curvature of the side wall of the cheek teeth.

*N. fossilis* is distinguished from "*N. olseni*" from the Curtis Ranch local fauna (Lammers, 1970) by its lower crowned cheek teeth and the curvature of the side wall of the teeth. For further discussion on "*N. olseni*," see the discussion section of *N. taylori* below.

The type specimen of *Neotoma fossilis* (USNM 10524, \( M_1 \)) and USNM 10526 (\( M_{1-2} \)) are all considerably worn teeth. Both \( M_1 \) and \( M_{1-2} \) are slightly larger, but \( M_2 \) is slightly smaller than the Duncan specimens. Both \( M_1 \) and \( M_{1-2} \) lack the protoflexus and metaflexid, respectively, which I believe is due to advanced wear because both the protoflexus and metaflexid are weak and shallow as described above.
DISCUSSION: Neotoma fossilis has been one of the most poorly known species of the genus mainly due to very limited material and the lack of M₃. Duncan specimens include two M₃'s that exhibit a characteristic S pattern. This and other dental characters (thicker enamel and lower crowned teeth) place N. fossilis in the subgenus Paraneotoma as discussed above.

One M₁ (UALP 14369) is smaller than other specimens, but is considered within the size range of N. fossilis.

Dalquest (1978) reported N. (P.) cf. sawrockensis from the Beck Ranch local fauna. His material seems slightly larger than N. sawrockensis, and fits the size of N. fossilis described above. Dalquest (1978) did not mention hypsodonty of M₂ in his comparison (the type, M₁, is too worn to compare the hypsodonty). The Beck Ranch specimens appear higher crowned than N. sawrockensis based on his illustration. Thus, the Beck Ranch Neotoma material may be N. fossilis, rather than N. sawrockensis. C. A. Repenning has tentatively identified this material as N. fossilis (pers. comm., Jan. 1981).

Neotoma (Paraneotoma) quadriplicatus (Hibbard, 1941) (Fig. 19I-J)

REFERRED MATERIAL: UALP no. 14168, left dentary fragment with M₂-₃ from UA loc. 8055, Country Club.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA loc. 8055 Country Club area, at about 12 m level of the Country Club section, Gila
Conglomerate, southern Arizona; Rexroad fauna, Kansas; Beck Ranch local fauna, Texas. Tentatively known also from the Hagerman local fauna, Idaho and the White Bluffs local fauna, Washington.

AGE: Blancan (late Pliocene).

DESCRIPTION: Except for its larger size, *N. quadriplicatus* from UA loc. 8055 is very similar to *N. fossilis* described above. For this reason, a complete description of each tooth of *N. quadriplicatus* is not given, but instead the differences are discussed below.

**M2:** Length 3.07 mm and width 2.50 mm, considerably larger (L: ca. 10-20%, W: ca. 20-30%) than *N. fossilis*. The ratio of the length to width is 1.23 in UALP 14168 whereas it is 1.34 in USNM 10526 and 1.38 in UALP 14371, both *N. fossilis*. The posterostriid is shallower than UALP 14371, but is about as shallow as USNM 10526. The roots are not observable.

**M3:** Length 2.78 mm, width 2.15 mm; also considerably larger (L: ca. 30%, W: ca. 30-40%) and slightly wider than in *N. fossilis*. The occlusal enamel pattern is more S-shaped than the two specimens of *N. fossilis* described above, but the union of the metaconid and entoconid at the mouth of the entoflexid would occur with a little further wear as in *N. fossilis*. A shorter anterior cingulum is present. The roots seem heavy at least in lingual view.

COMPARISONS: *N. quadriplicatus* is distinguished from *N. fossilis* by its larger size; it is also distinguished from *N. taylori*
(as described below) by its slightly larger size and the lower crowned teeth.

DISCUSSION: UALP 14168 is the only specimen referred to *N. quadriplicatus*. It includes only M₂-₃ which include characteristic features of the subgenus *Paraneotoma* (e.g., thick enamel, relatively lower crowned cheek teeth, and M₃ with the S-shaped occlusal pattern). Direct comparison with the casts of the type (KU 4496; Hibbard, 1941a) and other toptotypic specimens (UMMP 41197) indicates that the protoconid of M₂ is slightly shallower in UALP 14168, and the anterior cingulum of M₃ present in UALP 14168 is absent in the type and UMMP 41197. Other than these features UALP 14168 is morphologically identical with the type, including the size (Fig. 19I-J).

Zakrzewski (1969) and Gustafson (1978) reported *N. (P.) cf. quadriplicatus* from the Hagerman and White Bluffs faunas, respectively. *N. quadriplicatus* reported from the Beck Ranch by Dalquest (1978) seems slightly larger than but overlap the range of toptotypic specimens (incidentally, I suspect his measurements of M₁ and M₁ have been reversed).

**Neotoma (Paraneotoma) taylori** Hibbard, 1967

(Figs. 19K-AA, 20; Table 32)

REFERRED MATERIAL: UALP nos. 908-909, 912, 1012, 1035, 1076, 1088, 16319, maxillary fragments with one or more cheek teeth; 804, 950, 4544-4563, 16056, 16297-16299, isolated M₁'s; 4580-4602, 16321,
Figure 20. Scatter diagram of length and width of $M_1^1$ and $M_{2-3}$ of *Neotoma* species.

F, *N. fossilis* from Duncan (UA loc. 7937) and Benson; Q, *N. quadriplicatus* from Rexroad; T, *N. taylori* from Borchers, with open circle indicating the type specimen; solid circle, *N. taylori* from UA loc. 15-24; open triangle, *N. taylori* from UA loc. 7933; open square, *N. taylori* from UA loc. 8051; solid triangle, *N. quadriplicatus* from UA loc 8055.
Figure 20. Scatter diagram of length and width of $M^1_{1/1}$ and $M_{2-3}$ of Neotoma species.
Table 32. Measurements of *Neotoma taylori*

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<tr>
<th>Loc. 15-24</th>
<th>N</th>
<th>O.R.</th>
<th>Mean</th>
<th>S.D.</th>
<th>C.V.</th>
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<td>3.33-4.08</td>
<td>3.66</td>
<td>0.17</td>
<td>4.64</td>
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<td>2.03</td>
<td>0.11</td>
<td>5.42</td>
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<td>1.75</td>
<td>0.13</td>
<td>7.43</td>
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<tr>
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<td>0.16</td>
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<td>6.64</td>
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<td>1</td>
<td>8.33</td>
<td></td>
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</tr>
</tbody>
</table>

| Loc. 15-10 | M2/ L | 1 | 2.83 |
| W          | 1 | 2.08 |

| Loc. 7933 | M1/ L | 8 | 3.08-3.52 | 3.34 | 0.15 | 4.49 |
| W         | 7   | 2.20-2.32 | 2.26 | 0.04 | 1.77 |
| M2/ L     | 8   | 2.40-2.68 | 2.59 | 0.10 | 3.86 |
| W         | 7   | 2.00-2.16 | 2.09 | 0.05 | 2.39 |
| M3/ L     | 12  | 1.92-2.32 | 2.07 | 0.10 | 4.83 |
| W         | 11  | 1.52-1.76 | 1.68 | 0.07 | 4.17 |
| M1/ L     | 13  | 2.96-3.48 | 3.21 | 0.12 | 3.74 |
| W         | 14  | 1.80-2.04 | 1.89 | 0.08 | 4.23 |
| M2/ L     | 12  | 2.64-2.92 | 2.80 | 0.09 | 3.21 |
| W         | 12  | 1.80-2.20 | 2.04 | 0.11 | 5.39 |
| M3/ L     | 15  | 2.04-2.76 | 2.27 | 0.18 | 7.93 |
| W         | 15  | 1.60-1.84 | 1.68 | 0.07 | 4.17 |

| Loc. 8051 | M1/ L | 1 | 3.44 |
| W         | 1 | 2.36 |
| M1/ L     | 1 | 3.24 |
| W         | 1 | 1.96 |
| M2/ L     | 1 | 2.88 |
| W         | 1 | 2.12 |
M^2's; 4622-4637, 16057, 16300-16301, M^3's; 898, 911, 1011, 1032-1033, 1080, 1088, 16320, mandibular fragments with one or more cheek teeth; M^1's; 4603-4610, 4612-4613, 4615-4621, 16307-16308, M^2's; 2876, 4639-4649, 16309-16312, M^3's, from UA loc. 15-24. UALP no. 5740, M^2 from UA loc. 15-10. UALP nos. 14040-14047, M^1's; 14048-14055, M^2's; 14056-14069, M^3's; 14002, 14070-14083, M^1's; 14084-14096, M^2's; 14097-14111, M^3's, from UA loc. 7933. UALP nos. 14161, M^1; 14162, M^1; 14163, M^2, from UA loc. 8051.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA locs. 15-24 and 15-10 at about 40 m level, 7933 at about 85 m level, and 8051 at about 90 m level of the III Ranch composite section, Gila Conglomerate, southern Arizona; Borchers local fauna, Kansas (see also discussion section below).

AGE: Late Blancan (latest Pliocene).

DESCRIPTION: As with N. quadriplicatus, a complete description of the teeth is not given, but instead the differences are discussed below. For characters not discussed, N. taylori is considered morphologically identical with N. fossilis and N. quadriplicatus. For comparison with N. quadriplicatus I examined casts of the type (KU 4496) and several maxillary and dentary fragments with teeth (KU 4502, UMMP 41197 and 41198) in addition to UALP 14168 described above.

N. taylori is larger than N. fossilis and slightly smaller than N. quadriplicatus, although the size ranges overlap (Fig. 20). The sample of N. taylori from UA loc. 15-24 is slightly larger than the sample from UA loc. 7933 except for the M^3 length which is about
the same. *N. taylori* is the most hypsodont species within the subgenus *Paraneotoma*. Because of this the side walls of the cheek teeth are straighter (or less curved) than in other species of the subgenus. Thus, the cheek teeth of *N. taylori* are less rounded (or inflated) in appearance, especially in the lower cheek teeth.

**M1:** The anterocone is relatively narrow and slightly bilobed in non- or slightly worn teeth as seen in UALP 4555, and a broad, very shallow anterior groove (anteromedian stria) persists until an advanced stage of wear. The protoflexus varies in amount of inflection from very weak to moderate, and the protostria varies in depth from well above to nearly as deep as the hypostria. M¹ is slightly longer than other species of the subgenus *Paraneotoma* in comparison with the width. A fourth root is generally absent, but a small protuberance is present underneath the paracone on some old individuals.

**M2:** The labial anterior cingulum is very heavy and broadly joins the anterior arm of the protocone near the midline of the tooth as a slight but persistent swelling. This is also true in *N. quadruplicatus*, but the swollen lingual anterior cingulum—anterior arm of protocone union is less well developed in *N. fossilis* from Duncan. An enamel projection on the paracone ("parastyle") as seen in *Repomys* is present in the same specimens that possess the distinct swollen anterior cingulum—protocone union, but disappears with slight wear. The anterior and lingual roots are fused anterolingually, forming an L-shaped root in approx. 50% of the isolated M²'s.
M\(^3\): The occlusal pattern varies widely, but the majority is an E-shape with a single lingual flexus (hypoflexus) slightly shallower than the two labial flexi. The paraflexus is inflected more across the occlusal surface than the metaflexus, and is flexed posteriorly, directed toward the hypoflexus to almost bisect the tooth. One almost unworn specimen (UALP 14057) has a very shallow posterolingual flexus and seems likely to consist of four columns, although this pattern disappears with slight wear. The roots also vary widely: from three distinct roots to a single root elongated anteroposteriorly as seen in UALP 4629; most of the specimens are two-rooted, with a large anterior and a small posterior roots.

M\(_1\): This tooth is relatively long: the length/width ratio averages 1.65-1.70 in three samples of *N. taylori*, whereas the ratio is 1.55-1.57 in *N. fossilis* and *N. quadruplicatus* (Table 32). Some specimens from UA loc. 15-24 (e.g., UALP 4576, moderately worn specimen) exhibits a well developed ectostylid (Fig. 19T); UALP 4576 also exhibits a slightly developed mesostylid. But, both of these cannot be considered diganostic of the species. The specimens from UA loc. 7933 do not exhibit these structures.

M\(_2\): *M\(_2\)* of *N. taylori* appears to have broader flexids and narrower lophs between flexids.

M\(_3\): In the specimens from UA loc. 15-24, the occlusal pattern is S-shaped in early stage of wear; the entoflexid tends to close at its mouth with moderate wear leaving an obliquely elongated enamel lake, although the degree of wear that exhibits this condition
varies. The specimens from UA loc. 7933 exhibit much wider variation in the occlusal pattern: in some specimens (e.g., UALP 14101 and 14110) the metaconid and entoconid are connected at the mouth of the anterolingual reentrant from the beginning of wear; UALP 14102 exhibits a two-lophed occlusal pattern due to nearly oppositely placed reentrants, which is similar to M₃ of the subgenus Neotoma. Furthermore, UALP 14111 possesses an extra cusp posterior to the typical S pattern (Fig. 19X).

The presence of the anterior cingulum is rare (3 out of 13 relatively less worn specimens); when present the degree of the development varies. Two roots are present in most specimens as far as observable; UALP 14106 has a single root with labial concavity.

COMPARISONS: N. taylori is distinguished from N. sawrockensis and N. fossilis by its larger size and higher crowned teeth; it is also distinguished from N. quadripli-catus by its slightly smaller size (though the ranges overlap) and again its higher crowned cheek teeth. The occlusal enamel pattern of cheek teeth is essentially nearly identical in all species of the subgenus Paraneotoma. Thus, the species are distinguished primarily by the degree of hypsodonty and the size.

DISCUSSION: The population of UA loc. 15-24 is about the same size as that of the type locality, but the population of UA loc. 7933, which is approximately 45 m above loc. 15-24 in the Ill Ranch composite section, is slightly smaller than the former, especially in M₁. But, the size range overlaps and morphologically the teeth
are almost identical; therefore both the populations are treated as the same species.

Lammers (1970) described a new species, *N. olseni*, from the Curtis Ranch local fauna (early Irvingtonian) characterized as having $M_1^1-2$ with labial flexi oblique and lingual flexi perpendicular to the long axis of the occlusal surface, $M_1^1-2$ with labial flexids perpendicular and lingual flexids oblique to the long axis of the occlusal surface, and $M_3^3$ with the S-shaped occlusal pattern. These characters are identical with those of the subgenus *Paraneotoma*, and thus common with the species of that subgenus, as has been described above. Thus, the characters that he ascribed to *N. olseni* are diagnostic for the subgenus and cannot be the diagnosis of a single species.

Reexamination of some of his hypodigm (UALP 3234 = type, 1701) and an additional topotypic specimen (UALP 1773) indicates that although *N. olseni* differs slightly from *N. taylori* in its slightly smaller size and in having cheek teeth wider in comparison with the length, *N. olseni* is probably synonymous with *N. taylori*, based mainly on its hypsodonty and its less inflated (straighter) side wall of the teeth. Measurements (length and width in mm) of *N. "olseni"* specimens that I examined are as follows: UALP 1701: $M_1^1$, 3.00, 2.20; $M_2^2$, 2.44, 1.96. 1773: $M_1^1$, 2.80, 1.96; $M_2^2$, 2.64, 2.00. 3234: $M_1^1$, 2.88, 2.00; $M_2^2$, 2.64, 2.08; $M_3^3$, 2.24, 1.72.

*N. taylori* is reported from the White Rock local fauna in Kansas by Eshelman (1975). Although I have not examined the specimens, I believe that the White Rock *Neotoma* is too large to be *N.*
taylori and is even larger than N. quadriplicatus, though the smallest values of the several measurements overlap with the range of the latter. Thus, the presence of N. taylori in the White Rock fauna is doubtful.

Repomys May, 1981

Repomys arizonensis, n. sp.

(Figs. 21-22; Tables 33-34)

HOLOTYPE: UALP 1073, right mandible fragment with M1-2.

TYPE LOCALITY: UA loc. 15-24, III Ranch, southern Arizona.

HYPODIGM: In addition to the holotype, UALP nos. 16277-16285, M1's; 16286-16289, M2's; 16290-16292, M1's; 16293-16295, M2's, all isolated teeth from UA loc. 15-24.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA loc. 15-24, at about 40 m level of the III Ranch composite section, Gila Conglomerate, southern Arizona.

AGE: Late Blancan (latest Pliocene).

DIAGNOSIS: Smaller than R. gustelyi but larger than R. panacaensis in size; morphologically most similar to R. panacaensis, but M1 less simpler, with the lingual flexids extending further across the tooth and the metaconid less closer to the anteroconid than R. panacaensis, and with posterior cingulum better developed; M1 anterocone asymmetrically bilobed; M2 with anterior and lingual roots fused.
Figure 21. Occlusal enamel patterns of *Repomys arizonensis*, n. sp.

A, UALP 16280, left M\(^1\); B, UALP 16284, right M\(^1\); C, UALP 16281, right M\(^1\); D, UALP 16287, left M\(^2\); E, UALP 16289, right M\(^2\); F, UALP 1073 M\(_{1-2}\), holotype; G, UALP 16290, left M\(_1\); H, UALP 16291, left M\(_1\); I, UALP 16294, right M\(_2\); J, UALP 16293, left M\(_2\).
Figure 22. Scatter diagram of length and width of $M^1_1$ and $M^2_2$ of Repomys species

M, R. maxumi; G, R. gustelyi; A, R. arizonensis, n. sp.; P, R. panacaensis.
Table 33. Measurements of *Repomys arizonensis* n. sp. and ratios of measurements in average between two species of the genus *Repomys*

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<th>O.R.</th>
<th>Mean</th>
<th>S.D.</th>
<th>C.V.</th>
<th>A/P*</th>
<th>G/A*</th>
<th>M/G*</th>
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<tr>
<td>M1/</td>
<td>9</td>
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Table 34. Statistical comparison of mean length and widths of *Repomys arizonensis*

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<td>M1/</td>
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<td>&lt;0.05</td>
</tr>
<tr>
<td>W</td>
<td>2.45</td>
<td>8</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>M/2</td>
<td>6.12</td>
<td>7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>W</td>
<td>3.44</td>
<td>7</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>
DESCRIPTION: *Repomys arizonensis* is represented by a fragmentary mandible with M_{1-2} and isolated M^{1-2}_{1-2}'s; no M^{3}_{3} are known. The teeth are all slender and very hypsodont, becoming slightly wider toward the base of the enamel.

Since all four species of the genus are distinguished mainly with the size and are morphologically very similar to each other, the following description is in most part similar to the detail description by May (1981).

$M^1$: Very high-crowned, nearly as tall as long in slightly worn tooth, and with five major cusps (Fig. 21A-C). The anterocone is asymmetrically bilobed in slightly worn specimens, the labial conule slightly larger than the lingual; the anteromedian stria is very shallow and is obliterated with moderate wear. A small enamel projection from the posterolabial side of the anterocone (termed an anterostyle by May, 1981, p. 220) slightly constrists the paraflexus anterior to the paracone. A similar but less persistent projection (termed a parastyle by May, 1981) is located on the posterior arm of the paracone, projecting toward the anterior edge of the metacone. Both enamel projections never join the opposing enamel to produce a lake, and are lost with moderate wear, at roughly one-third down from the top of the tooth in slightly worn specimens.

The protcone is located slightly anterior to the paracone, whereas the hypocone and metacone are nearly transversely opposed. The protcone is differentiated lingually from the anterocone by a
broad inflection (protoflexus) that forms a shallow groove (protostria) on the anterolinguinal side, but the anterior arm of the protocone is broadly confluent with the anterocone. The posterior arm of the protocone is broadly confluent with the medial paracone near the enamel projection (May's parastyle). A minute enamel expansion projects posterolinguinally from the posterior arm of the protocone but is lost in early wear. The hypocone is similar in occlusal outline to the protocone and is separated from the latter by a broad hypoflexus. The metacone is broadly confluent with the posterior arm of the hypocone, with a small posterolabial style in slightly worn specimens.

The paracone is separated from the anterocone by a deep paraflexus directed posterolinguinally to nearly transversely. It is similarly separated from the metacone by a slightly less deep metaflexus. Both of these labial flexi continue nearly to the base of the enamel as striae and remain open throughout wear; they slightly retreat labially toward the base, whereas the broad hypoflexus extends deeper (labially) toward the base. The anterior enamel walls of the labial flexi are very thin in slightly to moderately worn specimens. There are three distinct roots arranged anterior, lingual, and posterior, all subequal in size.

M2: Similar to M1 except for its shorter length and the condition of roots. The shortness results from the absence of the anterocone. M2 is slightly taller than long in slightly worn specimens. The broad protoflexus is shallower than in M1, but the protostria
persists until late wear. A small enamel projection on the anterior cingulum ("anterostyle") is weaker and disappears with earlier wear than in M₁, whereas the enamel projection on the paracone ("parastyle") is as distinct as in M₁. The anterior and lingual roots are fused anterolingually, forming an L-shaped root, as seen on UALP 16286 and 16288. The roots are broken off from two other specimens (UALP 16287 and 16289), but the outline of the root base of those specimens indicates that they probably had fused roots.

M₁: Nearly as tall as long in slightly worn specimens. The anteroconid is single cusped; the anterolabial cingulum projects posterolabially from the anteroconid. The metaconid is broadly joined the anteroconid. The entoflexid is deep, directed nearly transversely to anterolabially but not anteriorly; thus, the anterior arm of the protoconid is broadly confluent with the anteroconid and metaconid in occlusal view. The protoflexid is short and narrow, and the protostriid terminates one-third way down from the top of the tooth in slightly worn specimens.

The posterior arm of the protoconid is broadly confluent with the anterior entoconid and the anterior arm of the hypoconid; a small enamel expansion (termed a mesostylid by May, 1981, p. 222) projects anterolingually from the anterior base of the entoconid in slightly worn specimens, slightly constricting the entoflexid. The anterior arm of the hypoconid joins the labial side of the entoconid. An indistinct, minute enamel expansion projects anterolabially from
the anterior arm of the hypoconid in slightly worn specimens, especially in UALP 16292.

The posterior cingulum is heavy, broadly confluent with the hypoconid to the lingual side of the tooth. The posteroflexid is slightly shallower and narrower than the entoflexid, and the postero-striid terminates at depth approximately one-third above the base of the enamel in slightly worn specimens. The posterior enamel walls of both lingual flexids are very thin in slightly worn specimens. $M_1$ has two distinct roots, anterior and posterior, which are subequal in size.

$M_2$: Similar to $M_1$ except for its shorter length; the shortness is due to absence of the anteroconid. The posteroflexid is slightly deeper than in $M_1$, and the postero-striid terminates roughly $1/3$ to $1/2$ way above the base of the enamel in slightly worn specimens. The posterior cingulum is broadly confluent with the hypoconid, is slightly longer, and is directed slightly more posteriorly than in $M_1$. Although maximum length is obviously shorter than $M_1$, the occlusal length is nearly equal to that of $M_1$ in slightly worn specimens. $M_2$ has two distinct roots as in $M_1$.

**COMPARISONS AND DISCUSSION:** Repomys arizonensis is distinguished from R. gustelyi and R. maxumi by its smaller size, $M_1$ with no anteriorly extended apex of the entoflexid, and $M_2$ with fused anterolingual and posterior roots. R. arizonensis is distinguished from R. panacaensis by its larger size, $M_1$ with the entoflexid extending slightly further across the tooth and the metaconid placed
slightly more distally from the anteroconid, and \( M_2 \) with longer and slightly more posteriorly directed posterior cingulum.

I agree with May (1981) that the degree of hypsodonty of all the species appears roughly comparable, and thus, the species cannot be distinguished by this feature.

Although *R. arizonensis* is most similar to *R. panacaensis*, it is intermediate between *R. panacaensis* and *R. maxumi* or *R. gustelyi* in many respects: degree of lateral extension of the paraflexus and protoflexus of \( M_1 \), degree of lateral extension and direction of the enteroflexid of \( M_1 \), and position of the metaconid relative to the anteroconid in \( M_1 \). If these characters are parallel with the trend in shallowing of the entoflexid of \( M_1 \) from *R. maxumi* to *R. panacaensis* as May (1981, p. 223) pointed out, there is a contradiction in between the geologic ages of *R. arizonensis* and *R. panacaensis*: *R. panacaensis* is supposed to be the middle Blancan (3.2-3.7 mybp; May, 1981) while *R. arizonensis* to be late Blancan (roughly 2.5 mybp; just below the Gauss-Matuyama boundary of Fig. 7). If the geologic age assignment of these species are true, *R. arizonensis* and *R. panacaensis* should represent different lineages.

In size *R. arizonensis* is also intermediate between *R. gustelyi* and *R. panacaensis*. In Figure 3 of May (1981), the distance between "G's" (*R. gustelyi*) and "P's" (*R. panacaensis*) is greater than the distance between "G's" and "M's" (*R. maxumi*). *R. arizonensis* ("A's" in Fig. 22) divides the former greater distance into two parts and makes all the distances approximately even
(Fig. 22). Although the sample size is not so large in most measurements, all the measurements are significantly different from those of both R. gustelyi and R. panacaensis (Table 34). Thus, if R. gustelyi and R. maxumi are valid species, R. arizonensis should also be valid, though the size difference between R. arizonensis and R. panacaensis is slightly smaller than that of between R. arizonensis and R. gustelyi or R. gustelyi and R. maxumi (Table 33).

Family ARVICOLIDAE Gray, 1821

Terminology of arvicolid cheek teeth such as Zakrzewski (1967) has been most commonly used. However, it always had some ambiguity, especially on the counting of the alternating triangles of M₁, or more specifically the distinction between the most anterior alternating triangle and the most posterior part of the anterior loop that is distinguished by a rather deep prism fold. Another problem was that the numbering of corresponding alternating triangles between M¹ and M²-³ did not correspond.

Van der Meulen's (1973) system solved these problems, although it invented slight confusion that M¹ does not possess AL₁, and M²-³ do not possess T¹. His terminology is followed here with the omission of the terms of salient angles that are not used in the following description (Fig. 23). Parenthetically the word "buccal" is restricted to the term "buccal reentrant angle" (BRA), and the
Figure 23. Cusp and fold terminology of Arvicolidae used in this paper, simplified after Van der Meulen (1973)
word "labial" is used in all other parts of the following
description, corresponding with the description of other families.

**Ophiomys** Hibbard and Zakrzewski, 1967

**Ophiomys** sp. cf. *Q. taylori* (Hibbard, 1959)

(Fig. 24A-F; Table 35).

REFERRED MATERIAL: UALP nos. 14374, right M\(^1\); 14375-14376,
right M\(^3\)'s; 14377, right M\(_2\); 14378-14379, right M\(_3\)'s, from UA loc.
7937.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA loc. 7937, at about 10 m
level of the Duncan section, south of Duncan, southern Arizona; *Q.
taylori* is known from the Glenns Ferry Fm. in Idaho and Washington.

AGE: Middle Blancan (Late Pliocene); *Q. taylori* ranges from
the early to late Blancan.

DESCRIPTION: Small arvicoline rodent having cheek teeth with
roots present and cementum lacking. Dentine bridges between anterior
loop/cap, each of the alternating triangles, and posterior loop/cap
are open in occlusal view.

M\(^1\) has a simple anterior loop (AL2) and four alternating tri-
angles (T1-T4). Dentine tracts are low on the posterior surface of
T4 and lingual side of T1. BRA2 is slightly constricted internally,
flexed posteriorly. Three roots are present, the lingual being the
smallest.

M\(^3\) has wide anterior loop (AL1), three small alternating tri-
angles (T2-T4) with the T4 indistinct in late wear, and a hook-shaped
Figure 24. Arvicolidae from Duncan and Ill Ranch.

A-F: *Ophiomys* sp. cf. *O. taylori*.
    A-B, UALP 14374, right $M^1$; C-D, UALP 14375, right $M^3$;
    E-F, UALP 14379, right $M_3$.
I-L: *Pliophenacomys* primaevus
    I-J, UALP 5198, right $M_1$; K-L, UALP 16184, right $M_3$.
M-T: *Mictomys* (Metaxyomys) *vetus*.
    M, UALP 887, right $M^{1-3}$;
    N and S, UALP 1010, right dentary with $M^{1-3}$;
    O, UALP 16143, right $M_1$; P, UALP 16152, right $M_1$;
    Q, UALP 16136, left $M_3$; R, UALP 16131, right $M^3$;
    T, UALP 5054, right $M_1$. 
Figure 24. Arvicolidae from Duncan and Ill Ranch
Table 35. Measurements of *Ophiomys cf. taylori*

<table>
<thead>
<tr>
<th>UALP Nos.</th>
<th>Length</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
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<td>2.12</td>
<td>1.24</td>
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<tr>
<td>14375</td>
<td>1.72</td>
<td>0.94</td>
</tr>
<tr>
<td>14376</td>
<td>ca.1.8</td>
<td>ca.1.0</td>
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<tr>
<td>14377</td>
<td>1.66</td>
<td>1.08</td>
</tr>
<tr>
<td>14378</td>
<td>1.48</td>
<td>0.86</td>
</tr>
<tr>
<td>14379</td>
<td>1.40</td>
<td>0.86</td>
</tr>
</tbody>
</table>
posterior cap. Dentine bridges between AL and T2 and between T4 and PC are widely open. BRA's are shallower than LRA's, especially in UALP 14375 (Fig. 24C-D). Dentine tracts are not developed, although enamel is distinctly higher on posterior cap.

$M_2$ has a posterior loop and four alternating triangles (T1-T4). T4 has an anterior swelling that broadens toward the base of the enamel. Dentine bridges between T3 and T4 are widely open; other dentine bridges narrow. Dentine tract is low at the anterolabial surface of T4.

$M_3$ has a posterior loop and three alternating triangles (T1-T3). T2 is small and the T3 is broadened anterolabially. Dentine tract is low on the anterolabial surface of the T3. Two roots are present.

COMPARISONS AND DISCUSSION: Size of the specimens described above is too small for the genera Cosomys or Ogmodontomys. Promimomys has lower crowned cheek teeth than those described above. Nebraskomys has higher dentine tracts, and the position of triangles of $M_2$ and $M_3$ is nearly opposite in Nebraskomys.

Of the six known species of the genus Ophiomys, O. mcknighti has no dentine tract developed, and O. parvus has dentine tracts higher than seen in Duncan material (I believe that "O." fricki Hibbard, 1972, does not belong to the genus Ophiomys). O. meadensis is larger.

O. magilli known from the Keim Fm. of Nebraska and O. taylori known from the Glens Ferry Fm., Idaho and Washington (Hibbard, 1959),
are the two closest species that Duncan material can be compared with. Development of dentine tracts is about the same in both species, though \textit{O. magilli} is slightly larger in size and slightly higher crowned (Hibbard, 1972). It is difficult to distinguish these two species without \textit{M} \textsubscript{1} and with so little material. However, Duncan \textit{M} \textsubscript{1} is slightly smaller than known ranges of \textit{O. magilli} (Hibbard, 1972) and other teeth also tend to be smaller than that species, while \textit{O. taylori} has tooth size about the same as the Duncan material. Thus, Duncan \textit{Ophiomys} is tentatively referred to \textit{O. taylori}.

**Pliopotamys** Hibbard, 1938

\textit{Cf. Pliopotamys sp.}

(Fig. 24G-H)

**REFERRED MATERIAL:** UALP no. 14170, left \textit{M} \textsubscript{3}, from UA loc. 7934.

**STRATIGRAPHIC AND GEOGRAPHIC RANGE:** UA loc. 7934 at 0 m level of the Duncan section, Gila Conglomerate, south of Duncan, southern Arizona.

**AGE:** Middle Blancan (late Pliocene).

**DESCRIPTION:** Material referred to this taxon is a left \textit{M} \textsubscript{3} of a medium sized vole. It has posterior loop and three alternating triangles (T1-T3), second of which is very small. Dentine bridges between posterior loop and alternating triangles are narrow but open in occlusal view, except that the bridge between T2 and T3 is much wider. Cementum is absent in the reentrant angles. BRA's are much shallower
than LRA's. Dentine tracts are low on labial side of T2 and anterolabial side of T3. Two roots are present, posterior being larger and gently curved posteriorly. The length is 2.20 mm on the occlusal surface. Width on the occlusal surface can not be measured; the maximum width near the base of the crown is 1.64 mm.

**COMPARISONS AND DISCUSSION:** *Pliopotamys* sp. is larger than *Cosomys*, *Ophiomys*, *Pliophenacomys*, *Ogmodontomys*, and *Nebraksomys* among arvicoline rodents with rooted cheek teeth, and other smaller genera are not comparable with UALP 14170. In size and the enamel pattern UALP 14170 is closest to *Pliopotamys* and *Ondatra idahoensis*. However, the T2 of UALP 14170 is considerably smaller than T1, which is characteristic in *Pliopotamys* in comparison with genus *Ondatra* in which T2 of M3 is not so small (Hibbard, 1959). In addition, *O. idahoensis* is slightly larger and has higher dentine tracts. Thus, UALP 14170 very probably belongs to the genus *Pliopotamys* (Hibbard, 1938). However, M3 is one of the less characteristic teeth in arvicoline rodents, and a single, isolated M3 cannot provide the basis for a definite identification. Thus, UALP 14170 is tentatively referred to the genus *Pliopotamys*.

**Pliophenacomys** Hibbard, 1938

**Pliophenacomys primaevus** Hibbard, 1938

(Fig. 24I-L)

**HOLOTYPE:** KUMNH 3905, right jaw with I1 and M1-2 from loc. KU-2 in the Rexroad Fm., Meade County, Kansas.
REFERRED MATERIAL: UALP nos. 5198, right $M_1$; 16184, right $M_3$, from UA loc. 15-24, 111 Ranch.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA loc. 15-24, at about 40 m level of the 111 Ranch composite section, Gila Conglomerate, San Simon Valley, southern Arizona; and Rexroad local fauna in Kansas; Sand Draw local fauna in Nebraska.

AGE: Middle to late Blancan (late Pliocene).

DESCRIPTION: Both $M_1$ and $M_3$ are high crowned, prismatic teeth with no cementum. The roots are broken off on both teeth, which are not rootless. Dentine bridges between alternating triangles and anteroconid or posterior loop are slightly open in occlusal view. The buccal reentrant angles (BRA's) are distinctly shallower than the lingual reentrant angles (LRA's). The enamel is slightly thinner on the posterior wall of each triangle.

$M_1$: $M_1$ is composed of a posterior loop (PL), lingual part of which is broken, seven alternating triangles (T1 to T7), and a simple anterior cap (AC3). Striids of the BRA4 and LRA5 are shorter than those of other reentrant angles. LRA's are broad, and as broad or broader than width of the lingual alternating triangles. Their apical angles are directed nearly perpendicular to the midline of the tooth and the apices do not constrict as they approach the midline. The dentine tracts are developed and extend as high as 2 mm from the base of the enamel on the buccal sides of both AC3 and PL, but do not interrupt the enamel pattern on the occlusal surface of UALP 5198. Dentine tracts on the labial alternating triangles are low, extending
higher in anterior triangles. The dentine tracts are not developed on the lingual side.

M₃: Composed of a posterior loop and four alternating triangles. T₄ broadens anteriorly, and is broadly confluent with the T₃. As in M₁, LRA's are broad with their apices, directed nearly perpendicular to the midline of the tooth, and are not constricted as they approach the midline. Dentine tracts are developed on the posterolabial and posterolingual sides of the PL, plus the anterolabial side of the T₄; they are not as high as in M₁.

COMPARISONS AND DISCUSSION: Zakrzewski (1984) recently examined in detail the specimens previously considered to be Pliophenacomys osborni and recognized three genera and four species, including P. osborni, within them. He also presented redefinition of P. primaevus as well as P. osborni along with descriptions of the two new genera and their contained species, and a new species of the genus Pliophenacomys. I follow his taxonomic framework for definition of those genera and species.

111 Ranch specimens described here are distinguished from Hibbardomys spp. by having broad LRA's with the apical angles directed nearly perpendicular to the midline and with their apices not constricted as they approach the midline. Five species of the genus Pliophenacomys are presently known: P. n. sp. from Yepomera, Mexico (Lindsay and Jacobs, in Press), P. finneyi, P. primaevus, P. dixonensis, and P. osborni. Although the size range overlaps each other, the new species from Yepomera is slightly larger than
all other species of the genus, which are not distinguishable to each other by size. Yepomera species and *P. finneyi* have dentine tracts lower, and *P. dixonensis* and *P. osborni* have dentine tracts higher on both lingual and labial sides, than *P. primaevus*, including the Ill Ranch specimens described here.

UALP 5198 is slightly smaller than the known size ranges of *Pliophenacomys* spp. (Zakrzewski, 1984), but I consider it still within the expected size range of the species.

The occurrence of *P. primaevus* in the Ill Ranch fauna extends its known geographic range to west side of the Rocky Mountains and this is the latest known occurrence of this species.

*Mictomys* True, 1894

**DISCUSSION:** Recently Koenigswald and Martin (1984) reviewed most of the lemming taxa, both Recent and fossil, based mainly on the detailed study of enamel micro-structure (Schmelzmuster). They recognized three genera in the subfamily Lemminae: *Lemmus* with *Lemmus* and *Myopus* as subgenera, *Synaptomys* with *Synaptomys* and *Pliocotomys* as subgenera, and *Mictomys* with *Mictomys*, *Metaxomys* and *Kentuckomys* as subgenera. *Mictomys* has long been considered as a subgenus of the genus *Synaptomys*. The confluency of the first and second alternating triangles (T1 and T2) of the lower molars was given as the character that distinguishes *Mictomys* from *Synaptomys* by Koenigswald and Martin (1984). I follow their taxonomic framework for the Lemminae although
I question the discrete limits of Mictomys subgenera, especially subgenus Kentuckomys which may be difficult to distinguish from the subgenus Mictomys except for the terminal position of lower incisor.

Mictomys (Metaxyomys) vetus (Wilson, 1933)
(Fig. 24M-T; Table 36)


REFERRED MATERIAL: UALP nos. 887, 893, 1028, 1031, 1985, 1101, 1107, 1110, 1119 partial or fragmentary skull or maxilla with one or more teeth; 811c, 16064-16104, M_1's; 16107-16128, M_2's; 16130-16140, M_3's; 874, 891, 892, 1010, 1021, 1027, 1029, 1082-1084, 1091, 1092, 1095, 1099, 1108, 1115, 1165, 5053, 5054, 16063, nearly complete to fragmentary mandibles with one or more teeth; 963, 16141-16166, M_1's; 16167-16176, M_2's; 961-962, 16177-16183, M_3's; all from UA loc. 15-24, 111 Ranch.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA loc. 15-24, at about 40 m level of the 111 Ranch composite section, Gila Conglomerate, San Simon Valley, southern Arizona; upper part of the Glenns Ferry Formation, Grand View local fauna, Idaho.
Table 36. Measurements of *Mictomy* (*Metaxyomys*) *vetus*

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>O.R.</th>
<th>Mean</th>
<th>S.D.</th>
<th>C.V.</th>
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<tr>
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</tr>
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<td>W</td>
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<td>1.32-1.68</td>
<td>1.49</td>
<td>0.063</td>
<td>4.23</td>
</tr>
<tr>
<td>M2/L</td>
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<td>0.123</td>
<td>5.30</td>
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<tr>
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<td>29</td>
<td>1.08-1.40</td>
<td>1.24</td>
<td>0.075</td>
<td>6.05</td>
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<td>2.78</td>
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<tr>
<td>M/1L</td>
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<tr>
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<td>1.42</td>
<td>0.067</td>
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<td>7.67-8.42</td>
<td>8.00</td>
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</tbody>
</table>
AGE: Late Blancan (latest Pliocene).

DESCRIPTION: Anterior part of the skull is preserved on the several specimens, of which UALP 887 is best preserved including the rostrum, anterior part of zygomatic arches, and palate with all six cheek teeth. The rostrum is noticeably short and broad, and the zygomatic arch is widely spreading laterally and the anterior plate of zygoma is broad as in other lemmings. The upper incisor has a shallow but distinct groove near the labial edge of its anterior surface, and the posterior end terminates immediately anterior to the base of \( M^1 \).

The lower jaw is also represented by several incomplete and fragmentary specimens. The masseteric ridge is well developed and extends posteriorly, but its posterior end is not observable because of the breakage. The ventral surface of the mandibular ramus is broad and fairly flat. The mental foramen is situated on the labial side of the ramus in front of the anterior end of masseteric ridge, as in other lemmings. The lower incisor is positioned lingual to the molars and terminates at the base of the T3 of \( M_3 \) as seen on UALP 1010 or between \( M_2 \) and \( M_3 \) as seen on UALP 5053.

Cheek teeth are rootless with cementum in the reentrant angles. The tooth axis of the lower molars is shifted labially but not as far as in some species of other subgenera. There is no noticeable difference in enamel thickness between anterior and posterior borders of each alternating triangle and anterior and posterior loops. However, there is noticeable reduction in enamel thickness where the enamel is
flexed at each reentrant angle, especially where the reentrant is very deep. Labial and lingual borders of all alternating triangles, and anterior and posterior loops lack enamel, but the break of enamel of the buccal triangles of upper molars and lingual triangles of lower molars is only slight.

\( M^1 \) consists of an oval shaped, wider than long, anterior loop with a gently rounded anterior face (AL2), four alternating triangles (T1-T4) with a relatively narrow, nearly flat posterior face. \( M^2 \) consists of an anterior loop (AL1) and three alternating triangles (T2-T4). In both teeth BRA1 and 2 are deeper than LRA1 and 2, but T1 and T3 are only slightly smaller than T2 and T4. Posterior alternating triangles (T3 and T4) are smaller than corresponding anterior alternating triangles (T1 and T2). The anterior loop and all alternating triangles are nearly closed. Apices of T1 or AL1 and T3 are broadly terminated and lack enamel along their lingual border. Posterior termination of T4 is broad and lacks enamel. LRA3 is incipient and shallow, lacking cementum.

\( M^3 \) consists of ALi, three alternating triangles (T2-T4), and a small posterior cap (PC). T3 and T4 are broadly open, unrestricted at their base; T2 and T3 are constricted but broadly confluent, and T4 is confluent with PC. LRA2 is much shallower than LRA3 which is nearly as deep as buccal reentrant angles. Posterior cap is small and ellipsoidal in outline and lacks enamel along the entire posterior face.
M₁ consists of a posterior loop, three alternating triangles (T₁-T₃), and an anterior cap. The T₁ is broadly confluent with T₂ which is poorly formed. T₂ is nearly closed to the T₃ in some specimens and is narrow but obviously open in other specimens; none of the specimens show complete closure. Anterior cap has shallow buccal and lingual reentrants (incipient BRA₃ and LRA₄; Fig. 240-P) lacking cementum and is narrower than the maximum width of the tooth. Enamel is thick on the posterior wall and at BRA₃ and LRA₄ of the anterior cap. LRA₃ and BRA₂ are more or less opposed to each other at near the midline of the tooth. LRA₁ and 2 are deeper than LRA₃ while the BRA₁ is much shallower than other reentrant angles.

M₂ consists of a posterior loop, three alternating triangles (T₁-T₃), and a vestige of an "anterior cap." T₁ and T₂ are broadly open to each other, and T₃ is broadly open anteriorly. Anterior face of the vestige of the "anterior cap" lacks enamel. M₃ consists of a curved posterior loop and three alternating triangles. T₁ and T₂ are broadly open as in other lower molars. Anterior face of the T₃ is wide, convex anteriorly, and lacks enamel. In both M₂ and M₃ the BRA's are much shallower than the LRA's but possess cementum except for the BRA₂ of M₃.

COMPARISONS AND DISCUSSION: As in other arvicolids, M₁ and M₃ are the most diagnostic teeth. The tooth axis of lower molars in Mictomys (Metaxyomys) is not shifted labially as much as in the subgenera M. (Mictomys) and M. (Kentuckomys), and in M₃ of M. (Metaxyomys) the T₄ is broadly open to the T₃, whereas the junction of these
alternating triangles is closed in other subgenera. In the subgenus M. (Metaxyomys) three species are presently known: Mictomys vetus, M. landesi, and M. anzaensis. M. anzaensis is distinguished from other species by its larger anterior cap with deeper external re-entrant angle (BRA3)(Zakrzewski, 1972). M. vetus is similar to M. landesi in enamel pattern of M₁ but is easily distinguished by the posterior cap of M₂, which is distinctly smaller in size and ellipsoidal in shape with no enamel on the posterior face in M. vetus; it is larger in size and triangular in outline with enamel on much of the posterior face in M. landesi (Zakrzewski, 1972).

Zakrzewski (1972) pointed out that the anterior cap of M₁ in M. vetus usually has a deep angular lingual reentrant angle (LRA4). Specimens from 111 Ranch (possibly except for UALP 891, 1095, and 5054 mentioned below) show no deep reentrant with cement as illustrated by Zakrzewski (1972, Fig. 1A). Wilson (1933) did not mention nor illustrate that character when he described M. vetus.

A few specimens from 111 Ranch (UALP 891, 1095, and especially 5054; Fig. 24T) differ from other specimens in some respects. The anterior cap has deeper reentrants (LRA4 and BRA3). There is no intercept of enamel pattern of the occlusal surface except for the anterior face of AC and the labial edges of PL and T₂. Dentine tracts are not present on PL, T₁, T₃, and "T5" in UALP 1095 and 5054; they are present on lingual edges of PL, T₁, T₃ (tend to be lower toward the anterior) in UALP 891 and labial edge of T₄ in all specimens. All the dentine tracts become wider toward the base of the tooth.
"BRA3" becomes shallower toward the base of the tooth. No cementum is present on LRA4 and BRA3. The dentine bridges between PL and T1, between T2 and T3, and between T3 and AC are more widely open than in other specimens. UALP 5054, 1095 and 891 are the three smallest specimens in size (UALP 5054 is 15% shorter than the mean length), but they become longer and wider toward the base of the tooth. All these differences are interpreted here as to the young ontogenetic age of these specimens. Zakrzewski (1972, p. 5) pointed out that loose closure of the dentine bridge may be due to the differences in the ontogenetic age. If this interpretation is correct, those young specimens indicate the order of development of the dentine tracts as follows: from the earliest to the latest, labial edges of PL-T2-"T4"-lingual edges of PL-T1-T3-"T5".

With regard to size, the III Ranch population is approx. 9% larger than the Grand View population in average length and width of M₁, though approx. half of the observed ranges overlap to each other. Since Zakrzewski (1972) gave bar diagrams rather than actual measurements, the above comparison is based on a reading of the diagrams. Wilson (1933) gave measurements for M₁-₃ and M₁. Most of his measurements are near the minimum of the observed range (of each tooth) and means are approx. 7-14% smaller than the means of the III Ranch population. Thus, the III Ranch population is slightly larger than the Grand View population of M. vetus which is the only previously described population of the species. However, since size ranges in both populations broadly overlap and means are too close to distinguish
separate species. I conclude that the 111 Ranch species is the same as the Grand View species. The morphological characters are almost identical in both populations, except for the degree of the development of the LRA4 of the anterior cap of M1 in certain specimens.

Although the precise geologic age of the Grand View local fauna is not known, it should be placed sometime during the oldest part of Matuyama chron if the interpretation of the paleomagnetic study by Neville et al. (1979) is accepted. Seneca local fauna from Nebraska is reported to include *M. (M.) vetus* (tentative identification: Koenigswald and Martin, 1984). The Seneca local fauna is correlated approximately with the age of the Grand View local fauna.

Dixon local fauna, which includes *Synaptomys (Pliocotomys) rinkerii*, is also correlated with the Grand View local fauna. As discussed in previous section, UA loc. 15-24 is situated just below the Gauss-Matuyama boundary in the paleomagnetic section (Galusha et al., 1984), and thus it is slightly older than the boundary of the Gauss-Matuyama chron, which is approx. 2.5 Ma (Ness, Levi, and Couch, 1980) and is older than any previously known faunas in North America that include fossil lemmings. Thus, *Mictomys (Metaxyomys) vetus* from 111 Ranch is the oldest known North American lemming and extends the chronological and geographical ranges of the species.
Family HYDROCHOERIDAE Gill, 1872

Neochoerus Hay, 1926

Neochoerus dichroplax Ahearn and Lance, 1980

REFERRED MATERIAL: UALP no. 15927, including fragments of lower incisor and unidentifiable cheek teeth from UA loc. 7323; UALP no. 15967, a fragment of lower incisor, from UA loc. 15-21.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: UA locs. 7323 and 15-21, both at about 30 m level of the 111 Ranch composite section, Gila Conglomerate, in addition to the 111 Ranch general and American Museum Dry Mt. locality near UA loc. 15-21 (approx. 1/2 mile south), all 111 Ranch area, southern Arizona; Sommers Pit and Mule Pen Quarry local faunas, Florida (Ahearn and Lance, 1980).

AGE: Late Blancan (latest Pliocene).

DISCUSSION: Ahearn and Lance (1980) described this species based partly on the UALP specimens. The specimens referred here are collected rather recently and were not included in their hypodigm. The cheek teeth are so fragmentary that it is not possible to identify the kinds of teeth. But, they are approx. comparable in size and are essentially topotypic specimens, I referred them to the same species. Width of right I₁ is 13.8 mm, that of two fragmentary laminae of cheek teeth are 11.0 and 13.2 mm, in UALP 15927.
SUMMARY AND CONCLUSIONS

1. The Safford and Duncan Basins are two of the structural basins in southern Arizona formed by Basin and Range extensional tectonics that began in middle Miocene. Major basin fill deposits in both basins are called the Gila Conglomerate. They consist of locally derived alluvial fan deposits (lower part) and more centrally located, lacustrine, paludal and fluvial overbank deposits (upper part). Abundant mammalian fossils have been collected from the upper part of the Gila Conglomerate since 1932; however, most of the fossils remained undescribed.

2. Magnetic polarity stratigraphy of the Gila Conglomerate in the Safford and Duncan Basins, combined with the biochronological age constraint based on the mammalian fossil assemblage, provide a framework for geochronology and contribute to knowledge of the geologic history of these basins and the effect of Basin and Range extensional tectonics.

3. Paleomagnetic sections were collected at Bear Springs and San Simon Power Line in the Safford Basin, and at Duncan, Pearson Mesa, and Country Club in the Duncan Basin. The III Ranch paleomagnetic section by Galusha et al. (1984) was also utilized in this study. Each section consists of one to three magnetozones, and none of the columns can be correlated directly with the MPTS, based on polarity sequence.
4. Faunal list for each area was compiled, utilizing both the UALP collection and the F:AM collection. Comparisons with other similar faunas that had been correlated with the MPTS narrow the possible correlation of the Safford and Duncan magnetic sequences with the MPTS.

5. The Bear Springs fauna includes a minimum of 12 taxa. The presence of *Sigmodon* sp., *Trigonictis macrodon*, and *Equus* sp. limits the oldest possible age, whereas the presence of *Nannippus phlegon* limits the youngest possible age. Thus, the Bear Springs fauna is approximately middle Blancan in age, or within the Gauss magnetic chron. The Bear Springs section consists of a lower short reversed and an upper long normal polarity zones. However, since the fauna does not include diagnostic species which would place the fauna more precisely within the Gauss, a secure correlation of the Bear Springs fauna and section with other faunas and the MPTS is not presently possible. Thus, two possible correlations are suggested: e.g., (1) from the upper most part of Gilbert chron to the lower normal zone of Gauss chron, or (2) from the Kaena subchron to upper normal magnetozone of the Gauss chron.

6. The San Simon Power Line fauna includes a minimum of 16 taxa. *Hypolagus virginiae*, *Geomys* cf. *persimilis* (may be similar to *G. anzensis*), *Dipodomys hibbardi*, and abundant *Equus* specimens accompanied with no *Nannippus* limit the age of the Power Line fauna to late Blancan and early Irvingtonian, or roughly from the Gauss-Matuyama chron boundary to the Olduvai subchron on the MPTS. Magnetic polarity determination could not be made on samples from the San Simon Power Line section because of random and unstable NRM directions. More
precise correlation is not reliable using faunal evidence alone. However, the topographic position of the San Simon Power Line section is most likely correlative with the upper part of the III Ranch section (or possibly only slightly above it). Thus, the San Simon Power Line fauna is likely correlative with the lowest reversed magnetozone of the Matuyama chron.

7. The Duncan fauna includes a minimum of 25 taxa of which 14 are small mammals. Geomys cf. persimilis, Perognathus gidiyi, Baiomys minimus, Neotoma fossilis, Ophiomys cf. taylori, Nannippus phlegon, and Odocoileus sp. are suggestive of middle Blancan age. With the paleomagnetic data (a lower normal and an upper reversed polarity zone), the Duncan fauna is most likely correlated with the base of the Mammoth (or Kaena) subchron of the Gauss magnetic chron, or the middle Gauss chron.

8. The Pearson Mesa fauna is represented by 5 taxa. Co-occurrence of Geomys cf. persimilis, Stegomastodon mirificus, Nannippus phlegon, and Equus sp. are suggestive of middle Blancan age, or roughly within the Gauss magnetic chron. The Pearson Mesa section is represented paleomagnetically by a single, long normal polarity zone, and is topographically higher than the Duncan section. Thus, the Pearson Mesa section is most likely correlated with the upper long normal zone of the Gauss magnetic chron.

9. The Country Club fauna includes a minimum of 11 taxa. The presence of Notolagus lepuscus, Neotoma quadriplicatus, and Sigmodon medius is similar to the Rexroad fauna, and the Country Club fauna is
considered early middle Blancan age based on this faunal similarity. The magnetostratigraphy of the Country Club section shows a normal polarity zone in the middle and reversed polarity zones above and below it. From these faunal and paleomagnetic determinations, the Country Club section is most likely correlated with the uppermost Gilbert magnetic chron to the Mammoth subchron. However, the discovery of *Glossotherium chapadmalense* from a site about 4 miles south of the Country Club area might negate the above correlation. Thus, alternative correlation of the Country Club section with the Mammoth subchron up to the base of the Matuyama chron (assuming the short normal polarity zone between the Mammoth and Kaena subchrons is not present in the section) is also possible.

10. The Ill ranch fauna has recently been analyzed relative to paleomagnetic analysis (Galusha et al., 1984). Discovery of new small mammal localities and identification of those mammals in this paper provide a more precise and expanded knowledge of the fauna, but require no change in the conclusions of Galusha et al. (1984). A minor faunal change in small mammals (changes in the species composition of *Baiomys* and *Reithrodontomys* and possible disappearance of *Calomys* (*Bensonomys*) *arizonae*) suggests the entire section of the Ill Ranch area may represent a greater length of time than previously determined (just below and above of the Gauss-Matuyama chron boundary).

11. Small mammal fossils were collected by surface pick-up and by screen-washing methods. Approximately 1.5 tons of matrix mainly
from three sites were screen-washed, and about 500 identifiable specimens were identified. In addition approximately 1,100 small mammal specimens from the III Ranch area that had been curated at UALP were included in this study. A minimum of 37 taxa of small mammals are now recognized in the Gila Conglomerate of the Safford and Duncan Basins.

12. Insectivores are represented by Notiosorex sp. and Sorex sp. in the Duncan fauna and Soricidae gen. & sp. indet. in the III Ranch fauna in the Gila Conglomerate.

13. Chiropterans are represented by several isolated teeth from the III Ranch fauna.

14. Leporids are rather poorly represented in the Duncan Basin. Notolagus lepusculus is recorded from the Country Club fauna, whereas Hypolagus sp. is recorded from the Duncan fauna, represented by one and two specimens, respectively.

15. Leporids are rather diverse in the Safford Basin. Three species of Hypolagus (H. arizonensis, ? H. virginiae, and H. sp.) are identified in the III Ranch fauna, in addition to Leporidae gen. & sp. indet. that may be a new genus.

16. Hypolagus virginiae is recorded from the San Simon Power Line fauna. H. virginiae was originally described as a species of Aluralagus from the Curtis Ranch fauna, but is referred to the genus Hypolagus based mainly on $P_4-M_2$ with a smooth anterior enamel border of the posterior column, $P^2$ with a deep anterior and a shallow
anteroexternal reentrants, and $P_3$ with a simpler enamel pattern than the genotype, *Aluralagus bensonensis*.

17. *Sylvilagus* or *Lepus* spp. are recorded from the San Simon Power Line and the Ill Ranch faunas in the Safford Basin, but is not known from the Duncan Basin.

18. Sciurids are represented by two forms. *Spermophilus* cf. *bensonii* is recorded from the San Simon Power Line fauna and the Ill Ranch fauna; it is relatively large in size and has $P_4$ with a rather wide trigonid. *Spermophilus* sp. is recorded from the Ill Ranch fauna; it is of smaller size.

19. *Geomys* (Nerterogomys) cf. *persimilis* is well represented, known from the Duncan, Pearson Mesa, San Simon Power Line, and 40-85 m level of the Ill Ranch section. *Geomys persimilis* is in need of review. If *G. persimilis* does not have an enamel plate on the posterior wall of $P_4$, then *G. anzensis*, known from the middle Blancan to early Irvingtonian beds of the Anza Borrego Desert, is very similar to *G. persimilis* and might possibly be synonymized with *G. persimilis*.

20. Another geomyid, *Pappogeomys* (Cratogeomys) *sansimonensis*, n. sp., is rather common in the San Simon Power Line fauna. It has $P_4$ with or without a narrow enamel plate and $M^{1-2}$ with narrow enamel plates posterolabially.

21. *Perognathus gidleyi* is recorded from the Duncan fauna in the Duncan Basin and from the Ill Ranch fauna in the Safford Basin; it is a less common element relative to other small mammals within the faunas.
22. Three Dipodomyines are known from the Gila Conglomerate in the Safford Basin; it is not recorded from the Duncan Basin. *Prodipodomys* sp. is very rare; it is known only from the III Ranch fauna. *Dipodomys hibbardi* is an abundant species; it is known from the 30–85 m level of the III Ranch section and from the San Simon Power Line fauna. *Dipodomys* cf. *gidleyi* is also known from the III Ranch fauna; it is distinguished from *D. hibbardi* primarily on its more hypsodont cheek teeth with a higher dentine tract.

23. Cricetid rodents are the most diverse and dominant small mammals from the Gila Conglomerate in both the Safford and Duncan Basins. *Onychomys pedroensis* is a less common species; it is known from the upper part of the III Ranch section.

24. *Peromyscus hagermanensis* is known from the Duncan and III Ranch faunas; it is a rather common element among the cricetines. *P. hagermanensis* and modern *P. eremicus* may be more closely related to the fossil genus *Copemys* than to modern *Peromyscus*.

25. Three species of *Baiomys* are recognized from the Gila Conglomerate. *B. minimus* is one of the less well known species of the genus and is recorded from the Duncan fauna. *B. cf. brachygnathus* is a comparatively large species of the pygmy mouse; it is known from the upper part of the III Ranch section. *B. sp.* is a very small species represented by only an upper dentition; it is known from the lower part of the III Ranch section.

26. Two species of *Reithrodontomys* are recorded from the Gila Conglomerate. *R. rexroadensis* is a primitive species of the genus and
shares characters of both the R. fulvescens species group and the R. megalotis species group. It is known from both the Duncan (Duncan fauna) and the Safford (lower part of the Ill Ranch fauna) Basins. R. galushai, n. sp. is a more advanced species, with more characteristics of the R. fulvescens species group.

27. Calomys (Bensonomyx) arizonae is recorded from the lower part of the Ill Ranch section; it is not known above the Gauss-Matuyama magnetic chron boundary. C. arizonae may have disappeared about that time; the occurrence of this species in deposits younger than the Gauss magnetic chron in the San Pedro Valley is open to question. C. (B.) sp. is known only from the Duncan fauna.

28. Sigmodon medius is the most common and abundant species of the small mammals from the Gila Conglomerate. It is recorded from three faunas in the Duncan Basin and nearly entire Ill Ranch section. S. medius does not change significantly in size during the time span from the middle Gauss chron to the lowermost reversed zone of the Matuyama chron.

29. Three species of Neotoma (Paraneotoma) are recorded from the Gila Conglomerate. N. fossilis has been one of the less well known species of the genus; specimens from the Duncan fauna indicate that it should be referred to the subgenus Paraneotoma. N. (P.) quadriplicatus is a large species; it is known from the Country Club fauna, based on a single jaw. N. (P.) taylori is most abundant species of Neotoma from Ill Ranch; it is known from the 40-90 m level
of the 111 Ranch section. *N. taylori* is a more hyposodont pack rat than the two other species.

30. *Repomys arizonensis*, n. sp., is recorded from the 111 Ranch fauna. *R. arizonensis* represents a species intermediate in size and in certain characters between *R. gustelyi* and *R. panacaensis*. *R. arizonensis* probably represents a different lineage if the age assignment of *R. panacaensis* (middle Blancan) is correct.

31. Arvicolids are rather rare in Duncan basin. *Ophiomys cf. taylori* is recorded from the Duncan fauna; it is small and a primitive species of the rooted arvicolids. *Pliopotamys* sp. is very rare, known only from the Duncan fauna.

32. *Pliophenacomys primaevus* is recorded from the 111 Ranch fauna. *P. primaevus* is slightly smaller size than the Rexroad specimens of *P. primaevus*, but within the expected size range. The 111 Ranch fauna probably represents the latest known occurrence of the species.

33. *Mictomys (Metaxyomys) vetus* is known from the 111 Ranch fauna; it is one of the most common small mammals of the fauna. *M. vetus* is the only rootless arvicolid species recorded from the Gile Conglomerate. 111 Ranch documents the earliest known occurrence of the species.

34. *Neochoerus dichroplax* is a large rodent, and the only neotropical element within the small mammal fauna. It is recorded from the 111 Ranch fauna which may represent the earliest record of this species in North America.
REFERENCES CITED


