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MAGNETIC POLARITY STRATIGRAPHY OF THE CHAMITA FORMATION STRATOTYPE (MIO-PLIOCENE) OF NORTH-CENTRAL NEW MEXICO

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ABSTRACT. The Chamita Formation stratotype (uppermost Santa Fe Group) consists of 500 m of poorly indurated fluviatile clayey silts, silts, sands, and gravels. Two informal units termed "lower tuffaceous zone" and "upper tuffaceous zone," which extend from 120 to 180 m and 320 to 360 m, respectively, are rich in air-fall and reworked volcaniclastic sediments. A minimum of 3 samples were collected from the finer-grained sediments for each of 135 sites spaced at a maximum stratigraphic interval of 7 m throughout the stratotype. Based on preliminary alternating field demagnetization studies, all specimens were routinely demagnetized in fields of at least 150 oersteds. Some specimens required further demagnetization in fields of up to 500 oersteds. Curie Point temperature determinations, which range from 555° to 580°C for 5 specimens, show that the remanence is probably carried by an iron-rich member of the titanomagnetite solid solution series as detrital remanent magnetization.

Based principally on 111 statistically significant sites, the stratotype consists of 12 magnetic polarity zones designated as "N1-R6". Two previously published fission-track dates, one each from the lower and upper tuffaceous zones, and fossil mammals provide the independent control for the correlation of this magnetic polarity zonation to the standard magnetic polarity time scale. The mammalian assemblage from the stratotype consists of at least 19 taxa mostly concentrated at 325 m above the base. This fauna is similar to other late Hemphillian (late Miocene-early Pliocene) mammalian assemblages, for example, the Coffee Ranch Local Fauna from the Hemphillian stratotype.

Magnetic polarity zones N1 to N3, which extend from the base of the stratotype to 285 m, are predominantly of normal polarity; these zones represent medial to late epoch 5 time. Within epoch 5, the characteristic event A of reversed polarity, which extends from 110 to 165 m, is represented by zones R1-R2. Zones R3-R6, which extend from 285 m to the top of the stratotype, represent early to medial Gilbert time. Within the Gilbert, the characteristic event C of predominantly normal polarity, which extends from 375 to 470 m, is represented by zones N4-N5. The stratigraphic position of the fossil concentration at 325 m corresponds to early Gilbert time.

INTRODUCTION

The knowledge that the Earth's magnetic field has reversed in the geological past and that these reversals are frequently recorded in many types of rocks has provided geologists with a powerful tool for correlation. To a first-order approximation, the Earth's magnetic field can be modelled to that of a dipole magnet. When this dipole reverses, the change is a worldwide phenomenon that is recorded in rocks. Magnetic polarity stratigraphy is a subdiscipline of earth science that deals with the correlation of magnetic reversals. One of the most attractive facets of magnetic polarity stratigraphy is that remanence signatures are virtually independent of rock type, and, therefore, this method is less constrained by the problems of lithofacies and biofacies that have plagued the traditional stratigrapher.

Magnetic polarity stratigraphy is, however, dependent upon numerous subdisciplines for input of data. Once a "magnetic polarity zonation" is established in a given sequence, it is then necessary to draw upon some other information in order to place this zonation into a proper geochronological framework. In this report, this procedure is termed "magnetic polarity chronology." The independent data used for control have traditionally been derived from extrapolated rates of geological processes, such as those found in sea-floor spreading and sedimentation, radiometric age determinations, and biochronology of fossils.

Intensive research in magnetic polarity stratigraphy has been conducted for the last two decades. One of the primary goals of this research has been to establish a standard "magnetic polarity time scale" (MPTS). Concentrated efforts in construction of the MPTS were started by Cox, Doell, and Dalrymple (1963), who determined the polarity and radiometric ages of late Cenozoic volcanic rocks in the southwestern United States, and McDougall and Tarling (1963), who determined the polarity and radiometric ages of late Cenozoic basalts from Hawaii. These studies and many later ones led to the presentation of the MPTS for 0 to 4½ m.y. This standard time scale has undergone many additions and modifications, and it is still in a state of flux. The history of its development is complex and has been adequately reviewed elsewhere (for example, Dalrymple, 1972; Watkins, 1972). It is interesting to note that the MPTS for 0 to 4½ m.y. was developed in terrestrial sequences, but the application of this standard to ocean basins had a profound effect on the current revolution in earth science. Almost simultaneously with Cox, Doell, and Dalrymple (1963), Vine and Matthews (1963), in a classic paper, postulated that bilaterally symmetrical marine magnetic anomalies on either side of mid-oceanic ridges recorded reversals of the Earth's magnetic field and that this ocean floor record had resulted from axial spreading of crust. Vine and Matthews have since been credited with supplying the impetus that sparked the study of plate tectonics. Equipped with the knowledge of the late Cenozoic standard MPTS, Heirtzler and others (1968) extrapolated the marine magnetic anomaly data back in time to the late Cretaceous and produced the MPTS for approximately 0 to 80 m.y. This time scale has also been amended and modified (for example, Opdyke, Burkle, and Todd, 1974; Theyer and Hammond, 1974a, 1974b; Tarling and Mitchell, 1976), and Larson and Pitman (1972) have extended it further back in time to late Jurassic. Thus, a standard time scale has been produced for approximately 0 to 160 m.y. (for a recent review, see Irving and Pullaiah, 1976).

Concomitant with the study of marine magnetic anomalies, there has been much work on the magnetic polarity stratigraphy of layer 1 oceanic sediments. The magnetic polarity stratigraphy of these marine sediments is calibrated primarily by the biochronology of microfossils. The study of marine sediments has contributed numerous embellishments to the MPTS. The history of the development of marine magnetic polarity stratigraphy has been reviewed by workers such as Opdyke (1972), Watkins (1972), and Berggren and Van Couvering (1974).

More recently there has been much interest in the magnetic polarity stratigraphy of terrestrial mammal-bearing sequences throughout the world. North America potentially possesses many mammal-bearing sediments and has been a logical place for this type of investigation. A biochronologic zonation sequence for mammals that define North American Land Mammal "Ages" has been presented by Wood and others (1941), Evernden and others (1964), Evernden and Evernden (1970), McKenna and others (1973), Tedford and others (1973, in press), and Lundelius and others (1973). These reports (except Wood and others, 1941) incorporate relevant radiometric data. Therefore, the necessary preliminary control for the magnetic polarity stratigraphy of the North American sequences is available to a greater or lesser degree depending on the case in study.

Johnson, Opdyke, and Lindsay (1975) present the magnetic polarity stratigraphy of the Plio-Pleistocene sequence from the San Pedro Valley of southeastern Arizona that represents medial Gilbert to early Brunhes time (early Blancan to late Irvingtonian age). Lindsay, Johnson, and Opdyke and others (1977) present the magnetic polarity stratigraphy sequences in the western United States that represent late epoch 5 to early Brunhes time (medial Hemphillian to early Rancholabrean age). Opdyke and others (1977) present the magnetic polarity stratigraphy of the Anza Borrego State Park of southern California that represents medial Gilbert to medial Matuyama time (late Hemphillian to early Irvingtonian age).

The purpose of this paper is to present the magnetic polarity stratigraphy and mammalian biochronology of the Mio-Pliocene sediments of the Chamita Formation stratotype of north-central New Mexico. MacFadden (1975) and MacFadden and Manley (1976) have already presented preliminary summaries and MacFadden (ms) has presented a complete report of this research.

ABBREVIATIONS

The following abbreviations are used in the text:

MPTS — magnetic polarity time scale
a. f. — alternating field
NRM — natural remanent magnetization
oe — oersteds
L. F. — local fauna in the strict sense (see Tedford, 1970)
l. f. — an undescribed geographically restricted assemblage
AMNH — Department of Vertebrate Paleontology, The American Museum of Natural History, New York

F:AM — Frick: American Mammals, Department of Vertebrate Paleontology, The American Museum of Natural History, New York

UCMP — University of California Museum of Paleontology, Berkeley

GEOLOGICAL SETTING

The Chamita Formation stratotype is located at the apex of a triangle formed by the confluence of the Rio Grande and Rio Chama at an altitude of approx 1740 to 1920 m in the Espanola valley of northcentral New Mexico (fig. 1). These outcrops are approx 47 km northwest of Santa Fe and 62 km southwest of Taos and are represented on the northwest half of the U. S. Geol. Survey 7.5′ San Juan Pueblo Quadrangle (lat 36° 07′-36° 03′ N; long 106° 03′-106° 05′ E). The lower part of the stratotype is contained within "the NW ¼ of sect. 10 and the W ½ of sect. 3, T. 21 N., R. 8 E., in Rio Arriba County,

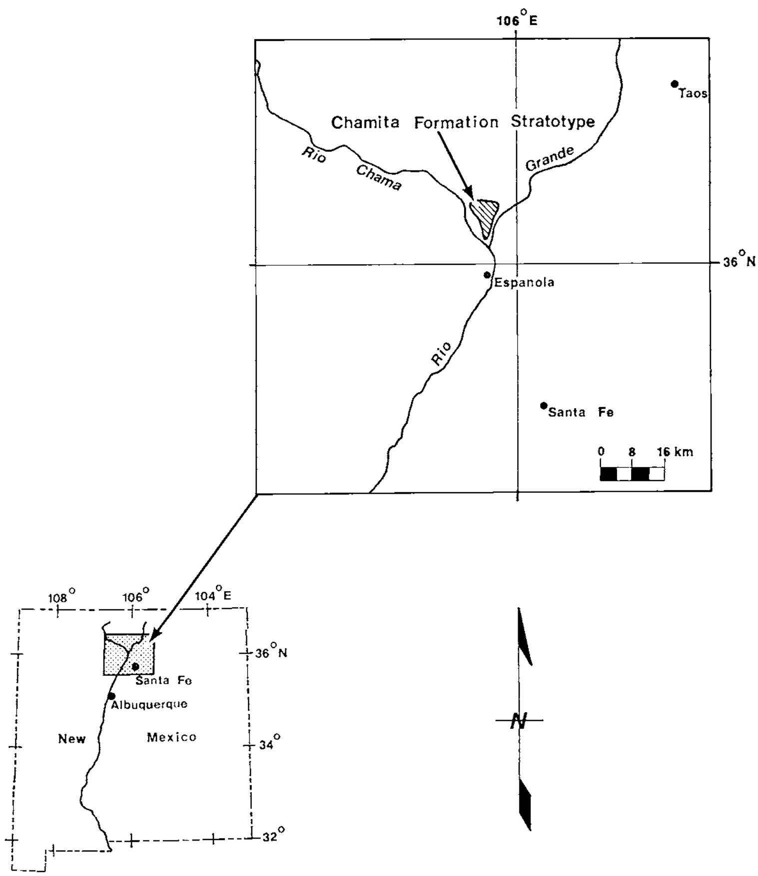


Fig. 1. Location of study area.

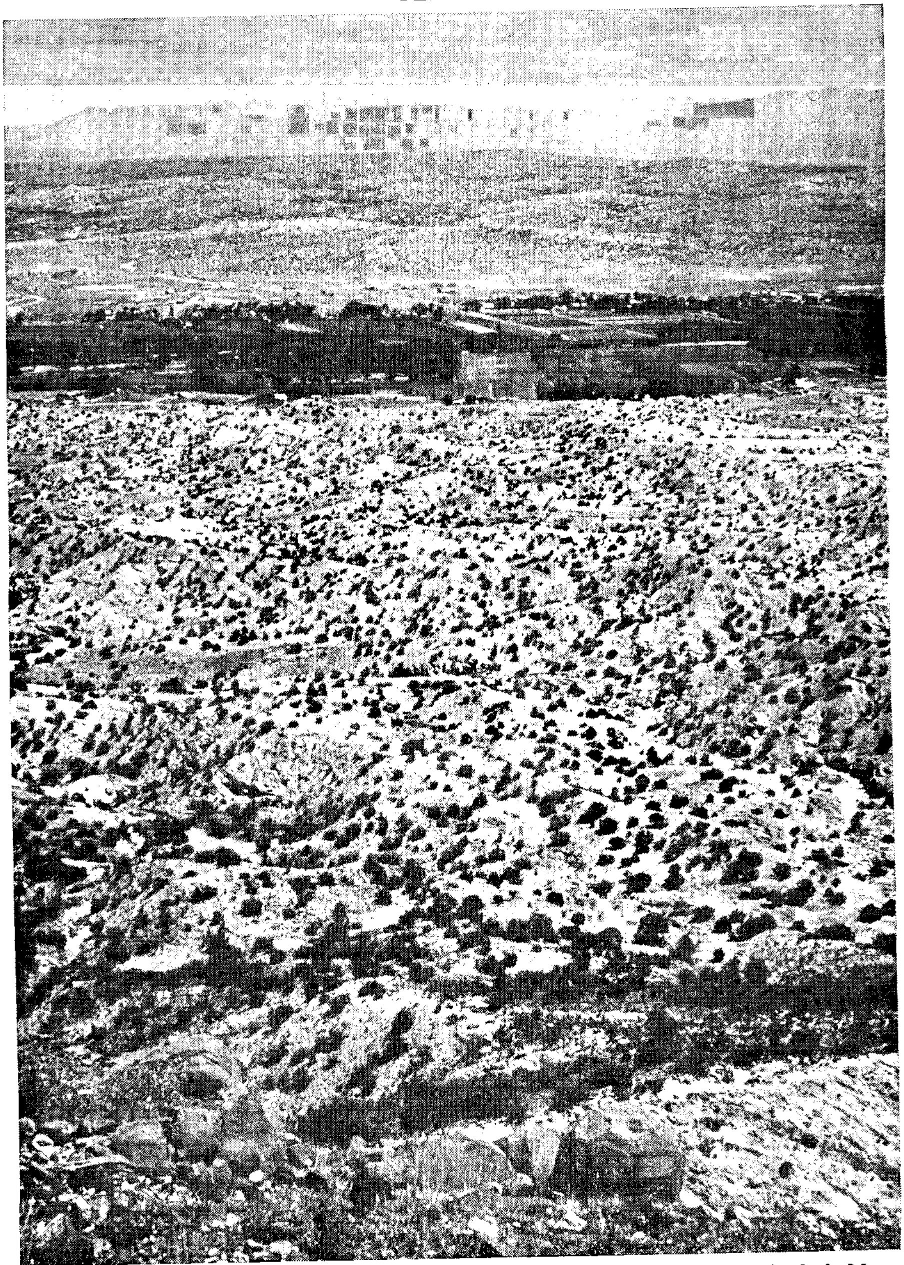
New Mexico (Galusha and Blick, 1971, p. 71)." The upper part of the stratotype is approx 4 to 5 km north-northwest of the lower stratotype (Galusha, personal commun., 1974; this report).

The Santa Fe Group consists of the Tesuque Formation overlain by the Chamita Formation (this latter unit was proposed by Galusha and Blick, 1971). Many geological aspects of these well-known sediments, first called "Santa Fe marls" by Hayden (1869), have been thoroughly discussed elsewhere (for example, Bryan, 1938; Denny, 1940; Kelley, 1952, 1956; Baldwin, 1956; Speigal and Baldwin, 1963; Galusha and Blick, 1971). In the broad sense, the Santa Fe Group has been a catch-all designation for a complex of fluviatile, aeolian, volcaniclastic, and extrusive igneous rocks that were deposited into the "Rio Grande depression" (Bryan, 1938, introduced this term). This major tectono-physiographic feature extends approximately 800 km from Leadville, Colo. to southern New Mexico and varies in width from approximately 15 to 60 km (Kelley, 1956; Chapin, 1971; Callender, Woodward, and Kelley, 1976; Cordell and Kottlowski, 1975). The Rio Grande depression is an approx north-south trending series of at least eight en echelon nearly contiguous horst-grabin basins. The Chamita Formation stratotype is found in one of these, the Espanola basin.

The Santa Fe Group is abundantly fossiliferous. In 1874, Cope first described fossil mammals collected from the Espanola basin (1874a, 1874b). During the present century, the Frick Laboratories, primarily under the direction of Ted Galusha and John C. Blick, collected thousands of specimens from this area over a period of decades. Galusha and Blick (1971) present a complete history of investigation of the Santa Fe fossil field. This same report discusses the biostratigraphy of some specimens, and Galusha (1974) presents a preliminary faunal list. The fauna is very diverse but has not been adequately studied. Taxonomic reports of Santa Fe fossils have been presented for carnivores (Frick, 1926a), mastodonts (Frick, 1926b, 1933), horned ruminants (Frick, 1937), and oreodonts (Schultz and Falkenbach, 1940, 1941, 1947, 1949, 1968). Some additional specimens were collected during the present study. It is beyond the scope of this paper to present a detailed taxonomic revision of the fauna from the Chamita Formation. The fossil mammals will be considered for their biochronologic value.

The Chamita Formation has a maximum thickness of 500 m in the stratotype and thins to a minimum of tens of meters in sections correlated to the stratotype. The stratotype is a composite of numerous local sections correlated to one another by laterally continuous marker horizons (see MacFadden, ms, app B). Locally, dips attain a maximum of about 25°; however, most of the Chamita Formation is of relatively low dip (less than 15°, see pl. 1). High-angle normal faults that trend approximately northwest-southeast are found throughout the stratotype. The base of the stratotype is not exposed, and correlation to sections where it lies on the Tesuque Formation is difficult. The

PLATE 1



Geological setting of Chamita Formation stratotype. View from top of Black Mesa looking approximately southeast. The sparsely vegetated badlands in the foreground include the upper part of the stratotype. These sediments dip approximately to the south. The fossiliferous horizon that includes San Juan and Rak Camel Quarries is found in this part of the section. The flat vegetated area in the far-middle distance is the flood plain of the Rio Grande. Farther to the southeast, past the Rio Grande flood plain, are more sediments of the Santa Fe Group. In the far distance are the Sangre de Cristo Mountains, which form the eastern boundary of the Rio Grande depression in the Espanola basin.

Chamita Formation is overlain by Plio-Pleistocene deposits of the Puyé Conglomerate, olivine tholeiites of the Servilleta Formation, and sediments of eroded high-level flood plain and pediment surfaces. Sediments of the Chamita Formation consist of poorly indurated tan, pink, and light brown clayey silts to medium sands. There are also interbedded conglomerates. Volcanic sediments include a basalt flow (approx 5 km west-southwest of the stratotype) and ashes that are rich in pumice and volcaniclastic fragments. These fragments have a maximum diameter of 2 cm and imply a relative close source, that is, the Jemez Mountains (Manley, personal commun., 1975). The ashes appear to be either primary air-falls or secondarily reworked. In the Chamita Formation stratotype these ashes are concentrated in two zones that have been informally referred to as the "lower and upper tuffaceous zones" by Galusha and Blick (1971), Galusha (1974), MacFadden (1975, ms) and MacFadden and Manley (1976). The fluviatile sediments of the Santa Fe Group, including those of the Chamita Formation, were probably deposited by alluvial fans in a semi-arid to humid climate (Bryan, 1938; Denny, 1940; Galusha and Blick, 1971).

PALEOMAGNETIC SAMPLING

A minimum of three separately-oriented samples were collected from each of 135 sites in the Chamita Formation stratotype. Within virtually every site, samples were separated by less than 1 m. Sites were chosen so that the maximum stratigraphic separation was no more than 7 m. Samples were exclusively collected from the clayey-silt through fine-sand fraction. Detailed stratigraphic sections, coordinated with a large-scale (1:2400) plane table survey, indicate lithologic units, paleomagnetic sites, and fossil quarries (see MacFadden, ms). Some sites were also collected from Chamita Formation sediments outside the stratotype. Due to the poorly indurated nature of most of the sediments, samples had to be collected with great care. Large oriented hand samples were extracted and carefully wrapped for shipping.

In the laboratory, the poorly indurated samples were cut to slightly larger than desired size on either a band saw or a metal-cutting hand saw. The specimens were then sanded into standard 2.54 cm cubes. The few samples that were well indurated due to the presence of calcium carbonate matrix were easily prepared on a diamond-bladed circular saw. By virtue of careful collection and preparation, approx 98 percent of the samples were found suitable for paleomagnetic analysis.

MAGNETIC MEASUREMENTS

Paleomagnetic specimens were measured on a high sensitivity, slow speed (7 hertz), fluxgate spinner magnetometer integrated with a DIGICO computer of the type described by Molyneaux (1971). A. f. demagnetization was performed on an apparatus similar to that described by McElhinny (1966). Susceptibility measurements were made on a commercially available susceptibility bridge.

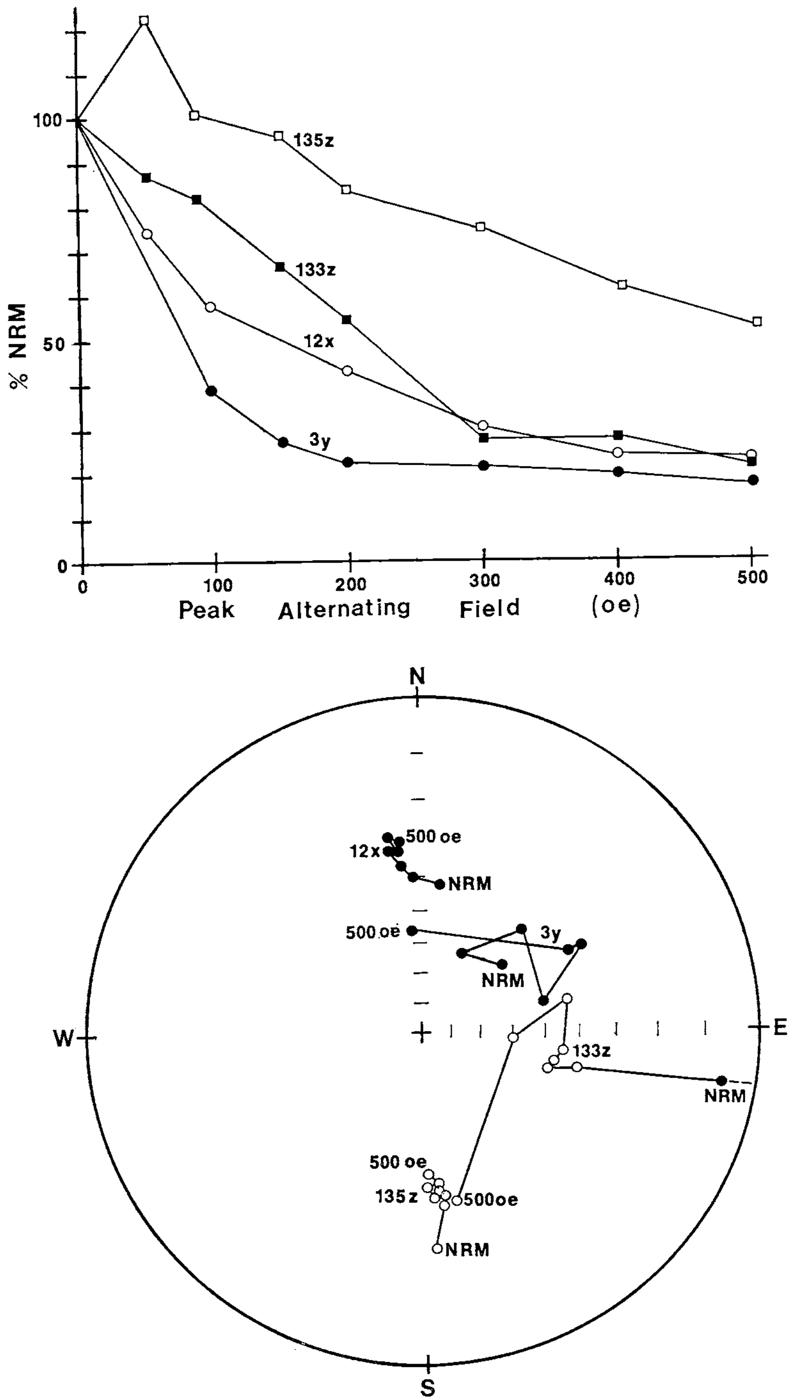


Fig. 2. Alternating field demagnetization curves for 4 specimens and equal-angle stereographic projections of same specimens showing change in directions of magnetization at successive alternating field demagnetizations. Filled circles represent positive inclinations, and open circles represent negative inclinations.

Preliminary demagnetization in successive peak alternating fields of up to 500 oe was performed on selected specimens from throughout the Chamita Formation stratotype. The median destructive field is usually between 100 to 150 oe. The majority of specimens, represented by 12x and 135z in figure 2, have weak secondary magnetizations that are removed in low demagnetizing fields. When viewed from equal-angle stereographic projection, these specimens rapidly attain what appears to be the primary direction of magnetization. Based on preliminary results, it was decided that all specimens be demagnetized in fields of at least 150 oe. During this routine demagnetization, it was found that specimens, such as 3y and 133z in figure 2, from a few sites, demonstrated behavior different from the majority of specimens. Little consistency within sites was seen from these specimens after demagnetization in fields of up to 500 oe. At 500 oe, some of these specimens appear to attain primary directions of magnetization and others appear unstable. Many of these sites were later considered to be of indeterminate polarity (see discussion below) or were rejected because they are statistically random.

NRM intensities for 101 specimens range from 1.66×10^{-6} emu/cc to 3.90×10^{-4} emu/cc with a geometric mean of 2.69×10^{-5} emu/cc (fig. 3). Intensities of magnetization for the same 101 specimens after demagnetization in peak alternating fields of 150 oe range from 8.21×10^{-7} emu/cc to 6.00×10^{-4} emu/cc with a geometric mean of 1.03×10^{-5} emu/cc. The bimodal distribution of intensities of magnetization at 150 oe (fig. 3, bottom) does not appear to be related to possible systematic factors such as lithologic differences. The susceptibility (χ), which was measured for 90 specimens, ranges from 6.28×10^{-7} emu/cc to 7.38×10^{-5} emu/cc with a geometric mean of 8.01×10^{-6} emu/cc. The ratio of NRM/χ for most of these specimens implies that they are probably stable (see Irving, 1964, p. 92). Based on the measurements presented above, it appears that these sediments, with a few exceptions, possess a relatively stable magnetization.

Whenever possible, it is desirable to determine which magnetic mineral is the principal carrier of the remanence. Identification of the dominant magnetic mineral oftentimes provides a clue to the mode of acquisition of the remanence. In this context, magnetic mineral separations were made for five specimens from representative lithologies spaced throughout the stratotype. The method of separation, which employs a modified Franz isodynamic separator, is described by Løvlie, Lowrie, and Jacobs (1972).

Thermomagnetic (J_s-T, where J_s is saturation magnetization and T is temperature) curves for each specimen (fig. 4) were next obtained from Curie Point balance determinations made on an apparatus described by Kent and Lowrie (1974). Curie Point temperatures (θ_c) were interpreted from these curves based on the graphic method described by Grommé, Wright, and Peck (1969).

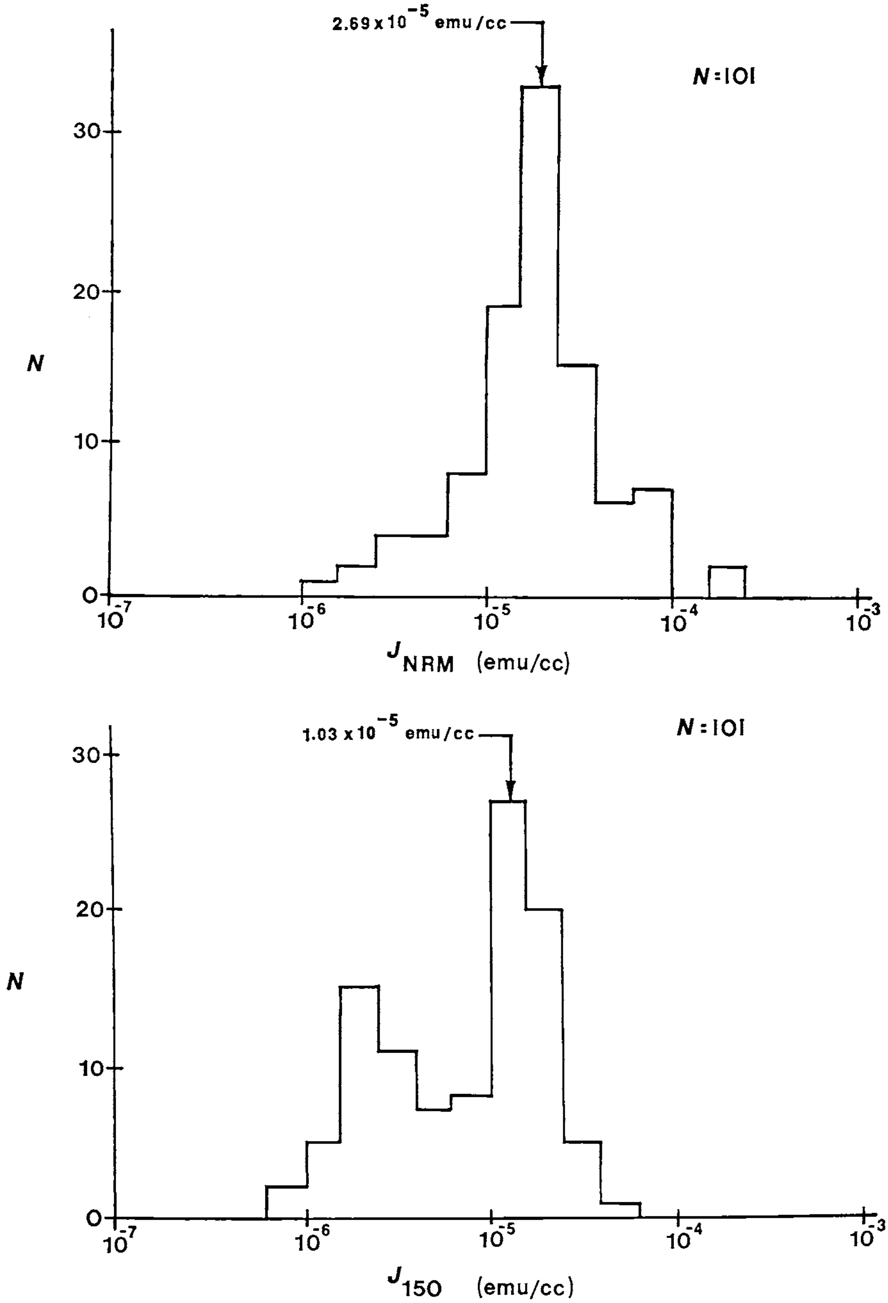


Fig. 3. NRM intensities of magnetization and intensities of magnetization after demagnetization in peak alternating fields of 150 oe. Geometric mean values for each are indicated by arrows.

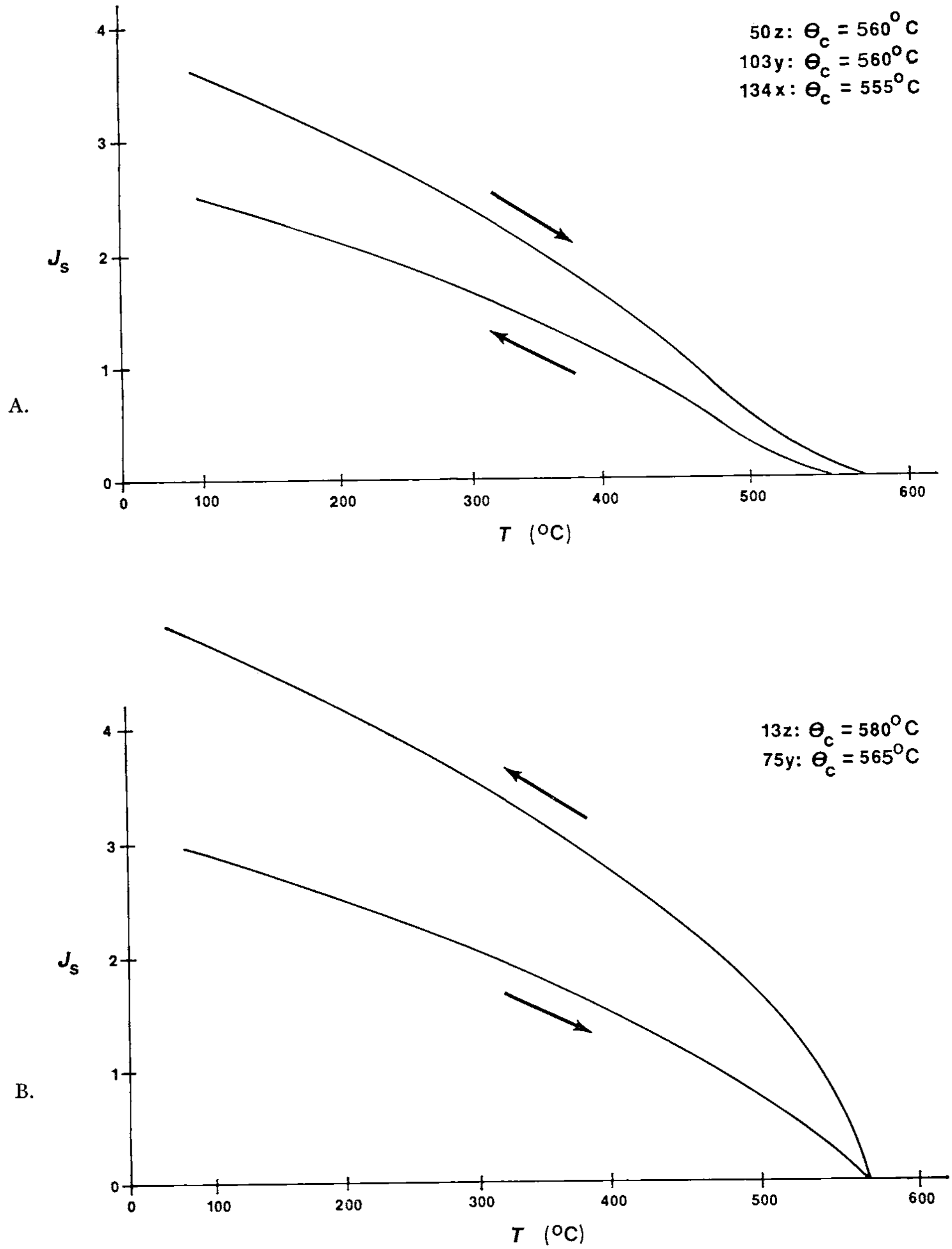


Fig. 4. Thermomagnetic (J_s-T) curves for magnetic mineral separations from 5 specimens (13z, 50z, 75y, 103y, 134x). Specimens are divided into two groups, represented by top and bottom curves, based on general behavior during heating and cooling. Saturation magnetization (J_s) is represented by arbitrary units. Curie point temperatures (θ_c) are indicated for each specimen.

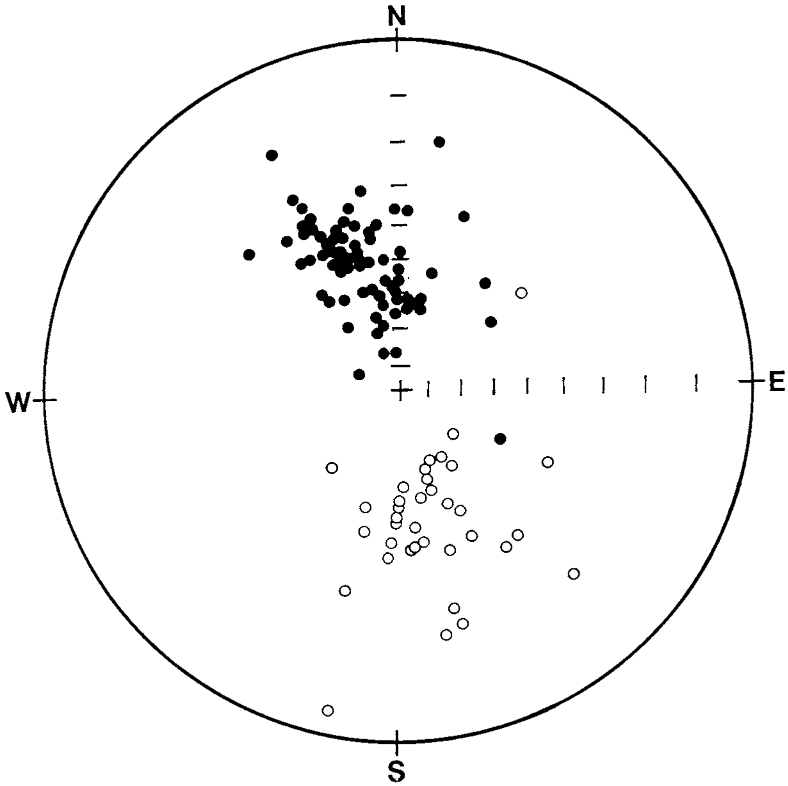


Fig. 5. Equal-angle stereographic projections of means for all 111 statistically significant sites. Filled circles represent positive inclinations, and open circles represent negative inclinations.

The behavior of the principal magnetic mineral, as evidenced in the thermomagnetic curves, can be classified into two groups: 1. Heating curve exhibits greater J_s than cooling curve (fig. 4, top). 2. Cooling curve exhibits greater J_s than heating curve (fig. 4, bottom). This latter type of curve is less common, and similar behavior is discussed for basalts (Grommé, Wright, and Peck, 1969) and marine volcanic ashes (Kent, ms.). This behavior results from the fact that the specimens were heated and cooled in air, as opposed to a vacuum. The greater J_s acquired during cooling is probably caused by oxidation of an unstable form of titanomagnetite (O'Reilly and Banerjee, 1967; Grommé, Wright, and Peck, 1969).

Stacey and Banerjee (1974) tabulate Curie Point temperatures for the titanomagnetite solid-solution series (Fe-Ti-O system). In this system, Curie Point temperatures are directly proportional to Fe content and attain a maximum of approximately 580°C for the magnetite end member. In the present study, θ_c ranges from 555° to 580°C. Therefore, based

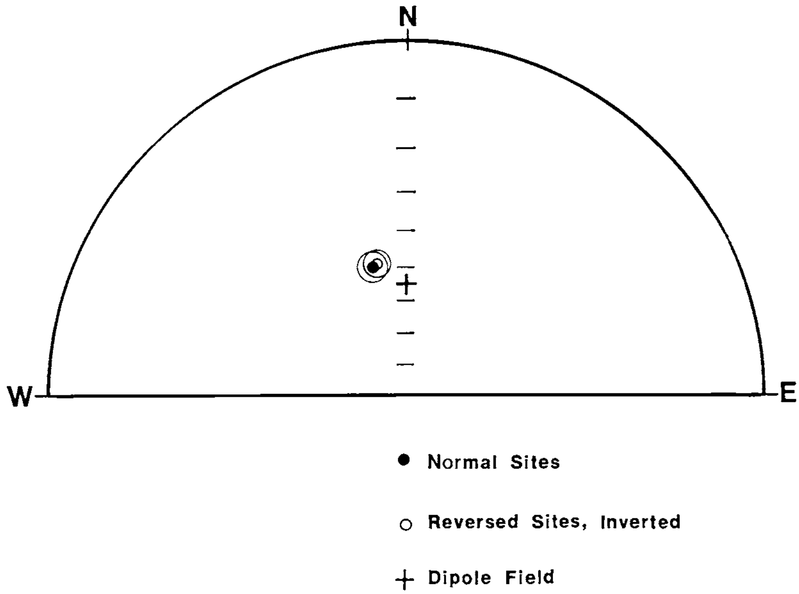


Fig. 6. Reversals test for consistency. Means of all normal and reversed sites with 95 percent circles of confidence for each. Note divergence from calculated dipole field (see discussion in text).

on thermomagnetic analysis, the principle magnetogenic mineral is an iron-rich titanomagnetite, which, in a sedimentary environment, usually indicates that the primary remanence was acquired by detrital remanent magnetization (DRM) during the process of sedimentation.

The directional data after maximum a. f. demagnetization of all specimens and sites were statistically analyzed using the method described by Fisher (1953). All sites were rejected in which the significance points were random at the 95 percent probability level. One-hundred eleven of the 135 sites collected from the Chamita Formation stratotype are statistically significant. These sites are interpreted as follows; 71 of normal polarity, 35 of reversed polarity, 2 of intermediate polarity, and 3 of indeterminate polarity (see discussion of these latter sites below). Mean directions for all these sites are plotted on equal-angle stereographic projection in figure 5. The normal sites have declinations less than the expected 360°, assuming an axial geocentric dipole for at least the Cenozoic. The reversed sites have declinations less than the expected 180°. The explanation for this observation is not clear, but it could possibly be a result of some small-scale tectonic rotation.

The normal sites have a mean direction of declination 345.4°, inclination 49.8° ($k = 21.7$, $\alpha_{95} = 3.6°$), and the reversed sites have a mean direction of declination 166.9°, inclination −46.7° ($k = 16.3$, $\alpha_{95} = 6.1°$). The mean of all normal and reversed (inverted) site directions is declination 345.8°, inclination 48.8° ($k = 19.7$, $\alpha_{95} = 3.1°$), as shown in figure 6.

Zone R6, represented by 6 sites, extends from 470 m to the top of the stratotype.

Magnetic polarity stratigraphy consists of two interrelated phases that are termed "magnetic polarity zonation" and "magnetic polarity chronology" in this paper (also see Oriel and others, 1976; Watkins, 1976). Once a magnetic polarity zonation has been established for a given sequence, it is next desirable to correlate this zonation to the MPTS. This correlation has usually been achieved by one or more of the methods mentioned above. In the present study, radiometric age determinations and mammalian biochronology provide the principal input of data to determine the magnetic polarity chronology of the Chamita Formation stratotype.

MAMMALIAN BIOCHRONOLOGY

Fossil mammals are abundant in the Chamita Formation stratotype. These are preserved as weathered scraps of bone frequently found throughout the section and remains occasionally found *in situ*. The majority of well-preserved fossil mammals come from a horizon of green silty clay in which the San Juan and Rak Camel Quarries (collectively referred to below as "San Juan-Rak Camel Quarries horizon") are found. San Juan Quarry is located on the south side of an east-west trending ridge crest approximately 250 m south of Arroyo de los Borregos and 250 m west of New Mexico route 291 (lat 36° 6′ N; long 106° 4′ E; U.S. Geol. Survey San Juan Pueblo 7 1/2′ Quadrangle). The Rak Camel Quarries are found a few hundred meters north and northwest of San Juan Quarry on the north side of the same ridge crest and south of Arroyo de los Borregos. The Rak Camel Quarries consist of numerous localities within the same horizon as San Juan Quarry. All quarries are 5 m above the base of the upper tuffaceous zone. They are also 1 m above the top of magnetic polarity zone I1.

At least 19 taxa of fossil mammals are found in the stratotype (table 1). As mentioned above, most of this fauna comes from one horizon. The remainder comes from scattered occurrences elsewhere in the section. Fossil occurrence data are indicated with varied limits in figure 8 based on available field records. In the present discussion, only taxa with adequate stratigraphic data are considered. Some specimens can be located precisely to a given stratigraphic horizon. These specimens are indicated with arrows pointing to the respective horizon (fig. 8). Other specimens can only be located within some stratigraphic interval as indicated by brackets (fig. 8). It is important to note that the brackets should not be mistaken for teilzones (observed local stratigraphic ranges of taxa).

Basically, three methods are used to determine a biochronology of an assemblage of fossil mammals (for a discussion, see Tedford, 1970): (1) first appearance of taxa, termed "datum planes" (see Berggren and Van Couvering, 1974; Johnson, Opdyke, and Lindsay, 1975; Lindsay, Johnson, and Opdyke, 1975; Opdyke and others, in press), (2) last appearance of taxa, also termed "datum planes,"and (3) concurrent range zones, also

TABLE I

Mammalian fauna from the Chamita Formation stratotype

Class MAMMALIA*

Order EDENTATA
- Family Megalonychidae
  - ?*Pliometanastes galushai*

Order LAGOMORPHA
- Family Leporidae
  - *Hypolagus vetus*

Order RODENTIA
- Family Mylagaulidae
  - ?*Mylagaulus* sp.
- Family Castoridae
  - *"Dipoides" williamsi*
- Rodentia, indeterminate

Order CARNIVORA
- Family Canidae
  - *Canis davisi*
  - *Aelurodon* cf. *haydeni*
- Family Procyonidae
  - *Bassariscus* sp.
- Family Mustelidae
  - *Plesiogulo* sp.
  - *Pliotaxidea garberi*

Order PROBOSCIDEA
- Family Gomphotheriidae
  - ?Longirostrine gomphotheriid

Order PERISSODACTYLA
- Family Equidae
  - *Astrohippus ansae*
  - *Dinohippus interpolatus*

Order ARTIODACTYLA
- Family Camelidae
  - *Megatylopus matthewi*
  - *Hemiauchenia vera*
  - *Hemiauchenia* sp.
- Family Antilocapridae
  - *Osbornoceros osborni*
  - *Ilingoceros alexandrae*
  - ?*Plioceros* sp.

* Higher categories follow classification of Simpson (1945).

termed "Oppelian Zones." For the purposes of establishing a biochronology of the fauna from the Chamita Formation stratotype, the latter method will be used exclusively. The first two methods are not applicable because the fossil information content in this fauna is not sufficient to make relevant statements concerning datum planes.

In the general overview, that is, with respect to higher categories, the fauna from the Chamita Formation stratotype is of Hemphillian age with many of the definitive faunal elements listed by Wood and others (1941, p. 12):

> "Hemphillian age — new provincial time term, based on the Hemphill member of the Ogallala [Group], which includes both the Hemphill local fauna from the Coffee Ranch Quarry and the Higgins local fauna, Hemphill County, Panhandle of Texas.
>
> Principal correlatives: Edson, Feldt Ranch, Wray, Thousand Creek, Rattlesnake.
>
> Index fossils: *Agriotherium, Dipoides, Ilingoceros, Plesiogulo.*
>
> First appearance: ground sloths, *Lutravus, Machairodus, Taxidea.*
>
> Last appearance: *Aphelops, Blastomeryx, Mylagaulus, Osteoborus, Pliauchenia, Pliohippus, Prosthenops,* rhinoceroses, *Sphenophalos Teleoceras.*
>
> Characteristic fossils: *Hypolagus, Megatylopus, Nannippus, Neohipparion.*"

Numerous taxa listed in the Wood Committee's definition of the Hemphillian are present in the fauna from the Chamita Formation stratotype.[1] The absence of certain taxa can be attributed to a few factors: (1)

[1] The Wood Committee lists "first appearance" and "last appearance" for certain Hemphillian faunal elements. In the present study, some of these same taxa, which are found in the Chamita Formation stratotype, are discussed with respect to their teilchrons (observed time ranges) and not their datum planes.

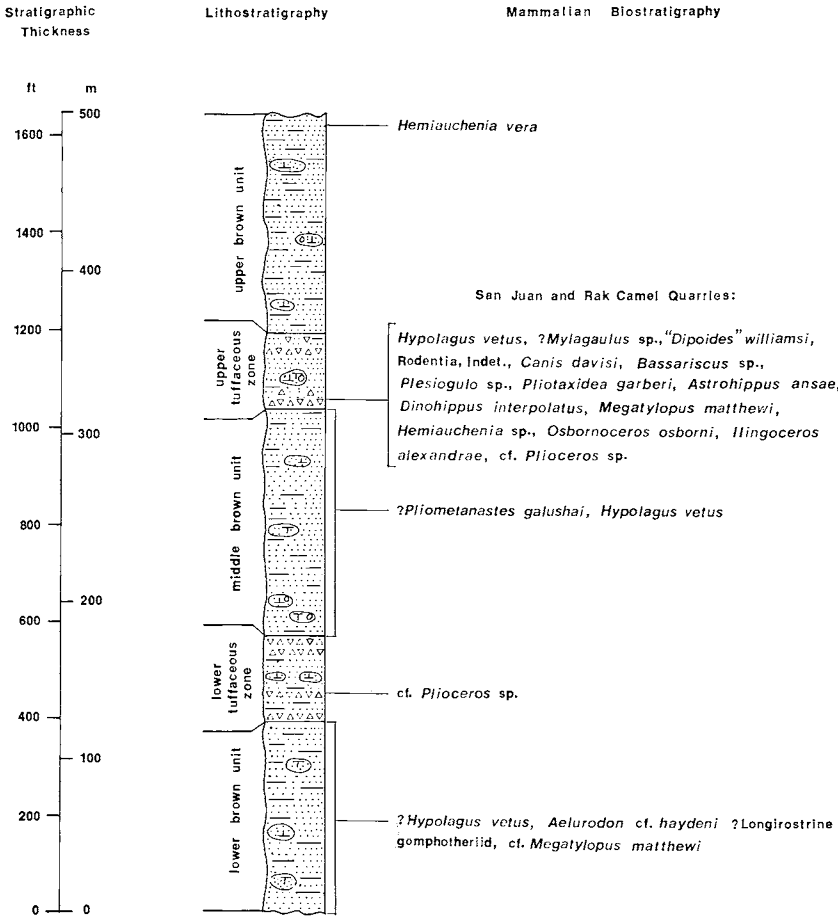


Fig. 8. Mammalian biostratigraphy of the Chamita Formation stratotype. See figure 7 for lithologic symbols.

This fauna represents a portion of time that is later than the last occurrence of some Hemphillian taxa, for example some horses. (2) Some faunal elements, particularly carnivores, when present in other Hemphillian assemblages, constitute a very small percentage of the individuals present (in contrast to ungulates). The absence of certain mammals in the stratotype is probably a result of sampling bias and not a biological phenomenon (for a discussion of sampling in mammalian assemblages, see Wolff, 1975). (3) Certain Hemphillian faunal elements had biogeographic ranges outside the stratotype and hence are not represented. (4) There has been a collecting bias against small-bodied forms, for example, insectivores, rodents, and lagomorphs. These factors should be tempered with the realization that the fauna from the stratotype, with only a minimum of 19 taxa present, is not an actual sample of the mammalian paleocommunity. It is actually a taxonomically small assemblage that can be attributed to an inadequate sample.

Approximately 4 m.y., from 8½ to 4½ m.y., are represented by Hemphillian time (Tedford and others, in press).[2] For the moment, let us set aside the radiometric data and discuss the power of resolution of the fauna from the Chamita Formation stratotype in its own right. We already know, based on a comparison of higher categories, that this fauna is of Hemphillian age. We also know that the Hemphillian spans approx 4 m.y. Given the frequency of geomagnetic reversals during the late Cenozoic, which is on the order of one per 10^5 yrs, it is not possible to correlate the magnetic polarity zonation of the stratotype to the MPTS using its mammalian fauna at this power of resolution. We actually need to examine more subtle aspects of this fauna, that is, whenever possible, to compare taxa with other Hemphillian assemblages on the species level. The following discussion presents an analysis of the biochronologic utility of the individual taxa of the fauna from the Chamita Formation stratotype.

?Pliometanastes galushai.—A single lower jaw of this megalonychid sloth, F:AM 77811, is described by Hirschfeld and Webb (1968). The authors list its occurrence from (1968, p. 283) "horizon stratigraphically between Round Mountain and San Juan Quarry." Galusha (personal commun., 1974) locates this specimen in the middle brown unit north of the stratotype. The genus *Pliometanastes* is found at many other localities that are all probably of early Hemphillian age (Hirschfeld and Webb, 1968; Tedford and others, in press). For reasons given below, and assuming that *?P. galushai* is most properly placed in this genus, the presence of this sloth in the fauna from the stratotype represents an extension of its teilchron.[3] The concurrent range zonation for this fauna is given in figure 9.

Hypolagus vetus.—Numerous specimens of this rabbit are known from the ?lower brown unit (postcranials), middle brown unit, and the San Juan-Rak Camel Quarries horizon. These specimens exhibit the deep, cement-filled anteroexternal fold and crenulated hypostriae on P_3 that are diagnostic for the genus. *H. vetus* from the stratotype agree with published measurements for material from the Thousand Creek Fauna, early Hemphillian of Nevada. This species also questionably occurs in sediments ranging from late Clarendonian to Blancan age from the Great Plains to Oregon (Hesse, 1935; Dawson, 1958; Tedford and others, in press).

[2] I am particularly grateful to Dr. Richard H. Tedford for allowing access to the presently unpublished manuscript cited above. This report provides a synthesis of mammalian biochronology that has been indispensible during the course of the present research.

[3] The species *?P. galushai* is of little biochronologic value, since it is restricted to the Chamita Formation stratotype. In the present discussion, the polytypic genus *Pliometanastes* is used for biochronologic analysis.

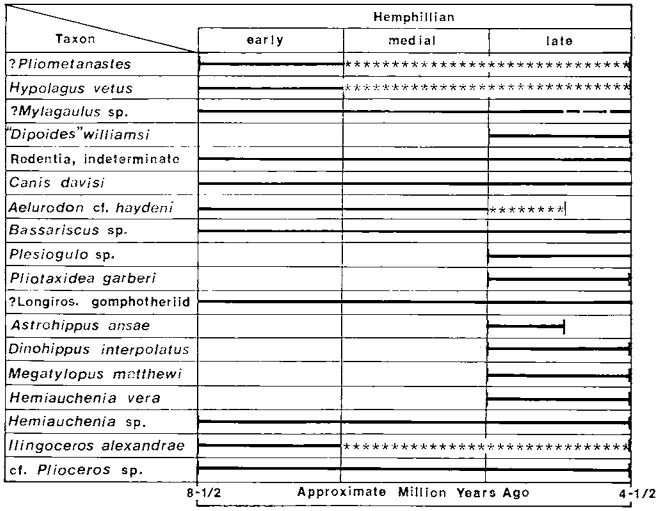


Fig. 9. Concurrent range zonation of the fauna from the Chamita Formation stratotype. Dashed lines indicate questionable range. Asterisked lines imply range extensions (see discussion in text).

?Mylagaulus sp.—A right lower jaw of this rodent, AMNH 100098, is from one of the Rak Camel Quarries. The taxonomy of mylagaulids is based primarily on the development of lakes in P_4 (Shotwell, 1958). In this specimen, the P_4 is missing unfortunately, and no reliable taxonomic assessment can be made. Mylagaulids are relatively rare in Hemphillian assemblages, but they have been reported from various localities; for example, Rome Fauna, early Hemphillian of Oregon (Shotwell, 1958); Feldt Ranch L.F., early Hemphillian of Nebraska (Hesse, 1935); McKay Reservoir L.F., late Hemphillian of Oregon (Shotwell, 1958); and Optima L.F., late Hemphillian of Oklahoma (Hesse, 1936). The mylagaulid from the Chamita Formation stratotype is questionably referred to *Mylagaulus, faute de mieux,* because all other Hemphillian mylagaulids are placed in this genus. This is admittedly circular reasoning, and little can be said about the biochronology of this taxon.

"Dipoides" williamsi.—Several specimens of this beaver are known from the San Juan-Rak Camel Quarries horizon. These agree in dental characters and size with the description given by Stirton (1936) and Shotwell (1955) from the White Cone L.F., late Hemphillian of Arizona (Stout, personal commun., 1976). The White Cone L.F. is bracketed by a maximum date of 6.7 m.y. (Scarborough, Damon and Shafiqullah, 1974) and a minimum date of 4.1 m.y. (Evernden and others, 1964). The magnetic polarity zonation of the Bidahochi Formation, in which this local fauna is found, is predominantly of normal polarity. This zonation probably correlates, at least in part, with epoch 5 of the MPTS (Opdyke, personal commun., 1976).

Rodentia, indeterminate.—Numerous unprepared specimens of rodents, which probably represent more than one taxon, are known from the San Juan-Rak Camel Quarries horizon.

Canis davisi.—There are several dentitions of this dog from the San Juan-Rak Camel Quarries horizon. There appears to be a progressive increase in size of this species correlated with time. The *C. davisi* specimens from the Chamita Formation stratotype are relatively large and compare with other samples from late-latest Hemphillian local faunas, for example, the undescribed Wikieup l. f. from Arizona (Taylor, personal commun., 1976).

Aelurodon cf. *haydeni.*—A partial lower jaw of this dog-like mammal, F:AM 27359A, is known from near the base of the stratotype, most probably from the lower brown unit. The cheek teeth are broken off at the base of the crown, and little of significance can be said with respect to dental morphology. However, the size of this specimen is significant; it is one of the largest and most robust in the AMNH-F:AM collection. The genus *Aelurodon,* as presently recognized, shows a great increase in size in later, that is, Hemphillian, forms. Leidy (1858) included large forms of this genus in the species *A.* (subgenus *Epicyon*) *haydeni.* Because of its large size, F:AM 27359A apparently represents a late form. *Aelurodon* cf. *haydeni* is known from some late Hemphillian localities, for example, Higgins L. F. of Texas (Hesse, 1940), but it is not known from other late-latest Hemphillian localities (Tedford and others, in press).

Bassariscus sp.—Two lower jaws of this racoon-like mammal are known from the Chamita Formation stratotype. AMNH 100099, which consists of teeth mostly broken off from below the crowns, is from one of the Rak Camel Quarries. F:AM 49210, which has some of the molars preserved, is from San Juan Quarry. The molars in the latter specimen are relatively robust and apparently represent an advanced form. The genus *Bassariscus* is known from the Hemingfordian to the Recent, and the specific biochronology has not been adequately presented. Earlier forms are relatively small, and there is a general trend toward increased size. The *Bassariscus* from the stratotype is similar to some other late-latest Hemphillian samples, for example, the F:AM specimens from the Wikieup l. f. of Arizona.

Plesiogulo sp.—A fragmentary palate of this carnivore, F:AM 49230, is known from the San Juan-Rak Camel Quarries horizon. The presence of *Plesiogulo* represents dispersal into North America during the late Hemphillian (Tedford and others, in press). In the AMNH-F:AM collection, besides its occurrence in the Chamita Formation stratotype, *Plesiogulo* is also found in the following late Hemphillian assemblages; Bone Valley Fauna of Florida, Edson L. F. of Kansas, Guymon Quarries, of Oklahoma, Coffee Ranch L. F. of Texas, Old Cabin Quarry l. f. of Arizona, and Wikieup l. f. of Arizona.

Pliotaxidea garberi.—One lower jaw with P_4-M_2 of this badger, F:AM 49232, is known from the San Juan-Rak Camel Quarries horizon. Wagner (1976) recently reviewed the specific taxonomy of the genus *Pliotaxidea* and recognized two species, *P. nevadensis* and *P. garberi*. The dental characters that differentiate these two species are principally found in the cusps of M^1. The lower dental morphology is not diagnostic, and with only the lower jaw, relative size becomes important in specific identification. The lower dentition of the type of *P. nevadensis,* UCMP 22290, appears to be significantly smaller than that of the type of *P. garberi,* UCMP 52422. The lower dentition of the badger from the Chamita Formation stratotype is very robust, even slightly more so than the type of *P. garberi,* and it apparently represents an advanced, that is, late Hemphillian, form.

?Longirostrine gomphotheriid.—Frick (1933, p. 643) illustrates an incomplete upper dentition, which includes both deciduous and permanent cheek teeth. Frick Laboratory field records for this specimen list the locality as; "San Juan, 1 mile up river from bridge in green layer." This occurrence is most probably from the lower brown unit in the southern part of the stratotype. This specimen is of little biochronologic significance due to its questionable taxonomy and stratigraphic position. Virtually its only value is to record the presence of a gomphotheriid in this fauna and to indicate a late Cenozoic teilchron.[4]

Astrohippus ansae.—Numerous specimens of this horse are known from the San Juan-Rak Camel Quarries horizon. This sample is similar in dental pattern and size to *A. ansae* from the Coffee Ranch L. F., late Hemphillian of Texas (Matthew and Stirton, 1930; Stirton, 1940). The teeth of *A. ansae* are much larger than *A. stockii,* a latest Hemphillian species described from the Yepómera Fauna of Chihauhua, Mexico (Lance, 1950). *A. ansae* has less anteriorly elongated protocones and less anteroposteriorly elongated metaconids and metastylids than does *A. stockii.* Based on the similarity to the *A. ansae* from the Coffee Ranch L.F., the *A. ansae* from the Chamita Formation stratotype indicates a late, but not latest, Hemphillian age.

Dinohippus interpolatus.—One lower jaw, F:AM 100091, and one lower molar of this horse are known from the San Juan-Rak Camel Quarries horizon. It compares both in dental characters and size with the sample from the Coffee Ranch L.F., late Hemphillian of Texas (Matthew and Stirton, 1930). Besides these occurrences, *D. interpolatus* is also known

[4] Tobien (1973, p. 223) records the presence of *"Trilophodon (Tatabelodon) riograndensis"* from the "Chamita formation, which is of Hemphillian age, i.e. medial Pliocene or even partially of the early part of the late Pliocene (Galusha and Blick, 1971: 7, 10)." It should be noted that the remains of this gomphothere are actually from Battleship Mountain (Frick, 1933, p. 533). Presently, there is no way to corroborate the hypothesis that the Battleship Mountain locality is of Hemphillian age. It is just as plausible that this locality correlates to Round Mountain Quarry, which appears to have a late Clarendonian aspect to its assemblage.

from other late Hemphillian sites, for example, the Turlock Lake L.F. of California (Wagner, 1976).

Megatylopus matthewi.—Several specimens of this camel are known mostly from the San Juan-Rak Camel Quarries horizon. There are also some large camelid postcranials from the lower brown unit that are referred to this species. *M. matthewi* can be diagnosed by the reduced P^3 with a complete posterointernal crescent and a reduced, but present, P_3 (Webb, 1974). The type material of *M. matthewi* comes from the Coffee Ranch L. F., late Hemphillian of Texas. The sample from the Chamita Formation stratotype is similar to that of the Coffee Ranch L. F. and suggests a late Hemphillian age.

Hemiauchenia.—Several specimens of what appear to be two species of llama are present in the Chamita Formation stratotype. These exhibit the generic characters of *Hemiauchenia* as diagnosed by Webb (1974) such as the "llama buttresses" (anteroexternal and anterointernal stylids) and reduced, simple, and triangular P_4. The larger species, *H. vera,* is represented by one lower jaw, F:AM 47940, and some referred metapodials from approx 10 m below the top of the stratotype. This sample is similar in dental morphology and size to that of some other late Hemphillian localities, for example, Higgins and Coffee Ranch L. F.'s. The smaller species, *H.* sp., is known from several specimens from the San Juan-Rak Camel Quarries horizon. This species is significantly smaller than the hypodigm of *H. vera*. In particular, the cheek teeth are very narrow transversely. The presence of *H.* sp. probably indicates a Hemphillian age (Webb, 1974).

Antilocaprids.—There are at least two, and possibly three, taxa of antelopes from the stratotype, namely, *Osbornoceros osborni, Ilingoceros alexandrae,* and cf. *Plioceros* sp. Frick (1937) bases the taxonomy of antilocaprids primarily on the morphology of horn cores. *Osbornoceros* is a small-sized form with curved, pointed, and gracile horn cores. *Plioceros* is an intermediate-sized form with robust horn cores that bifurcate distally. *Ilingoceros* is a large-sized form with spiralled horn cores. The dental morphology of these antilocaprids is very conservative, and it is of little value in the identification of particular taxa. Without horn cores available, it is necessary to separate these taxa based on size. The identifications that follow are basically those of Frick (1937).

Osbornoceros osborni is represented by numerous dentitions from the San Juan-Rak Camel Quarries horizon. This sample appears to represent a discrete group of small-sized forms. The monotypic genus *Osbornoceros* is known only from the stratotype and referred sections of the Chamita Formation. Little can be said with regard to the biochronological significance of this taxon, since it is not recognized in other assemblages. A diagnostic sprialled horn core fragment of *Ilingoceros,* F:AM 52153, is from the San Juan-Rak Camel Quarries horizon, and it compares in size with the larger species, *I. alexandrae*. There are also numerous large-sized dentitions from this same horizon that are referable to *I. alexandrae*.

The type locality and only other published occurrence of this species is from the Thousand Creek Fauna, early Hemphillian of Nevada (Frick, 1937; Tedford and others, in press). There are numerous specimens of intermediate size that are questionably referred to *Plioceros* sp. These appear to represent a discrete group, but they could also be statistical end-members of the range of variation of either *Osbornoceros* or *Ilingoceros*. There is one specimen, AMNH 100090, that is from the lower tuffaceous zone, 140 m above the base of the stratotype. The remainder of this sample is from the San Juan-Rak Camel Quarries horizon. *Plioceros,* which has a relatively long teilchron, is also known from Clarendonian-Hemphillian localities in Nebraska, Kansas, New Mexico, Nevada, and Oregon.

CONCLUSION: MAGNETIC POLARITY CHRONOLOGY

The magnetic polarity zonation for the Chamita Formation stratotype is presented above (text, fig. 7). As a conclusion to this report, it is now desirable to correlate this zonation to the MPTS. This correlation is achieved by input of data from the independent disciplines of mammalian biochronology and radiometric age determinations.

Based on the discussion of individual taxa and concurrent range zonation presented above (text, fig. 9), the biochronology of the mammalian fauna suggests a late, but not latest, Hemphillian age for the Chamita Formation stratotype. The individual taxa are of varied utility in this assertion. The majority of taxa, including the beaver *"Dipoides" williamsi,* the dog *Canis davisi* (see discussion above), the procyonid *Bassariscus* sp. (see discussion above), the mustelid *Plesiogulo* sp., the badger *Pliotaxidea garberi,* the horses *Astrohippus ansae* and *Dinohippus interpolatus,* and the camels *Megatylopus matthewi* and *Hemiauchenia vera,* support the hypothesis of a late Hemphillian age. The long-ranging taxa, including the rodents ?*Mylagaulus* sp. and "indeterminate," the ?longirostrine gomphotheriid, the camel *Hemiauchenia* sp., and the antelope cf. *Plioceros* sp., are of little biochronologic value. The sloth ?*Pliometanastes,* the rabbit *Hypolagus vetus* (definite, not questionable occurrence, see Dawson, 1958), the dog *Aelurodon* cf. *haydeni,* and the antelope *Ilingoceros alexandrae* are found elsewhere in early Hemphillian faunas (Frick, 1937; Dawson, 1958; Hirschfeld and Webb, 1968; Tedford and others, in press). It is asserted that the presence of these four taxa in the late Hemphillian fauna from the Chamita Formation stratotype represents extension of their teilchrons. The monotypic genus *Osbornoceros* is of little biochronoglic utility since it is unique to the Chamita Formation.

The fauna from the Chamita Formation stratotype is generally similar to the late Hemphillian assemblages of the southern Great Plains, including the Coffee Ranch L.F. of the Hemphillian stratotype, Panhandle of Texas, and the adjacent Optima L. F. from the Panhandle of Oklahoma (see Reed and Longnecker, 1932; Hesse, 1936, 1940; Wood and others, 1941; Evernden and others, 1964; Tedford and others, in press). A fission-track (glass) date of 5.3 ± 0.4 m.y. is known from the Hemphillian stratotype (Boellstorff, 1976). MacFadden and Manley (1976) present two fission-track (zircon) dates from ashes in the Chamita Formation stratotype. The lower ash is 5 m below the top of the lower tuffaceous zone at 170 m and also 5 m above the base of magnetic polarity zone N3. This ash is dated at 5.2 ± 1.0 m.y. The upper ash is 5 m below the top of the upper tuffaceous zone at 365 m and also 15 m below the top of magnetic polarity zone R4. This ash is dated at 5.6 ± 0.9 m.y. These age determinations corroborate the correlation of these mammalian assemblages and the assertion of approximate contemporaneity of the Chamita Formation and southern Great Plains faunas.

The late Hemphillian fauna from the Chamita Formation stratotype and radiometric ages suggest an absolute time interval of roughly 6 to 4½ m.y. With this control in mind, it is now desirable to compare the magnetic polarity zonation of the Chamita Formation stratotype to the MPTS (fig. 10). Considering all the relevant data, numerous hypotheses could be constructed; the following is the most plausible: I assert that zones N1-N3, which extend from the base of the stratotype to 285 m and are of predominantly normal polarity, represent medial to late epoch 5 time. Within epoch 5, the characteristic event A of reversed polarity, which extends from 110 to 165 m, is represented by zones R1-R2. Zones R3-R6, which extend from 285 m to the top of the stratotype, represent early to medial Gilbert time. Within the Gilbert, event C of predominantly normal polarity, which extends from 375 to 470 m, is represented by zones N4 and N5. Some workers represent event C as two events of normal polarity, termed "C_1" and "C_2," punctuated by a short event of reversed polarity (Opdyke, 1972). This latter reversed event is probably represented by zone R5 that locally extends from 430 to 450 m in the stratotype. The existence of this event in the stratotype is not certain, because it is only recorded in one local section and not in another local section that apparently represents the same time interval.

Within event A of epoch 5 there is one zone of normal polarity, represented by N2, that has not previously been reported in the literature. Zone N2 is represented by one site each from two local sections. This zone is interpreted as a previously unrecognized short-period event that, based on average rates of sedimentation, has a duration on the order of 10^5 yrs. Detection of a short-period event is not surprising for the Cenozoic prior to approx 5 m.y. ago (Blakely, 1974).

Studies of terrestrial magnetic polarity stratigraphy in places such as southwestern North America demonstrate the feasibility of integrating different subdisciplines of earth science to formulate hypotheses. In this type of study there is positive feedback from paleomagnetism, paleontology, sedimentology, and geochronology. Extension of paleomagnetic studies to land has opened a new area of interest. Recognition of terrestrial sequences that correlate to the sea-floor anomaly and deep-sea sedimentary records corroborate the utility of the MPTS. The terrestrial record has been intensively investigated for the time interval of roughly

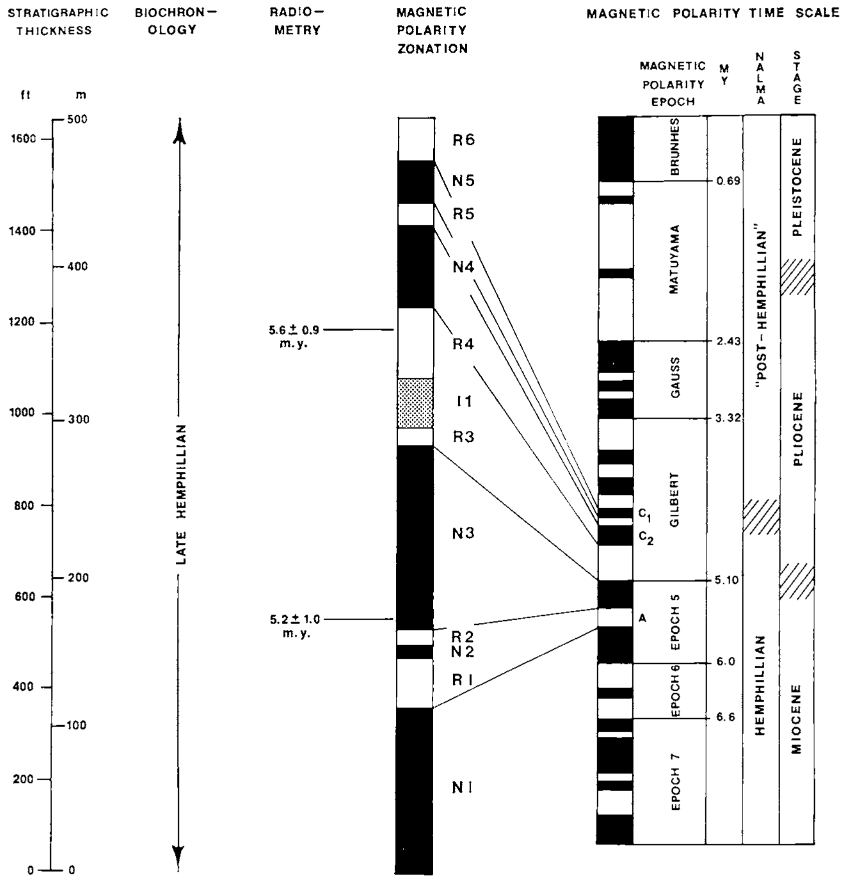


Fig. 10. Correlation of magnetic polarity zonation to standard magnetic polarity time scale using independent biochronologic and radiometric control. Radiometric age determinations are from MacFadden and Manley (1976). Boundaries of magnetic polarity epochs, in absolute m.y., are taken from Opdyke (1972) and Berggren and Van Couvering (1974). Boundaries between North American Land Mammal Ages and Cenozoic Stages are approximately indicated by zones of diagonal lines. See figure 7 for symbols.

0 to 5 m.y. ago. The next task is to extend the time scale back into the Cenozoic. This will be somewhat more difficult principally because of the proportional error margin associated with radiometric dates. Prior to roughly 5 m.y. ago, the error margin on most radiometric dates is too great to facilitate correlation of isolated magnetic polarity zones to the MPTS. In these cases terrestrial sequences that span several million years will be more attractive because of the possibility of pattern recognition, especially when dealing with time intervals with distinctive polarity signatures, for example, the long period of predominantly normal polarity that represents epoch 9 (= anomaly 5 on the ocean floor). Ultimately, in geographically separated areas characterized by faunal endemism, mag-

netic polarity stratigraphy will be used for interregional correlations. Further ramifications of magnetic polarity stratigraphy will include testing biological hypotheses concerned with rates and stages of faunal evolution. Studies that integrate different subdisciplines, which at first glance may appear unrelated, have initiated a new approach to earth science.

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Appendix

Sites outside stratotype

Five sites were sampled from sediments correlated by Galusha and Blick (1971) to the Chamita Formation stratotype. Based on paleomagnetic analysis, three of these proved to be statistically significant.

Galusha and Blick (1971) correlate sediments north of the type area to the stratotype. This correlation is made in a general way based on lithologic and faunal similarities. This correlation is indeed difficult because there are no distinct marker beds, for example, volcanic ashes, that can be traced laterally. North of the settlement of Lyden (U. S. Geol. Survey Lyden $7\frac{1}{2}'$ Quadrangle), in sediments underlying the Servilleta Formation of Black Mesa, Frick field parties collected numerous fossil mammals from "Lyden Quarry."[A1] The assemblage from this horizon is generally similar to the fauna from the stratotype. Two paleomagnetic sites were analyzed from the approximate locality of Lyden Quarry; both are of reversed polarity. With preliminary data such as these, it is not worthwhile to make a definite statement with respect to the magnetic polarity chronology of this locality. As a first-order approximation based on the general similarity of the fossil mammals, one might very tentatively correlate the reversed sites at Lyden Quarry to early-medial Gilbert as represented in the stratotype. It must be realized that this hypothesis is quite vulnerable to falsification.

One site was collected from the Servilleta Formation that uncomformably overlies Chamita Formation sediments several hundred meters northwest of the type area. This site is of reversed polarity. Ozima and others (1967) present radiometric dates for the Servilleta Formation near Taos that range from 4.5 to 3.6 m.y. Manley (1976) has obtained a K-Ar (whole rock) date of 2.78 ± 0.44 m.y. from the Servilleta Formation near the paleomagnetic locality sampled for the present study. This date demonstrates that the Servilleta Formation is younger to the south. The paleomagnetic site probably represents a reversed event during the Gauss Epoch, which is predominantly of normal polarity.

Two sites were sampled from Round Mountain Quarry. This quarry is located approximately 24 km southwest of the stratotype (a detailed locality description is given by Galusha and Blick, 1971). Only one site, which is located less than 5 m below the quarry horizon, proved to be statistically significant, and it is of normal polarity.

There has been considerable confusion with regard to the correlation of sediments outside the Chamita Formation stratotype. Galusha and Blick (1971) correlate the abbreviated section that includes Round Mountain Quarry to the stratotype. The mammalian assemblage from this locality is one of the most diverse from the entire Santa Fe Group, but it is largely undescribed. This assemblage appears to be considerably older than the fauna from the stratotype and is probably most similar to other late Clarendonian assemblages.

It is not possible to support a hypothesis concerning the single site of normal polarity at Round Mountain Quarry. It must be remembered that this locality and others, such as Battleship Mountain, appear to be significantly older than the stratotype. It is possible that the Round Mountain section is older than part of the upper Tesuque Formation.

[A1] In F:AM field notes, there is occasional reference to a Lyden Quarry locality that is either "east of Taos road" or "east of Rio Grande." Any of these entries are actually geographically (and ?stratigraphically) closer to the *Osbornoceros* locality, and should not be correlated definitely to Lyden Quarry.

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