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DATING ROCKS OF THE SANTA FE GROUP: PROGRAMS AND PROBLEMS

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INTRODUCTION

Pilot programs have been under study for several years in the type locality of the Santa Fe Group to test the feasiability of coordinating traditional stratigraphic paleontology with radiometric and paleomagnetic dating techniques. These programs are sponsored by the Department of Vertebrate Paleontology of the American Museum of Natural History, under the leadership of Dr. Malcolm C. McKenna, in cooperation with the University of Pennsylvania's Department of Geology where fission-track dating of volcanic tuffs is being done under the direction of Dr. Henry Faul. Studies of paleomagnetism in the Santa Fe Group have also been initiated. Dr. Neil D. Opdyke of the Lamont-Doherty Geological Observatory, has investigated the paleomagnetic character of the Barstovian and Hemingfordian time-stratigraphic units, and Bruce J. MacFadden of Columbia University is involved in a doctoral study of the magnetic stratigraphy of the Chamita Formation. Each of these age determination procedures-1) "North American Land-Mammal Ages" (Savage, 1962) utilizing fossil mammals, 2) radiometric age determinations, principally K-Ar and fission-track methods, and 3) paleomagnetic calibration of normal and reversed remanent paleomagnetization—has merit; however, the inherent shortcomings of each technique must be acknowledged. Such techniques appear to be mutually reinforcing and have shown promise for producing a workable chronostratigraphy for the beds of the Santa Fe Group in the Espanola Valley and Abiquiu reentrant.

THE SANTA FE GROUP

The complex geological relations of Tertiary beds exposed along the western boundary of the Rio Grande depression north of Santa Fe, New Mexico have been dealt with in four major stratigraphic reports (Bryan, 1938; Denny, 1940; Spiegel and Baldwin, 1963; Galusha and Blick, 1971) which describe the main body of deformed Tertiary sedimentary rocks in the type area of the Santa Fe Group. Tertiary and (or) Pleistocene sedimentary rocks that crop out in the Rio Grande depression (Bryan, 1938) and extend from Colorado to Texas, and which have been radiometrically dated, have been given amorphous and noncommittal assignments to the "Santa Fe Formation" or to the "Santa Fe Group." However, the practice of determining the rock-stratigraphic unit to which a sedimentary unit belongs by relying solely on its known "absolute age" is contrary to established procedures outlined in the Code of Stratigraphic Nomenclature (A.C.S.N., 1970). The Commission stated [p. 5, art. 4 (d)] , "Concepts of time-spans, however measured, properly play no part in differentiating or determining the boundaries of any rock-stratigraphic unit."

In an effort to conform to the requirements of the Code of Stratigraphic Nomenclature and to the requirements of the Geologic Names Committee of the U.S. Geological Survey, Galusha and Blick (1971) first acknowledged that Bryan (1938) and Denny (1938, 1940) had formally established the type area of the Santa Fe Formation and that Spiegel and Baldwin (1963) had formally subdivided the Santa Fe Formation in its type area. They (Galusha and Blick, 1971) then proposed that the term "Santa Fe" be raised to group status and include (p. 39) "sedimentary and volcanic rocks related to the Rio Grande trough, with a range in age from middle(?) Miocene to Pleistocene(?)." They also restricted the term "Santa Fe Group" to the type area and recognized two formations, the Tesuque Formation of Spiegel and Baldwin (1963) and the overlying Chamita Formation (Fig. 1). The Tesuque Formation has been divided into the five members shown in Figure 1.

Most of the sediments of the Nambé, Skull Ridge, and Pojoaque members of the Tesuque Formation were derived from the predominantly granitic rocks of the Sangre de Cristo Range. These sediments accumulated as part of a great system of alluvial fans along the mountain front. The Chama-el rito Member, although deposited at the same time as part of the Skull Ridge Member and all of the Pojoaque Member, was built by a separate system of alluvial fans that derived their clasts mainly from the San Juan Mountain region of southern Colorado and northern New Mexico. The sediments of the Chama-el rito are almost exclusively volcanic clasts and show dramatic lithologic differences from those of the contemporaneous Skull Ridge and Pojoaque. Recognition of these two great intertongued alluvial fan systems is fundamental to an understanding of the stratigraphy of the Tesuque Formation. Current biostratigraphic interpretations of the range of several fossil mammals that were collected in the Chama-el rito Member suggest that the time span covered by the member was about 7 million years. The period of time during which the Ojo Caliente Sandstone was deposited is difficult to estimate inasmuch as a maximum of 450 feet of eolian soft sandstones are involved in which volcanic ash beds are missing and fossils are virtually absent.

The Chamita Formation, which includes the youngest Santa Fe Group deposits recognized by Galusha and Blick (1971), contains several tuffaceous beds that should provide radiometric and paleomagnetic cross-references for the early to medial Hemphillian "North American Land-Mammal Age" assigned to it on the basis of the contained fossil mammals. Although a precise radiometric age has not been determined for the Chamita, it is probably older than 6.6 million years and represents about 1.5 to 2 million years of deposition. Fission-track age determinations will be made in the near future.

In its type locality the Santa Fe Group displays an essen-

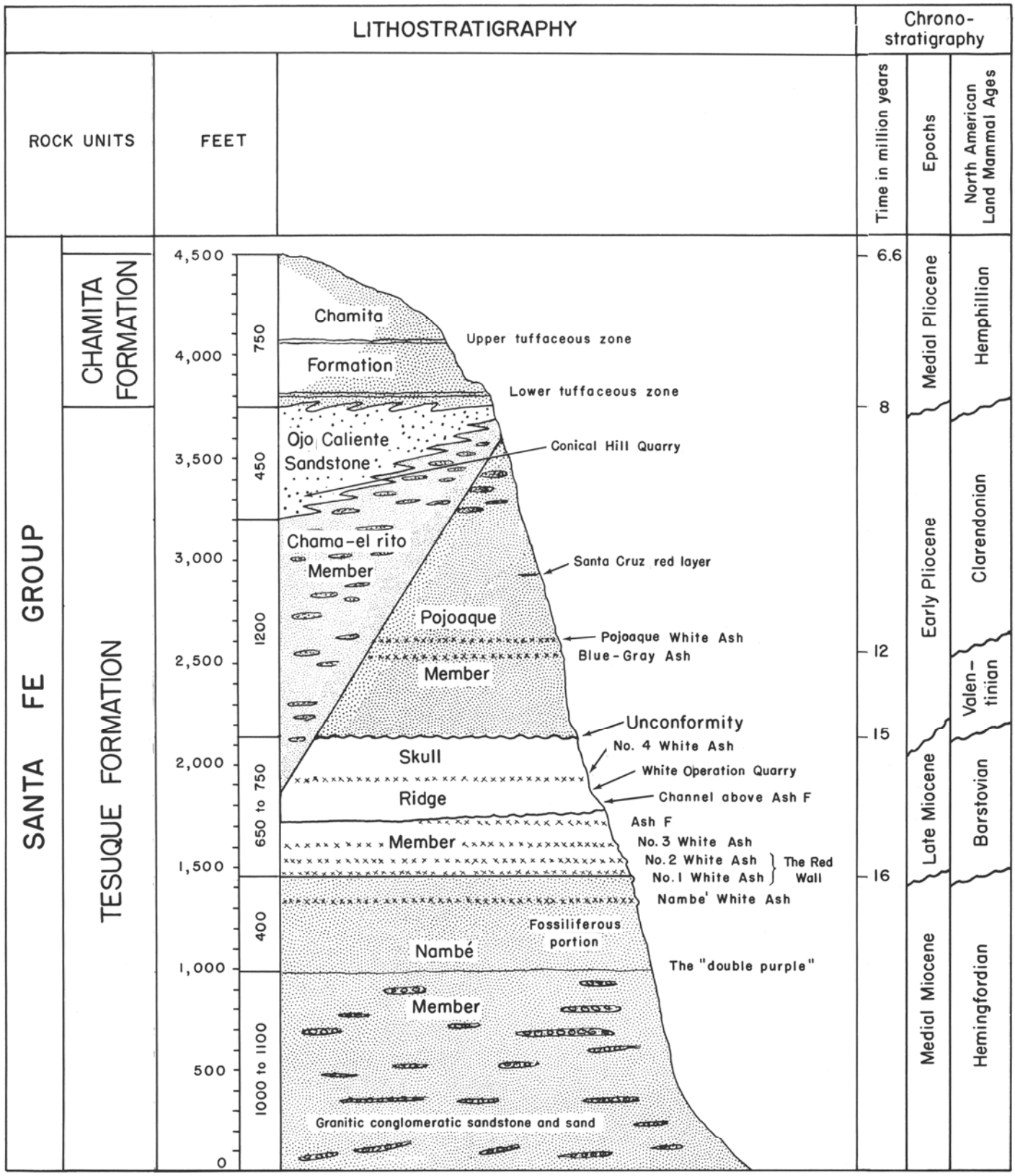

Figure 1. Composite stratigraphic section and chronostratigraphic correlations of the type locality of the Santa Fe Group.

tially complete stratigraphic section which has been deposited during an unusually long segment of late Tertiary time. These rocks (Fig. 1) accumulated over a span of about 11 million years and contain a reasonably complete sequence of representative mammalian faunas that provide potentially good biostratigraphic control. Deposits of the Nambé Member of the

Tesuque Formation have produced a stratigraphically controlled collection of fossil mammals, which are either congeneric with those from the Sheep Creek Formation in western Nebraska or are equivalent in stage of evolution to that of the Sheep Creek forms. These fossils are recognized as typical of late Hemingfordian "North American Land-Mammal Age." Rocks of late Hemingfordian age commonly are considered to have an "absolute age", as determined by radiometric dating techniques, of slightly more than 16 million years.

PRE-SANTA FE TERTIARY DEPOSITS

Tertiary deposits that immediately underlie the Santa Fe Group in the type area are: 1) the Picuris Tuff (Cabot, 1938, p. 91), which crops out along the eastern edge of the Rio Grande depression and in adjoining foothills of the Sangre de Cristo Range, 2) the Espinaso Volcanics (Stearns, 1953, pp. 415-452), which are exposed intermittently along the southern periphery of the type area, and 3) the Abiquiu Tuff (Smith, 1938, p. 944), which is composed mostly of volcanic sediments from the general San Juan Mountain region and is well exposed in the northern and northwestern parts of the type area. Dating of these three formations should be relatively easy, since each contains a variety of volcanic rocks for which careful stratigraphic control can be maintained.

An older set of rocks that underlies the Abiquiu Tuff, and crops out as a narrow belt of brick-red deposits along the northwestern edge of the Rio Grande depression in the Abiquiu quadrangle, was named the El Rito Formation by Smith (1938, p. 940). The formation consists of sandstone, conglomerate, and breccia. Clasts are dominantly quartzite. Commonly the rocks are so well consolidated that they break across the pebbles rather than around them. The scarcity of volcanic rocks in the El Rito may make the acquisition of "absolute dates" difficult.

TERTIARY CHRONOLOGY

General

A system of chronology for continental Tertiary beds in the interior of North America has been based traditionally on the provincial time scale proposed by the Wood Committee (Wood and others, 1941), emended by Savage (1962), and analyzed by Tedford (1970). The time scale, commonly composed of "North American Land-Mammal Ages," now involves the identification, interpretation, and correlation of local faunas by various biostratigraphic, geochronologic, and stratigraphic criteria, many of which were not foreseen by the original Wood Committee. Post World War II refinement of radiometric dating techniques has provided the potential for considerable refinement of the classic Tertiary chronology.

Evernden, Savage, Curtis, and James (1964) made the first large-scale attempt to date volcanic tuffs, volcanic ash beds, and basalts, that were closely associated with fossil mammals of known stratigraphic position. Their determinations were based mainly on the K-Ar method and were successful in demonstrating its fundamental accuracy; moreover, they showed the "North American Land-Mammal Ages" to be time-sequential and to have validity in stratigraphic paleontology. Subsequent refinements of old techniques and the adoption of new (for example, fission-track dating of volcanic glass) have introduced conflicting data that often confuses rather than clarifies the hoped-for goal of "absolute age" determinations for any particular set of rocks.

In recent years, a paleomagnetic time scale that utilizes natural remanent magnetization of rocks has received widespread attention. This procedure has been closely tied to radiometric dating and a chronostratigraphy of accomodation between the two has gradually evolved. One of the latest and most ambitious attempts to provide a review of worldwide Late Neogene chronostratigraphy, biostratigraphy, biochronology, and paleoclimatology was made by Berggren and Van Couvering (1973) who stated (p. 1), "the integration of modern paleomagnetic, radiometric, and hiostratigraphic studies has provided an accurate geochronological framework for the past 10 million years—the late Neogene."

Paleontologic Study of the Santa Fe Group

In the past, studies of Late Tertiary formations in the Santa Fe area have been oriented mostly, but not exclusively, toward stratigraphic paleontology. Some of these formations were named and described more than 100 years ago, but, because they lacked economic minerals or oil, they have not received the same degree of close stratigraphic scrutiny that commonly is applied to deposits with known reserves. With little or no potential for commercial exploitation, the geological investigations of the area have been strongly weighted toward basic research.

The first large collection of fossil mammals was made during the month of August, 1874, by Professor E. D. Cope, of the University of Pennsylvania, who was attached to the U.S. Army Engineer's expedition that was called the "Wheeler Geographical Surveys West of the One Hundredth Meridian". Thirty-one species of vertebrates were reported by Cope later that year, and his work was the first on the stratigraphic paleontology of the region.

In 1924 Childs Frick of the American Museum of Natural History sent a field party into the Santa Fe area and initiated a field program that has continued until the present time, although sporadically and with different objectives since his death in 1965. The scope of Frick's interest in the beds of the Santa Fe area was briefly outlined by Galusha and Blick (1971, pp. 14, 22). Yet, despite the tremendous amount of work that has been done on the geology and stratigraphy of the Santa Fe Group in its type area (Bryan, 1938; Denny, 1938, 1940; Kottlowski, 1953; Galusha and Blick, 1971), no concerted attempt has been made to compile a faunal list for the Tesuque or Chamita formations.

Vertebrate fossils have been diverse but not particularly abundant in the beds of the type locality. More than 5000 major specimens, each of which may range from a single jaw or limb bone to a partial or complete skeleton, have been collected and are now preserved in the Frick Collection at the American Museum of Natural History. Unfortunately little has been published concerning this collection, and this small preliminary report does little more than outline a few of the constraints that have operated to impede the appearance of a viable biostratigraphic report on the formations of the Santa Fe Group.

Five thousand specimens, at first glance, may seem to be a tremendous collection, but, when measured against the expenditure of thousands of hours of field work, laboratory preparation, and scientific research over a period of 50 years, it is not large. Collection size, however, becomes awesome when biostratigraphic correlations are attempted, since classification at the generic and species level is required for such correlation.

For example, although only a few hundred camel specimens have been collected from the Santa Fe Group, each must be collated with comparable or allied forms among the more than 30,000 other camel specimens in the Frick Collection. Such initial comparison is followed by a search of the world literature on fossil camels. Similar problems exist in identification of the horses, rhinoceroses, carnivores, and other mammals from the beds of the Santa Fe Group. In addition, all require, for proper identification, the revision of the entire family to which each taxon belongs. If a particular specimen belongs to a known taxon, it can be referred to the appropriate biological category with dispatch, but if it is new it must be checked against all known specimens and then against the continually burgeoning worldwide literature on the group.

The list of taxa for the Santa Fe Group, which are currently recognized by specialists dealing with fossil mammals, graphically shows that 23 families (Table 1) and 106 genera are represented. The list gives an idea of the various kinds of mammals that occur in the Santa Fe Group without sacrificing the availability of names that eventually may be proposed for new taxa. Additional faunal information is given in Galusha and Blick (1971).

CONCLUSION

A start, at times faltering but nevertheless a start, has been made in combining traditional stratigraphic mammalian paleontology with radiometric and paleomagnetic techniques in examining beds in the type area of the Santa Fe Group. In my opinion, preliminary studies show that the combination will work; several paleomagnetic reversals have been recognized, radiometric dates appear to be appropriately sequential, and fossil mammals demonstrate expected evolutionary stages and trends. A major effort will be required to properly coordinate and synthetize work in all these fields. These same preliminary studies also show that the investigations should be as broad-based as possible and should include those individuals and institutions with a genuine interest in participating in any or all of these methods or procedures, or in conducting research in the area on allied and complementary projects. Regardless of the difficulties encountered in attempting to coordinate research in stratigraphic paleontology with radiometric dating of volcanic tuffs and basalts and with paleomagnetic determination of normal and reversed events, the scientific results of a concerted effort in these three fields should be exciting and spectacular.

Table 1. Preliminary list and stratigraphic position of the fauna from the Santa Fe Group.

		SANTA FE GROUP					
		Tesuque Formation					Chamita Formation
	Genera	Nambé Member	Skull Ridge Member	Pojoaque Member	Chamita Member	Ojo Caliente Sandstone	
Class Amphibia							
Order Anura							
Family Ranidae	?		x	x			x
Class Reptilia							
Order Testudines							
Family Testudinidae	?	x	x	x	x		x
Family Indeterminate	?	x	x	x	x		x
Order Squamata							
Family Iguanidae	?		x	x			
Family Varanidae	?		x	x			
Class Aves							
Order Falconiformes							
Family Accipitridae	1		x				
Class Mammalia							
Order Insectivora							
Family Erinaceidae	4		x	x			
Family Talpidae	1			x			
Family Soricidae	1			x			
Order Edentata							
Family Megalonychidae	1						x
Order Lagomorpha							
Family Leporidae	3			x			x
Order Rodentia							
Family Mylagaulidae	3		x	x	x		x
Family Sciuridae	2			x			x
Family Heteromyidae	2			x	x		
Family Castoridae	6		x	x	x		x
Family Cricetidae	1		x	x			x
Order Carnivora							
Family Amphicyonidae	2			x			
Family Canidae	10	x	x	x	x		x
Family Procyonidae	3		x	x			x
Family Felidae	2		x	x	x		x
Order Proboscidea							
Family Gomphotheriidae	6			x	x		
Order Perissodactyla							
Family Equidae	17	x	x	x	x		x
Family Rhinocerotidae	3	x	x	x	x		x
Order Artiodactyla							
Family Tayassuidae	3	x	x	x			x
Family Merycoidodontidae	4	x	x	x	x		
Family Camelidae	14	x	x	x	x	x	x
Family Gelocidae	1						x
Family Cervidae	4	x	x	x	x		
Family Antilocapridae	13	x	x	x	x		x

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