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VERTEBRATE PALEONTOLOGY OF THE SAN JOSE FORMATION, EAST-CENTRAL SAN JUAN BASIN, NEW MEXICO

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INTRODUCTION

Over a century ago the renowned American paleontologist, Edward Drinker Cope, collected vertebrate fossils in the San Jose Formation along the east-central margin of the San Juan Basin. Cope's collection was the first large assemblage of Wasatchian (early Eocene) vertebrates known in North America and contains type specimens of many Wasatchian species. Consequently, the vertebrate fossils of the San Jose Formation play a central role in the study of the early Eocene vertebrate faunas of North America.

But in spite of their importance, these vertebrates have received relatively less attention in recent years than many contemporaneous faunas in Wyoming, Colorado and other Rocky Mountain states. Several collections have been made since Cope's time, but unfortunately this work has been sporadic and incompletely reported in the paleontological literature. A thorough reexamination and revision of the San Jose vertebrates is thus badly needed. This and other unresolved problems make the San Jose Formation a ready field for paleontological investigation. Several of these problems are discussed later in this paper. First, a review of the vertebrate paleontology of the San Jose Formation is presented.

HISTORY OF STUDY

E. D. Cope journeyed to the San Juan Basin as a member of the Wheeler Geological Survey in the fall of 1874. While still in the field, camped along the Rio Gallina and principally collecting in arroyos Almagre and Blanco (fig. 1), Cope (1874) described twenty-five new species of fossil vertebrates. Complete summaries were later written by Cope (1875a, b), as well as several shorter papers related to various aspects of the fauna (Cope 1875c, 1876a, b, c, d, e). Cope's description of his collection culminated in his large illustrated report for the Wheeler Survey (1877). Cope left the San Juan Basin in 1874 and never returned to collect fossils. Nevertheless, he considered his discovery of early Eocene fossils in the San Juan Basin to be *"the most important find in geology I ever made"* (Osborn, 1931, p. 201).

During the late 1870's and the 1880's, David Baldwin, a native New Mexican, worked in the San Juan Basin as a hired collector for both Cope and O. C. Marsh. While Baldwin mainly concerned himself with other horizons, notably the "Puerco Eocene," he did collect some Wasatchian fossils. Cope focused his attention on the Puercan, but reported (Cope, 1882) a new species of Meniscotherium (a primitive herbivorous mammal, fig. 2) from the Wasatchian. The specimens of *Meniscotherium* collected by Baldwin for Marsh were reported much later (Thorpe, 1934).

In 1896, an American Museum expedition led by Jacob Wortman revisited Cope's San Juan Basin localities to obtain good specimens of the primitive hippo-like herbivore *Coryphodon* (Osborn, 1898, fig. 3). However, the expedition found few fossils, and only a small collection was obtained.

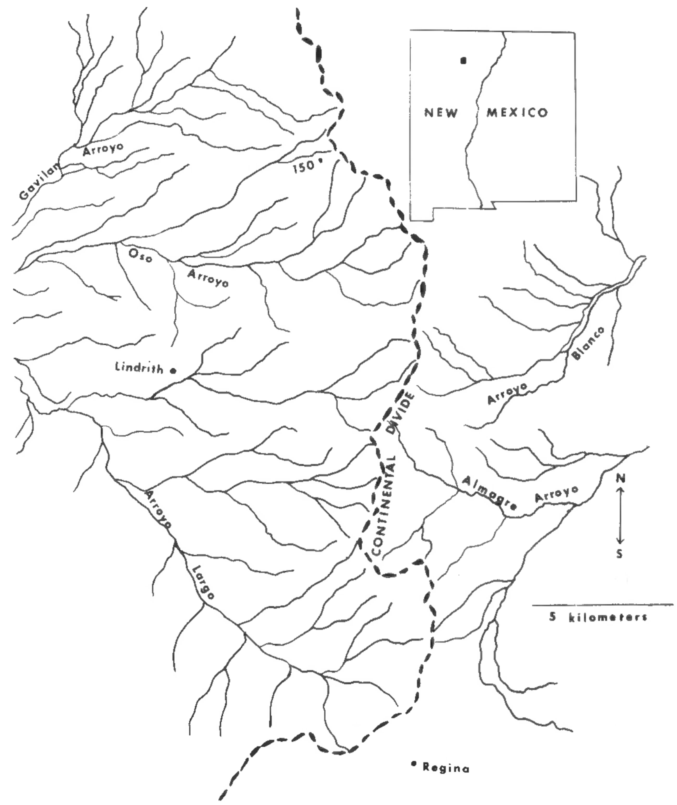

Figure 1. Major arroyos on the east-central margin of the San Juan Basin where fossil-bearing strata of the San Jose Formation are exposed. Simpson's Meniscotherium *Quarry 150 at the head of Oso Arroyo is also marked. The drainage pattern has been redrawn from the Bureau of Land Management land use map of the area.*

A second American Museum expedition, led by Walter Granger, visited the San Juan Basin in 1912 and 1913. In contrast to the previous expedition, a large representative collection was obtained. This collection, and many of the specimens collected by earlier workers, were described and discussed by Matthew and Granger in their classic revision of the lower Eocene faunas of North America (Matthew, 1915a, b, c, 1918; Granger, 1915).

Whereas previous workers in the San Juan Basin considered the Wasatchian beds to possess only one fauna, Granger (1914) recognized two distinct horizons. The upper horizon, Largo, was distinguished from the lower horizon, Almagre, by the presence of *Meniscotherium.* The Largo beds were also distinctively dominated by red clays, whereas the Almagre beds

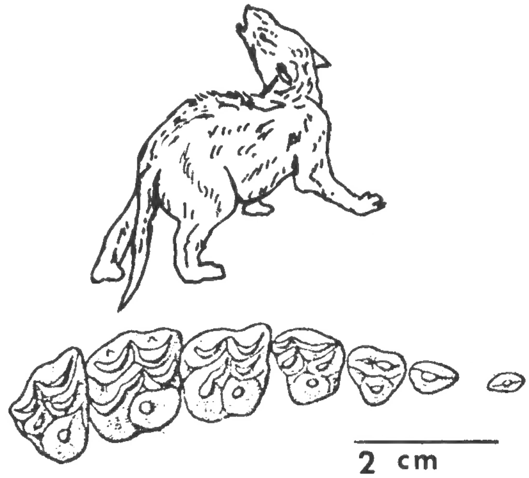

Figure 2. Reconstruction of Meniscotherium *(above) as it may have looked in life, about 200 cm. long (redrawn from Kurten, 1971). Below are the upper right cheek teeth (from Romer, 1966).*

were more variegated in color. Fossil-bearing Largo beds are principally exposed at the heads of arroyos Largo, Oso and Gavilan and in the vicinity of the present town of Lindrith (fig. 1). Fossil-bearing Almagre beds are mainly exposed in arroyos Almagre and Blanco and the vicnity of the present town of Regina (fig. 1).

After Granger's work, interest in the New Mexican Wasatchian subsided for a number of years. C. Lewis Gazin and a team from the United States National Museum briefly collected in Arroyo Almagre in 1936 but obtained little more than some *Hyracotherium* (=*Eohippus*, the first horse, fig. 4) (Gazin, 1937). In 1945 Franklyn Van Houten reviewed the latest Paleocene and early Eocene faunas of North America and gave complete lists of the Largo and Almagre mammalian faunas. The only prior lists (Cope, 1875b; Matthew, 1899, 1909) did not recognize the Largo-Almagre division.

Field work in the New Mexican Wasatchian began again in 1946, when G. G. Simpson led a third American Museum expedition and obtained the largest collection of Wasatchian vertebrates ever collected in New Mexico (Simpson, 1948a, b). Although he did not describe his entire collection, Simpson reported two new species (Simpson, 1954, 1955) and wrote two papers in which he outlined the history of collecting and general character of the Largo and Almagre faunas (Simpson, 1950a, b).

After the termination of Simpson's field work in the early 1950's, paleontological field work in the New Mexican Wasatchian ceased for about two decades. In the 1970's, collecting of vertebrate fossils has been resumed by the University of Arizona Department of Geosciences and Laboratory of Paleontology, and the University of New Mexico Departments of Anthropology and Geology. Both schools have obtained representative collections. The University of New Mexico collection is included in the collections in stratigraphy and paleontology of the Department of Geology and contains over 200 identified specimens and casts, covering a wide range of Wasatchian species known from the San Juan Basin.

STRATIGRAPHY

Cope (1875b) referred to the rocks in which he collected early Eocene fossils as the "Green River" or "Wahsatch" (=Wasatch) beds, equating them with formations in Wyoming already familiar to him. Between the time of Cope and Simpson (1948b) the name "Wasatch Formation" was most commonly used, but geologists disagreed as to exactly which rocks were included in this formation.

Simpson (1948b) wrote a complete historical summary of the terminology of the Eocene rocks of the San Juan Basin. In this important paper he also defined the San Jose Formation. Simpson applied Granger's Largo and Almagre faunal horizons to two clay facies, primarily basing his distinction on color (red=Largo, drag and variegated=Almagre) and the presence of *Meniscotherium* (present only in the Largo). He also recognized, but did not name, a basal sandstone facies of the formation.

Recent geological work has been undertaken by Baltz (1967) and Baltz and West (1967). Baltz essentially accepted Simpson's definition of the San Jose Formation and went on

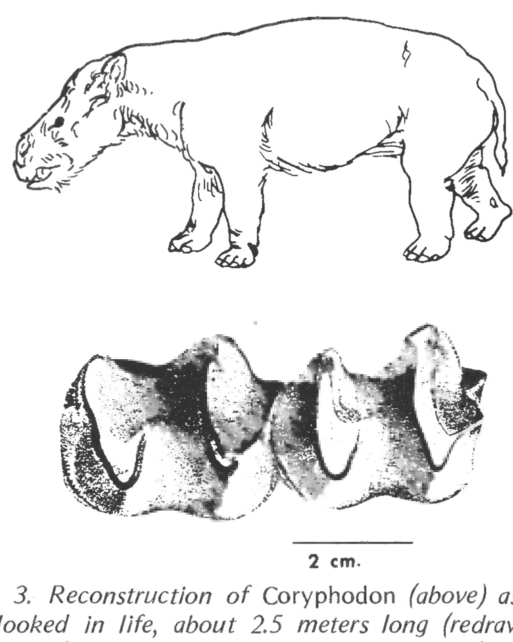

Figure 3. Reconstruction of Coryphodon *(above) as it may have looked in life, about 2.5 meters long (redrawn from Scott, 1937). Below are two lower right molars (from Cope, 1877).*

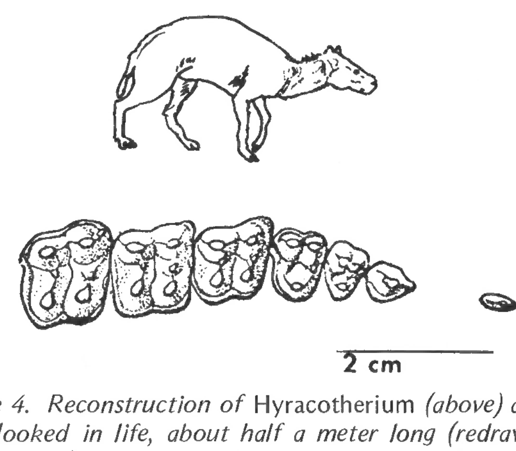

Figure 4. Reconstruction of Hyracotherium *(above) as it may have looked in life, about half a meter long (redrawn from Scott, 1937). Below are the right upper cheek teeth (from Romer, 1966).*

to define and map four units as formal members of the formation (fig. 5).

Cuba Mesa Member

A conglomeratic, arkosic sandstone comprises the lowest part of the formation. This member is named for the exposures on Mesa de Cuba where the sandstone forms a prominent cliff. The small amount of paleontological prospecting that has been done in this sandstone shows it to be essentially unfossiliferous.

Regina Member

A thick sequence of drab-colored, variegated shale with some interbedded sandstone overlies the Cuba Mesa Member throughout much of the San Jose Formation. These strata are particularly prominent near the town of Regina and further north in arroyos Almagre and Blanco. The Regina Member includes the Almagre of Granger and Simpson as well as the lower part of the Largo. Its exposures are the most fossiliferous ones known in the San Jose Formation.

Llaves Member

The Llaves Member mainly consists of massive beds of resistant, arkosic, conglomeratic sandstone and some beds of red and variegated shale. It overlies the Cuba Mesa Member in some areas, grading laterally or intertonguing with the Regina Member and in other areas overlies the Regina Member. These beds are hard to differentiate from those of the Regina Member but seem to be unfossiliferous.

Tapicotos Member

The youngest member of the San Jose Formation is principally composed of maroon shale and some lenticular sandstones. It either grades laterally into the Llaves Member or lies above it. This member includes the majority of Granger and Simpson's Largo. Its exposures are fairly fossiliferous, though apparently not as rich as strata in the Regina Member.

Baltz has done much towards clearing up what is a complex and sometimes confusing stratigraphic picture. However, relating vertebrate fossil finds to his stratigraphic divisions to determine a biostratigraphic succession of vertebrates in the San Jose Formation still remains to be done.

DISTRIBUTION AND PRESERVATION OF FOSSILS

Fossil remains in the San Jose Formation are, as a rule, fragmentary. One very rarely finds more than a few isolated teeth and bone scraps. A complete jaw is an unusual find and a great cause for rejoicing.

Vertebrate fossils are quite common in exposures of the Regina Member in arroyos Almagre and Blanco. Fossil bone and teeth are generally solid, but often fractured beyond recognition or reconstruction. A few uncommonly good quarries have been found, including one where twelve essentially complete skeletons of *Coryphodon* were excavated (Whitaker 1950). However, a typical fossil locality contains numerous gar scales and vertebrae (fig. 6a), a multitude of turtle shell fragments (fig. 6b), a crocodile's jaw and isolated teeth (fig. 6c) and numerous badly broken postcranial bones of *Coryphodon.* This accumulation was found weathering out of the reddish brown shale at the base of a hill. Unfortunately no extensive producing horizon has been discovered in the Regina Member. Fossil finds are a product of patient and prolonged search covering all accessible strata.

The Tapicitos Member, the other fossiliferous member of the San Jose Formation, presents an even more difficult prospect to the paleontologist. Fossil finds are infrequent. With the exception of several concentrations of *Meniscotherium,* notably Simpson's Quarry 150 near the head of Oso Arroyo (fig. 1), no areas of fossil concentration are known.

FAUNAS

Table 1 contains a list of vertebrate families present in the Largo and Almagre faunas. This compilation is based on a complete list of species given by Lucas (1977a). Thirty one nonmammalian and 71 mammalian species have been reported from the Largo and Almagre faunas. This number, however, is greatly inflated and can be reduced by a systematic revision. In particular the Trionychidae (soft-shelled turtles) and the Coryphodontidae (includes *Coryphodon*) are in great need of revision. Only such revision will give an accurate picture of the diversity of early Eocene vertebrates in New Mexico.

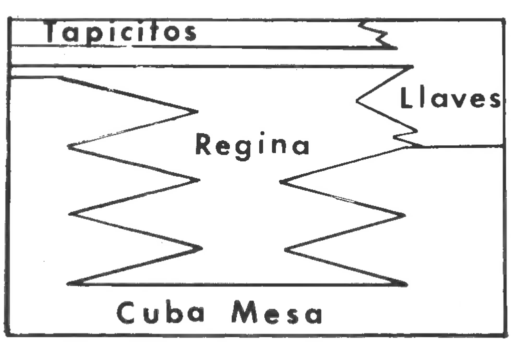

Figure 5. Schematic diagram showing the relationship of members of the San Jose Formation (redrawn from Baltz, 1967).

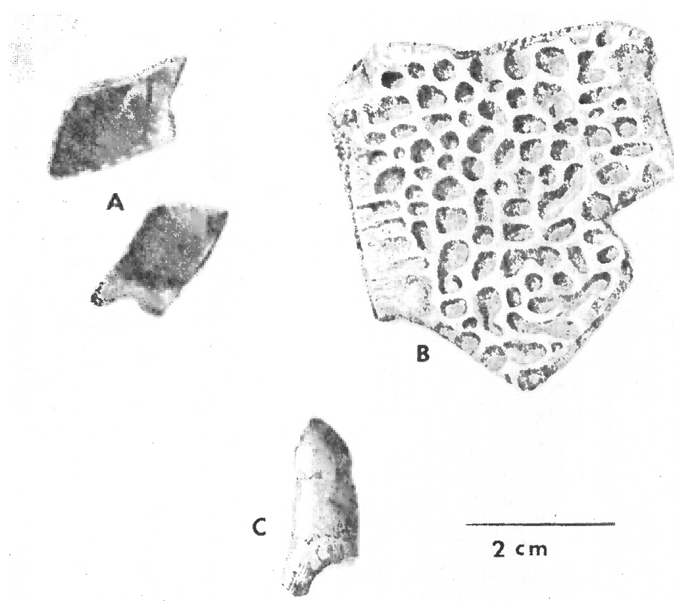

Figure 6. Some typical fossils from the San Jose Formation—gar scales (A), a piece of turtle shell (B) and a crocodile's tooth (C) (all from Cope, 1877).

Correlation

There is no doubt that the vertebrate faunas of the San Jose Formation are Wasatchian in age. However, a more precise correlation is less certain on the basis of known data.

Van Houten (1945) discussed the correlation of the San Jose faunas and suggested that the Largo was middle Wasatchian (Lostcabinian) in age and the Almagre was early Wasatchian, probably closely related to the Gray Bull fauna of Wyoming. Simpson 1948b) accepted these conclusions, and they remain essentially unchallenged to the present. However, recent analysis of the composition of the fauna (Lucas, 1977a) and specimens of the fossil primate *Pelycodus* (Gingerich, written comm.) suggests that both faunas are Lostcabinian in age. There would thus seem to be a small time interval between the Largo and Almagre faunas. Of course, this correlation will be more certain if it is corroborated by other evidence, such as paleomagnetic dating. Hopefully such evidence will eventually be available.

LARGO-ALMAGRE DISTINCTION

Perhaps the most important paleontological problem to be solved in the San Jose Formation is that of the Largo-Almagre distinction. The problem centers on the question of differences between the Largo and Almagre fossil assemblages and whether these differences warrant the distinction of two local faunas. The solution of such a far-reaching problem is clearly beyond the scope of this paper, but a few suggestions can be made.

The principal faunal distinction made between the Largo and Almagre faunas by Granger, Simpson and VaHouten was the presence of *Meniscotherium* in the Largo and its absence in the Almagre. However, this distinction is no longer valid because *Meniscotherium* has been found in Almagre beds. Four specimens of *Meniscotherium* are known from the Almagre whereas hundreds of specimens are known from the Largo. The difference is thus one of numbers, not presence or absence. It should also be noted that the overwhelming number of Largo specimens are from one quarry, Simpson's Quarry 150, so there is probably a significant bias in the sample.

The selenodont dentition of *Meniscotherium* led Simpson (1948b) to conclude that it inhabited an environment where grazing was possible. Simpson, perhaps overemphasizing the importance of *Meniscotherium*, concluded that the Largo beds were deposited in an upland environment and the Almagre represented a swampy lowland environment. However, Simpson neglected to explain how gar fish, crocodiles and soft-shelled turtles, among others, are buried in an upland environment. Indeed it is probable that very few vertebrate remains are preserved in upland environments (Voorhies, 1969).

Baltz (1967), in discussing the depositional environments of the Almagre (Regina Member) and Largo (Tapicitos Member), found it difficult to reconcile his sedimentologically based conclusions with the paleontologically based conclusions of Simpson. He concluded the following:

> *"Simpson (1948, p. 380-382) inferred that the Almagre facies (included in the Regina Member of the present report) was deposited in a swampy environment and that the Largo facies (included in the uppermost part of the Regina Member, and in the Tapicitos Member of the present report) was deposited in savannahlike conditions. Although this inference seems to be correct in light of ecological evidence deduced from the faunas of the two facies, the present writer believes that the main reason for the difference in color of the lower and upper parts of the San Jose must be the difference in color of the older sedimentary rocks from which most of the Eocene sediments were derived. The Cretaceous rocks, which seem to have provided much of the sediment of the Regina Member, are drab-colored rocks which were deposited originally in marine environments or in swampy lowland areas. Sediments eroded from Cretaceous rocks in Eocene time were deposited in the San Juan Basin after being transported for only moderately short distances; they were probably buried rapidly, thus retaining part of their original character. Red beds of Jurassic, Triassic, and Permian age, which were exposed after stripping of Cretaceous rocks from the uplifts surrounding the San Juan Basin, were already oxidized, and sediments derived from these rocks were deposited as second- or third-cycle red beds of the upper part of the Regina Member and the Tapicitos Member. The lithology of some beds of the Llaves and Tapicitos Members is strikingly similar to that of the Chinle and Cutler Formations." (Baltz, 1967, p. 53).*

Recent comparison of the two faunas (Lucas, 1977b) reveals no reason why the Largo should have been deposited in a

Table 1. List of vertebrate families reported from the San Jose Formation. Determination of faunal horizon (A=Almagre, L=Largo, ?=uncertain) is also listed (from data given by Lucas, 1977a).

Class CHONDRICHTHYES		Class MAMMALIA		Order RODENTIA	
Order SELACHII		Order MARSUIPCARNIVORA		Family PARAMYIDAE	A,L
Family ISURIDAE	A	Family DIDELPHIDAE	A	Family SCIURAVIDAE	A,L
Family CARCHARHINIDAE	A	Order INSECTIVORA		Order CARNIVORA	
Class OSTEICHTHYES		Family LEPTICTIDAE	A	Family MIACIDAE	A,L
Order SEMIONOTIFORMES		Family PANTOLESTIDAE	A	Order CONDYLARTHRA	
Family LEPISOSTEIDAE	A,L	Family APATEMYIDAE	A	Family ARCTOCYONIDAE	A
Class REPTILIA		Family ADAPISORICIDAE	A	Family PHENACODONTIDAE	A,L
Order TESTUDINES		Order DELTATHERIDIA		Family HYOPSODONTIDAE	A,L
Family BAENIDAE	?	Family PALAEORYCTIDAE	A	Family MENISCOTHERIDAE	A,L
Family DERMATEMYIDAE	?	Family HYAENODONTIDAE	A	Family APHELISCIDAE	?
Family TESTUDINIDAE	?	Family OXYAENIDAE	A,L	Family MESONYCHIDAE	A
Family TRIONYCHIDAE	A,L	Order PRIMATES		Family ANCHIPPODONTIDAE	A,L
Order SQUAMATA		Family PAROMOMYIDAE	A	Order PANTODONTA	
Family ANGUIDAE	?	Family ANAPTOMORPHIDAE	A	Order CORYPHODONTIDAE	A,L
Order CROCODILIA		Family MICROSYOPIDAE	A,L	Order PERISSODACTYLA	
Family CROCODYLIDAE	A,L	Family ADAPIDAE	A,L	Family EQUIDAE	A,L
Class AVES		Order TAENIDONTA		Family ISECTOLOPHIDAE	A
Order DIATRYMIFORMES		Family STYLINODONTIDAE	A,L	Order ARTIODACTLA	
Family DIATRYMIDAE	?	Order EDENTATA		Family DICHOBUNIDAE	A,L
		Family METACHEIROMYIDAE	?		

savannahlike environment. Paleontological evidence does not contradict the sedimentological evidence presented by Baltz. The Almagre fauna is more diverse than the Largo, but both contain animals that undoubtedly inhabited a riparian environment, perhaps one of swampy lowlands. The major differences between the Largo and Almagre faunas are probably due to taphonomic factors and sampling bias. If this conclusion is accepted, it would seem dubious to retain a distinction between a Largo fauna and an Almagre fauna. They should be considered one fauna, perhaps retaining the name Almagre.

CONCLUSION

This paper has outlined and, in some cases, offered tentative solutions for several of the problems facing vertebrate paleontologists in the San Jose Formation. Many of these problems would not have arisen if previous collectors had carefully recorded stratigraphic and geographic provenance and also thoroughly studied and reported their collections. Unfortunately such ideals are almost never met in the study of paleontology.

The road is now open for thorough restudy and revision of former collections. In addition, further collecting, using new methods and a rigorous stratigraphic framework, is necessary. The method of screenwashing for microvertebrate fossils (McKenna, 1965) should be especially productive of new information. With the solution of the problems outlined here and the influx of new information, paleontologists will finally gain a relatively clear and unbiased picture of the vertebrates existing during Wasatchian time in the San Juan Basin of New Mexico.

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