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Late Cretaceous and Early Cenozoic in the San Juan Basin

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Northwestern New Mexico is famous among stratigraphers and paleontologists as one of the few places where the Mesozoic-Cenozoic boundary has been precisely established in a fairly continuous sequence of continental sediments. This area also has the type provincial stage sequence for most of the American continental Paleocene. That sequence was the basis for redefinition of the Paleocene as now generally accepted by American stratigraphers, and in that sense this may be considered the type or at least neotype area for the Paleocene epoch as a whole.

HISTORICAL NOTE

J. S. Newberry, traveling with the Macomb expedition in 1859, was probably the first trained geologist to examine the crucial Cretaceous-Eocene sequence. He established the presence of fossiliferous marine Cretaceous overlain by a minimum of 2,000 feet of sandstones and "marls" in which only silicified wood and obscure plant impressions, indeterminate as to age, were found. He assigned all these beds to the Cretaceous but mentioned the possilibility that the upper part might extend into the Eocene.

In 1874 E. D. Cope, working for the Wheeler Survey, found fossil mammals, which he immediately recognized as Eocene, in the striking exposures of the two major arroyos between Yegua Canyon and Ojo San Jose (a spring near the present site of Regina). In the vicinity of the later town of Cuba, and especially the southern end of what is now called Cuba Mesa, Cope identified another series of "soapy marls" below the Eocene sandstones but above the recognized Cretaceous. He gave the name "Puerco Marls" to those beds and, although he found no identifiable fossils there, he hazarded the excellent guess that they might be equivalent to the Fort Union beds of th Upper Missouri, as indeed they are, in part.

In 1880 David Baldwin, a colorful pioneer fossil collector, discovered fossil mammals in Cope's Puerco beds and sent them to Cope. Baldwin was an untrained and almost illiterate but perceptive field stratigrapher, and his observations and collections soon enabled Cope to interpret the whole Cretaceous-Eocene sequence of the San Juan Basin in a broad but essentially correct way. The Cope-Baldwin collaboration continued until 1888, after which both turned to other fields. Cope recognized that the Puerco mammals were essentially of Tertiary type, but more primitive than those of the "Wasatch," the oldest previously recognized continental Eocene. His sequence was:

"Wasatch" — Lower Eocene, with a rich mammalian fauna similar to that of the "Wasatch" of Wyoming.

Puerco — "Lowest Eocene," with a very primitive mammalian fauna, in detail unlike any other then known.

"Laramie" — Continental late Cretaceous, with dinosaurs, (Marine late Cretaceous.)

In the 1890's the American Museum of Natural History began work on this sequence that it has pursued intermittently ever since then. Large collections of fossil vertebrates were obtained and accurately placed in stratigraphic sections. Mostly as a result of the American Museum's work, all three of Cope's pertinent units have been subdivided and more precisely correlated. The nomenclature also has been revised, not only by provision of names for subdivided rock units but also by replacement of the terms "Wasatch" and "Laramie," which have become almost meaningless as rock units and are not in any case correctly applicable in this area where the rocks never were continuous with and are not really equivalent to those of the type areas. Extensive areal mapping and further stratigraphic studies have been carried out especially by the U.S. Geological Survey, notably by Bauer, Reeside, and Dane, among several others.

SEQUENCE AND AGES

What might be called the classical sequence occurs along the arc of late Cretaceous-Paleocene exposures from the vicinity of Aztec to that of Cuba. Conditions in the northernmost part of the San Juan Basin, mainly in Colorado, are notably different and will be discussed separately.

Late Cretaceous

The continental late Cretaceous overlies the Pictured Cliffs sandstone in the west and the southwest and lies directly on Lewis shale in the east and southeast, where the Pictured Cliffs is not recognized in surface exposures. The continental beds are a highly heterogeneous mass of somber and banded shales, sandstones, and (mostly in the lowest beds) coal. These beds seem to be conformable throughout and there is no demonstrated or probable significant difference in age among them. Brown proposed the name Ojo Alamo for the whole mass, but Bauer and subsequent authors have confined that name to the thin (up to about 100 feet) top sandstone member. In the western and southwestern exposures the lower coal-bearing beds or called Fruitland, with the Kirtland between Fruitland and Ojo Alamo. (The massive Farmington sandstone is generally considered a wedgelike member of the Kirtland.) Fruitland and Kirtland differ only by the presence of potentially commercial coal in the former. Both "formations" thin to the eastward and so do the coals until they are no longer of possible commercial interest. In the vicinity of Cuba only the Kirtland is recognized and mapped. It would, however, seem more significant stratigraphically to say that the Fruitland-Kirtland constitutes a single formation with coal in the lower part to westward, rather than to speak of two formations one of which is absent to eastward.

The Ojo Alamo "sandstone" has numerous and sometimes thick clay lenses, but these are usually covered and inconspicuous on surface exposures. The Ojo Alamo does not thin markedly to eastward, and it retains its individuality not only in the Cuba area but also for some miles northward from Regina where, however, it is exposed only intermittently and usually poorly.

Turtles, crocodiles, and dinosaurs occur in Fruitland, Kirtland, and Ojo Alamo, most abundantly in the Kirtland. Some species have been recorded from only one of the three "formations," but this is probably due to the chances of collecting. The whole fauna seems to be essentially a unit. The facies is somewhat different from those of more northern faunas and correlation may not be quite exact.

The Fruitland-Kirtland-Ojo Alamo fauna is clearly of very late Cretaceous age, but perhaps not quite as late as the uppermost Lance in Wyoming and Montana.

Nacimiento Formation

Cope's "Puerco marls," overlying the Ojo Alamo, were found by Wortman and Matthew to contain two sharply different successive faunas. The name Puerco was restricted to the beds containing the older fauna and the younger beds were called Torrejon. Although long given formation status, these beds have never been distinguished except by faunas, which are too sparsely distributed to serve for mapping. Gardner accordingly proposed that the mapping unit be called the Nacimiento group, and that is now generally accepted but as a formation. The Puerco and Torrejon are now considered as faunas and faunal zones within the Nacimiento formation, not as rock units. The Puerco fauna is known only in a limited southwestern strip across Kimbetoh and Ojo Alamo and adjacent arroyos. Elsewhere only Torrejon fossils are known. In the vicinity of Cuba, for instance, which is the type area of Cope's Puerco, it is fairly sure that the Puerco of present usage is represented only by a hiatus between Ojo Alamo and Nacimiento and that the whole Nacimiento is of Torrejonian age.

The Nacimiento formation consists largely of somber and banded clays and lenticular sandstones. It has a general resemblance to the Kirtland formation and in limited exposures the two can be readily mistaken for each other if the intervening Ojo Alamo sandstone is not identified.

The Puerco and Torrejon faunas include no dinosaurs but do contain numerous mammals mostly of primitive Tertiary aspect. Their ages are by definition early and middle Paleocene, respectively, as those epoch subdivisions of current American usage were based on these faunas. When they were first distinguished, there were no other known faunas comparable with them, but age equivalents have now been identified in Montana, Wyoming, Colorado, and Utah.

San Jose Formation

The New Mexican "Wasatch" of Cope and most others up until 1948 is now known as the San Jose formation, with the type area along and near the Continental divide in the vicinity of Regina. The road from Regina almost to Cuba is continuously on this formation, which consists mostly of banded variegated and red clays or siltstones and lenticular or sheetlike sandstones. A basal sandstone members caps Cuba Mesa, and its contact on the somber Nacimiento clays is strikingly evident where the highway descends the hill just northwest of Cuba. The somber, carbonaceous clays common in both Kirtland and Nacimiento formations are absent in the San Jose.

In its type area and everywhere in New Mexico where mammalian fossils are known from it, the San Jose is early Eocene in age, its base probably earliest Eocene and its highest beds perceptibly but not much later in the early Eocene. The known fauna is large and, with the Wyoming Bighorn Basin faunas, is a principal source of knowledge of the North American continental earliest Eocene. No late Paleocene has been surely identified in New Mexico, and specifically in the Cuba region it is probable that none occurs and that the Nacimiento-San Jose contact involves a late Paleocene hiatus. The problem of the late Paleocene in northern San Juan Basin, especially in Colorado, is mentioned below under "Tiffany."

BEDS IN NORTHERN SAN JUAN BASIN

Animas

As the late Cretaceous and Paleocene are followed northward and northeastward from the vicinity of Aztec into Colorado, they evidently grade laterally into the Animas formation, a mass of highly varied continental sediments, predominently greenish in color and containing much andesitic debris. Known fossils from the Animas are few and somewhat equivocal as to age, and the local sections are highly variable with no single key beds extending more than a few miles at most. Precise equivalents in the Animas of the Fruitland, Kirtland, Ojo Alamo, and Nacimiento have therefore not been distinguished. From late Cretaceous through middle Paleocene, andesitic sediments were apparently derived from the north simultaneously with sedimentation of more usual clays and sands from the south or southwest into the southern and central parts of the basin.

Similar gradation of Kirtland, Ojo Alamo, and Nacimiento into the Animas presumably also occurs in the northeastern part of the Basin, between Yegua Canyon and the general vicinity of Dulce. The pertinent exposures are, however, generally poor and the exact relationships have not been adequately worked out, as far as published data establish.

Tiffany

North of the San Juan River the Animas formation is overlain by nonandesitic sediments, lacking the characteristic greenish tone of the Animas, and with some reddish beds and banding. These sediments contain late Paleocene mammals, distinctly later than any part of the Nacimiento formation and distinctly earlier than the typical San Jose. These were named the Tiffany beds by Granger, but most stratigraphers have continued to consider them as part of the "Wasatch" or San Jose. The usual conception has been that the San Jose simply thickens to the northward and that its lower part there extends downward into the late Paleocene. There is, however, no evidnce that there is any early Eocene or strictly lateral equivalent of typical San Jose in this region. There is a strong possibility, at least, that the Tiffany is a distinctly separable formation that wedges out southward and southeastward beneath the San Jose, but no published observations reveal the exact relationships or settle the question one way or the other.

The Animas-Tiffany transition seems to represent a shift in source of sediments without appreciable lapse of time. The nominal contact does not represent a boundary between middle and upper Paleocene, for an upper Paleocene mammal has been found actually extending across that nominal boundary.

SOME STRUCTURAL RELATIONSHIPS

The Fruitland, Kirtland, Ojo Alamo, and Nacimiento are everywhere essentially parallel, as far as known, and the first three, all of essentially the same late Cretaceous age, are apparently fully conformable. Contact of the Nacimiento clays on the Ojo Alamo is everywhere a sharply defined disconformity. In places where the Puerco fauna occurs, time represented by the disconformity must be comparatively short, but over much of the Basin the disconformity probably involves a long hiatus representing the whole of the early Paleocene, at least.

Where basal San Jose is observed lying directly on Nacimiento, the beds are also parallel or very nearly so, but there is usually here again a sharp erosional disconformity which on present evidence seems to represent the whole of the late Paleocene. (It has nowhere been demonstrated clearly that the early Eocene San Jose directly overlies the late Paleocene Tiffany.) Those relationships suggest that some upwarping, if not definite folding, occurred between late Paleocene and early Eocene beyond the present eastern rim of the San Juan Basin.

The strong and more definitely localized movements represented by the Nacimiento overthrust and by the folds continuing that structure to the north began while the lower part of the San Jose was being deposited. That tectonic event can therefore be closely dated in the earliest Eocene (early Wasatchian). In accordance with this change in topography, much or all of the (true) San Jose sediments apparently came from the east and included material reworked from Cretaceous and older beds. The major part of the folding and faulting, however, occurred after completion of San Jose deposition. It was therefore no older than late early Eocene (late Wasatchian) and may have been considerably later. This is one of the good items of the now widespread evidence that Laramide mountain-making was not concentrated around the Mesozoic-Cenozoic boundary but occurred, for the most part, well along in the Cenozoic.

Ages and relationships of the principal formations here discussed are indicated in the accompanying diagram.

PALEOCENE AGES AND STAGES

The San Juan Basin section forms the main basis for North American continental (nonmarine) Paleocene ages (time units) and stages (time-rock units), the most solidly established of which are designated by the times represented or typified by the Puerco, Torrejon, and Tiffany mammalian faunas. The marked advance of the Torrejon over the Puerco fauna indicates a considerable lapse of time, although a corresponding disconformity and hiatus have not been identified in the strata. A fauna, the Dragon, intermediate in evolutionary character and almost certainly in age has in fact been found in Utah and a corresponding age-stage has been tentatively recognized on that basis. In the Bighorn Basin the Clark Fork beds contain a fauna transitional from a Tiffany age equivalent to the earliest true Eocene, and that is the basis for a tentative terminal Paleocene age-stage. The currently usual age-stage subdivision and terminology are thus as follows:

Age and Stage	Epoch Subdivisions
(Wasatchian)	(Early Eocene)
Clarkforkian Tiffanian	Late Paleocene
Torrejonian Dragonian	Middle Paleocene
Puercan	Early Paleocene
(Lancian)	(Late Cretaceouse)