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CRETACEOUS AND TERTIARY ROCKS OF THE EASTERN SAN JUAN BASIN, NEW MEXICO AND COLORADO'

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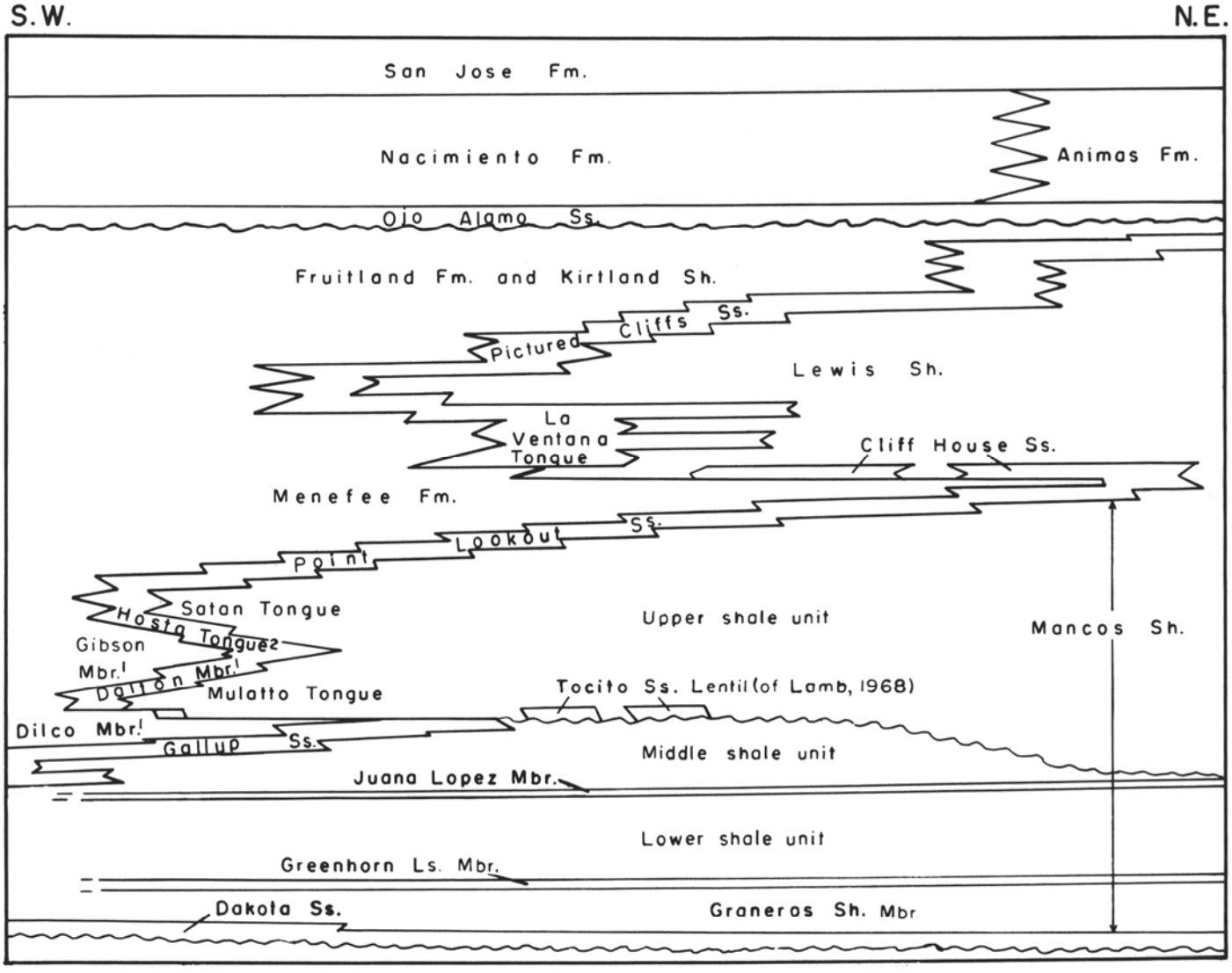
INTRODUCTION

The San Juan Basin area of New Mexico and Colorado was situated in the SCI-SWO (sea came in—sea went out) zone during deposition of Cretaceous rocks. There were three major sea-came-in episodes and three sea-went-out episodes interspersed with several less extensive regressive-transgressive cycles. A diagrammatic stratigraphic cross section through the basin (Fig. 1) illustrates these relations.

The Tertiary rocks of the basin were deposited after a hiatus during which time the topmost Cretaceous rocks were upwarped and truncated. Today only Paleocene and Eocene rocks represent the Tertiary sediments of the San Juan Basin.

DAKOTA SANDSTONE

The Dakota Sandstone of probable Early and Late Cretaceous age was deposited on a vast erosion surface, at least in



1. Of Crevasse Canyon Fm.
2. Of Point Lookout Ss.

Figure 1. Diagrammatic stratigraphic cross section of Cretaceous and Tertiary rocks of the San Juan Basin. Vertical exaggeration about X 150. (After Fassett, 1973a)

[1] Publication authorized by the Director, U.S. Geological Survey.

the San Juan Basin area, of generally progressively older rocks from east to west as the Cretaceous trough bisecting North America formed and was flooded by the sea. In general, the lower part of the Dakota is composed of fluvial, flood plain, and paludal deposits; these deposits grade upward into strandline and offshore marine deposits that intertongue with the overlying Mancos Shale. There is some evidence that the Nacirniento uplift-Archuleta anticlinorium may have been either a positive area or a shoal in the Late Cretaceous sea at the time of Dakota deposition (Dane, 1960, p. 67, Muehlberger, 1967, p. 24): however, evidence for this positive area is not overwhelming. Papers by Owen and Grant, and Landis, Dane, and Cobban deal with the Dakota in greater detail elsewhere in this volume.

Figure 2 is a geologic column based on tops picked from the electric log of the Magnolia Schmitz 1 well located in the NE'/ SE'/ sec. 34, T. 24 N., R. 1 W. This well is located about 11/2 miles northwest of the Mesaverde hogback at stop 3 on the first day's road log. The 257-foot section shown at the base of this column includes the Dakota Sandstone and possibly part of the Lower Cretaceous Burro Canyon Formation at the base. Tongues of Mancos Shale arc included with the upper part of the Dakota.

MANCOS SHALE

General Discussion

The Mancos Shale, for the most part, represents deeper and farther offshore marine deposition as the Cretaceous shoreline moved further and further westward. There are, however, three significant lithologic changes in this depositional continuum: the Greenhorn Limestone Member, the Juana Lopez Member, and a thin-bedded sandstone member in about the middle of the Mancos Shale sequence. Also, an unconformity separating rocks of Carlile and Niobrara age (Dane, 1960) is located in the sequence above the Juana Lopez Member.

Graneros Shale Member

The Graneros is dark gray marine shale and is the basal member of the Mancos Shale. It contains in places thin sandstone beds, which are laterally equivalent to, or continuous with tongues of Dakota Sandstone, bentonite beds, and limestone concretion zones. The Graneros is conformable with overlying and underlying units.

Greenhorn Limestone Member

The Greenhorn consists of alternating beds of limestone and calcareous shale. Its outcrops usually hold up low hills above the adjoining shale lowlands. The Greenhorn is a conspicuous marker on well logs and apparently represents a time line in the basin. Dane (1960, p. 69) suggested that its deposition may have been related to "... more concentrated volcanic activity ..." as evidenced by its proximity to several bentonite beds. The Greenhorn probably represents the time of greatest transgression of the Late Cretaceous seaway. According to Molenaar (1973, p. 211) the shoreline was about 280 miles southwest of the San Juan Basin at that time.

Lower Shale Unit

The Greenhorn is conformably overlain by a unit similar to the Graneros, called the lower shale unit.

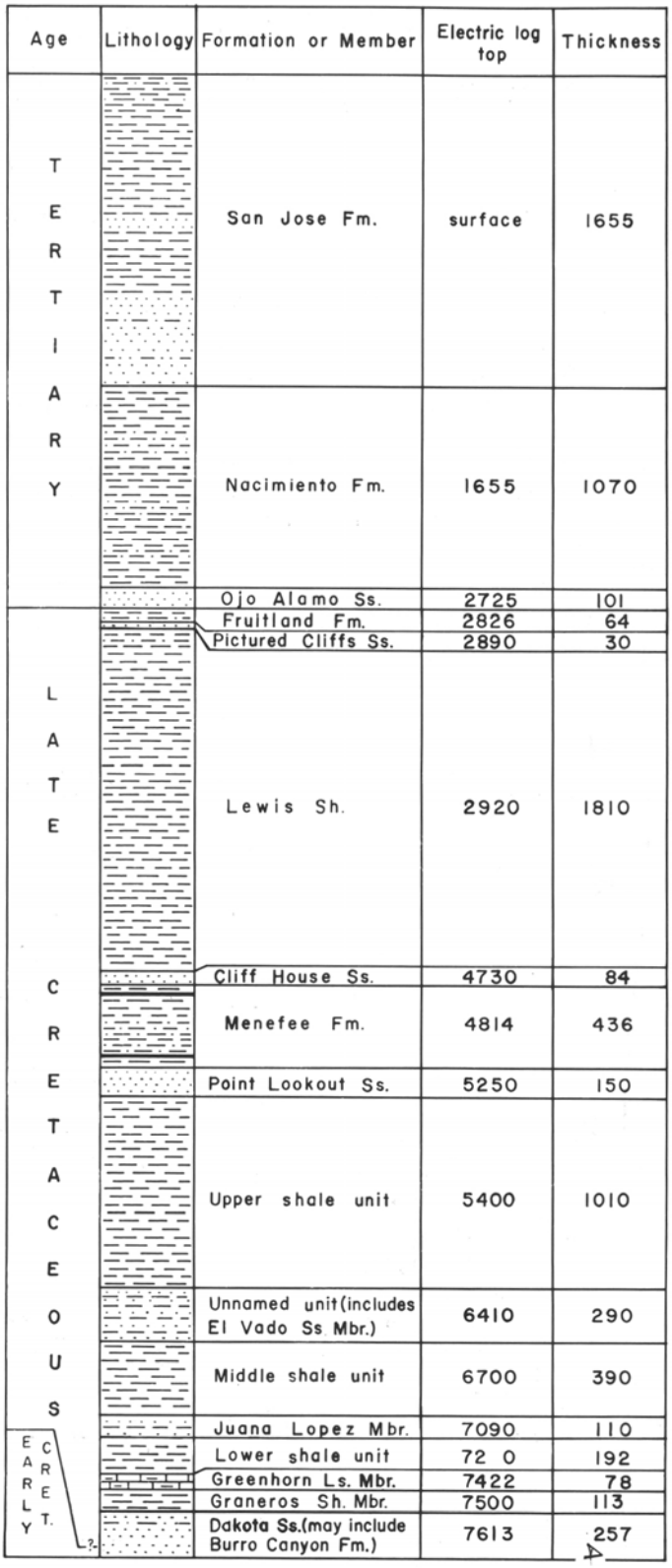


Figure 2. Geologic column of subsurface Upper Cretaceous and Tertiary rocks of the east-central San Juan Basin. Formation and member tops and thicknesses are derived from the electric log of the Magnolia Schmitz 1 well in the NE¼ SE¼ sec. 34, T. 24 N., R. 1 W. (See Fig. 3 for well location)

Juana Lopez Member

The Juana Lopez conformably overlies the lower shale unit and is composed of thinly interbedded calcarenite and calcareous shale. The calcarenite is usually a carbonate cemented fossil hash containing broken shell fragments and shark teeth with occasional complete fossils. The Juana Lopez may represent a general shoaling of the sea throughout most of the basin areas.

Middle Shale Unit

This unit is similar to the lower shale unit and contains the aforementioned Carlile-Niobrara unconformity which truncates older rocks in the northern part of the basin.

Unnamed Unit

These rocks are composed of a series of thinly interbedded very fine grained sandstone to siltstone and gray marine shale beds. Dane (1960, p. 73) tentatively correlated this unit with the Dalton Sandstone Member of the Crevasse Canyon Formation; however, it would seem that at least part of this unit would more likely correlate with the El Vado Sandstone Member of the Mancos (Landis and Dane, 1967, p. 8, 9). See Figure 3 of Molenaar (this volume) for the correlation of this member and its relationship to the Dalton Sandstone Member.

Upper Shale Unit

The upper shale unit is similar in lithology and mode of deposition to the middle and lower shale units.

MESAVERDE GROUP

The Mesaverde Group of the San Juan Basin was originally divided into three units: the Point Lookout Sandstone, the Menefee Formation, and the Cliff House Sandstone. This group is a wedge, in cross section, with the narrow edge to the northeast. It represents a regression to the northeast depositing the Point Lookout Sandstone, the basal unit, followed by a transgression to the southwest depositing the Cliff House and its La Ventana Tongue, the upper unit (Fig. 1). Between these marine strandline sandstones, the continental coal-bearing Menefee Formation was deposited.

The uppermost sandstone of what is now called the Mesaverde Group was mapped by Dane (1936) as the La Ventana Sandstone Member of the Mesaverde Formation in the southeast part of the basin. Later, this unit was mapped northward along the eastern basin rim and its stratigraphic designation was changed by Beaumont, Dane, and Sears (1956) to the La Ventana Tongue of the Cliff House Sandstone. The author's studies (Fassett, 1971) of these rocks in the surface and subsurface of the basin clearly show that La Ventana rocks wedge out between La Ventana and Cuba. In many parts of the eastern San Juan Basin the Cliff House is missing and the Lewis Shale overlies the Menefee Formation (Fig. 1).

The Mesaverde Group of the eastern basin thins northward until near Pagosa Springs, Colo., it wedges out into the Mancos Shale. The Mesaverde near Gallina (Fig. 2) is about 670 feet thick.

LEWIS SHALE

The Lewis Shale conformably overlies the Mesaverde Group and represents deeper water farther offshore marine deposition as the Cretaceous shoreline again advanced to the southwest. The Lewis along the eastern basin contains limestone concretion zones, thin limestone beds, and becomes more silty and more sandy to the southwest as it approaches a wedgeout between the underlying Cliff House and overlying Pictured Cliffs Sandstone.

PICTURED CLIFFS SANDSTONE

Along parts of the eastern rim of the San Juan Basin the Pictured Cliffs Sandstone is absent on the outcrop according to Dane (1936) and Fassett and Hinds (1971). Other workers (Baltz, 1967 and Woodward and others, 1972) have mapped Pictured Cliffs in the southern part of this area. The difference seems to be based on the lithologic definition of the Pictured Cliffs. Dane (1936) and Fassett and Hinds (1971) mapped the Pictured Cliffs as a sandstone bed which by definition contains more sandstone than shale. Baltz and Woodward and others on the other hand have defined the Pictured Cliffs as "... clay shale and interbedded thin rusty-weathering concretionary sandstone and siltstone overlain by soft thin shalt' sandstone that is slightly carbonaceous" (Baltz, 1967, p. 17); and "Gray to buff, thin-bedded sandstone and gray shale, grades laterally into Lewis Shale and is absent north of sec. 23, T. 21 N., R. 1 W., 0 to 45 feet thick" (Woodward and others, 1972). A photograph of a roadcut in sec. 23, T. 21 N., R. 1 W. is in the first day's road log in this volume and clearly shows the nature of the "Pictured Cliffs" in this critical area.

The Pictured Cliffs is a regressive strandline sandstone deposited during the last retreat of the Cretaceous sea from the San Juan Basin area. The sea retreated to the northeast with the Pictured Cliffs rising stratigraphically some 1,250 feet across the basin (Fassett and Hinds, 1971).

The absence of Pictured Cliffs along parts of the east side of the basin (Fig. 3) strongly suggests that there was uplift along the Nacimiento front at the time of or shortly after the Pictured Cliffs regression resulting in either lack of deposition or erosion of this unit. The Pictured Cliffs is present for about a 10-mile stretch along the north-central east rim of the basin (Fassett and Hinds, 1971, pl. 1).

FRUITLAND FORMATION

The Fruitland Formation represents swamp, river, lake, and flood plain deposits laid down landward from and on top of the Pictured Cliffs Sandstone. The Fruitland has been defined as the lower or coal-bearing portion of the continental sequence above the Pictured Cliffs. To the west, the Kirtland Shale overlies the Fruitland, but because this unit does not crop out on the east rim of the basin it will not be discussed further.

Lithologically, the Fruitland is composed of shale, siltstone, coal, carbonaceous shale, and rarely sandstone. The sandstone beds are invariably in the form of discrete channels. Silicified logs and wood fragments are abundant in the Fruitland and are useful criteria in separating the Fruitland from the underlying Lewis Shale in areas of poor exposure along the east side of the basin. The Fruitland is the most commercially important coal-bearing unit in the basin; however, it contains almost no coal along the eastern rim (Fassett and Hinds, 1971). Again, this suggests uplift along the Nacimiento front at the time of Fruitland deposition because the creation of coal requires stable swamps in which vegetal matter can accumulate. Coal does occur in the Fruitland in the subsurface only a few miles

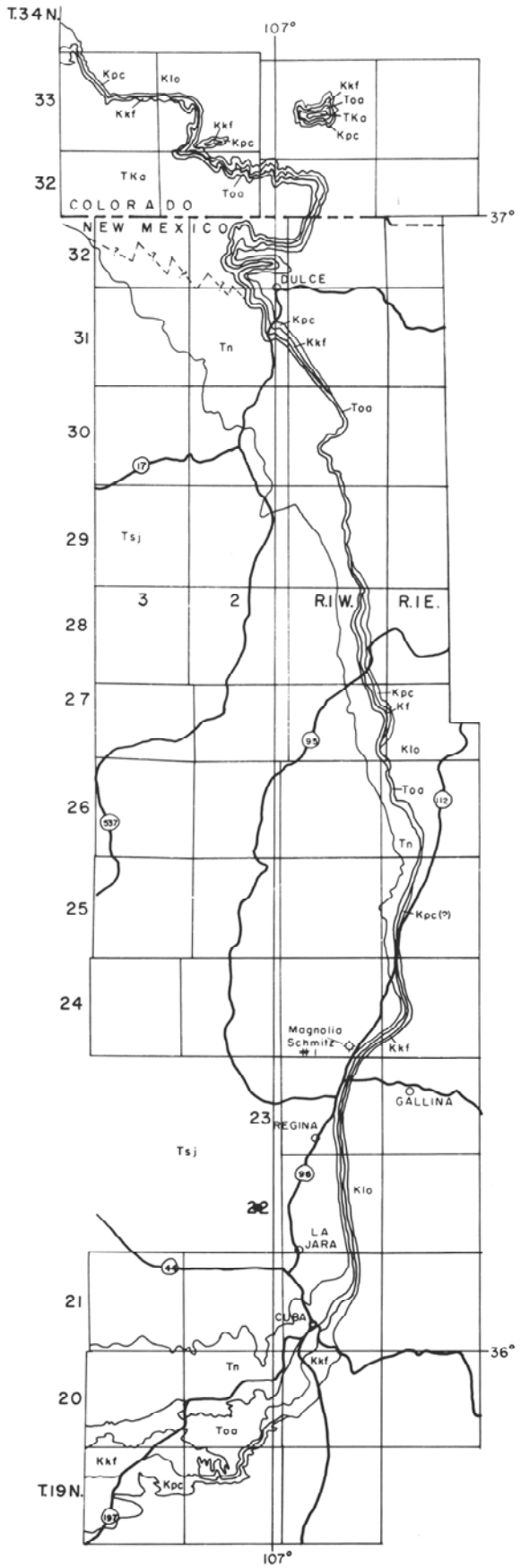


Figure 3. Geologic map of the eastern San Juan Basin showing Pictured Cliffs Sandstone and younger rocks. (After Fassett and Hinds, 1971) Tsj, San Jose Fm; Tn, Nacimiento Fm; Tka, Animas Fm; Toa, Ojo Alamo Ss; Kkf, Kirtland and Fruitland Fms; Kpc, Pictured Cliffs Ss; Klo, Lewis Sh and older rocks.

west of the outcrop (Fassett and Hinds, 1971) indicating that the uplift taking place in the Nacimientos was not of large magnitude and probably only produced a shoal in the Pictured Cliffs sea and probably had relatively little relief at the time the Fruitland was being deposited.

OJO ALAMO SANDSTONE

The Ojo Alamo Sandstone of Paleocene age is the basal Tertiary unit of the eastern San Juan Basin. This unit is composed of sheet-like sandstone bodies interspersed with shale beds. Lithologically the Ojo Alamo is a coarse-grained, arkosic, conglomeratic sandstone; the pebbles, which are primarily quartzite and jasper, become smaller eastward across the basin until on the east rim, pebbles are scarce. The absence of pebbles in the subsurface on the east side of the basin has been documented (Fassett, 1968) at at least one locality. The Ojo Alamo contains abundant large silicified logs almost everywhere.

The unconformity at the base of the Ojo Alamo seems to be present throughout the basin and truncates progressively older rocks from west to east indicating a regional tilting and uplift of the entire basin area prior to Ojo Alamo deposition (Fassett and Hinds, 1971). As much as 2,100 feet of Kirtland and Fruitland rocks may be missing along the east edge of the basin. In places along the eastern San Juan Basin (Fig. 3) the pre-Ojo Alamo unconformity has completely cut out the Fruitland and the Ojo Alamo rests directly on the Lewis Shale. This indicates that the uplift preceding the pre-Ojo Alamo erosion cycle was not uniform along the east side but rather was somewhat wavy resulting in the Fruitland being stripped off the highs and preserved in the lows (Fassett and Hinds, 1971).

The Ojo Alamo does not seem to crop out along part of the southeast rim of the basin (Fassett and Hinds, 1971). Alluvial cover makes difficult the determination of whether the Ojo Alamo was not deposited or possibly is not resistant enough to crop out in these areas of poor exposures. Well log data indicate the latter, inasmuch as all logs along the east edge of the basin which include this interval show Ojo Alamo. Outcrops of the Ojo Alamo in the northeastern part of the basin are excellent and can be traced into Colorado to an area a few miles north of the San Juan River (Fassett and Hinds, 1971). In this area Dane (1948), Dane and Bachman (1957), and Wood, Kelley, and MacAlpin (1948) had mapped the Ojo Alamo with the Animas Formation. Baltz and others (1966), however, showed the Ojo Alamo queried along the northeast rim of the basin up to the Colorado State line.

The nature of the Ojo Alamo basal contact and indeed the very definition of the Ojo Alamo has been the subject of some disagreement over the past few years. Recent papers dealing with this problem, which is too complex to discuss in the short space available here, include: Baltz and others (1966), Fassett and Hinds (1971), Powell (1973), Tschudy (1973), Clemens (1973), and Fassett (1973b), and two recent geologic maps: Fassett (1966) and Hinds (1966).

The location of the Cretaceous-Tertiary boundary in the southeastern basin had for some time been another controversial problem; however, recent palynological studies by R. H. Tschudy of samples from the Mesa Portales quadrangle (Fassett, 1966) have narrowed this boundary to a 36-foot interval "... below the lower sandstone bed pinching out on

the south edge of Mesa Portales in figure 12" (Fassett and Hinds, 1971, p. 33). Throughout most of the basin this boundary is probably coincident with the base of the Ojo Alamo; however, in some places it may be found slightly below the base of the Ojo Alamo (Fassett and Hinds, 1971).

NACIMIENTO FORMATION

The Nacimiento Formation conformably overlies the Ojo Alamo in the southern two-thirds of the San Juan Basin. The Nacimiento is made up of black and gray shale with occasional channel sandstone beds. It is thought that the finer elastics represent lake bed deposits in the central basin area. Those beds now comprising the Nacimiento Group were called the Puerco and Torrejon Formations by Gardner (1910), but according to Simpson (1960, p. 76), "The Puerco and Torrejon are now considered as faunas and faunal zones within the Nacimiento Formation, not as rock units."

The basal contact of the Nacimiento was at one time thought to be unconformable but recent work (Fassett, 1966, Baltz and others, 1966) has shown this contact to be one of intertonguing with the underlying Ojo Alamo and thus conformable.

According to Simpson (1959, p. 1): "The faunas (of the Nacimiento Formation, San Juan Basin) are classical and are still the standard of comparison for the most clearly established lower (Puercan), (Torrejonian), and upper (Tiffanian) stages and ages." Mammals from the Nacimiento have been collected by Baldwin for Cope in 1880, Granger in 1910, Simpson and others in 1949, and others (Simpson 1959, p. 2, 3). The Nacimiento is about 900 feet thick south of the southern tip of Cuba Mesa west of Cuba, New Mexico (Fassett, 1966).

ANIMAS FORMATION

In part of the San Juan Basin the Animas Formation seemingly ranges in age from Late Cretaceous to Tertiary, but in most areas of the basin the Animas overlies the Ojo Alamo and accordingly is of Tertiary age. The Animas contains an abundance of material of volcanic origin. It is conglomeratic and characteristically contains boulders and pebbles of andesite in a tuffaceous matrix; the conglomerate beds are interbedded with variegated shale and sandstone. The Animas is limited to the northern part of the basin and grades laterally into the Nacimiento Formation to the south in the vicinity of Dulce, New Mexico. The diagnostic feature of the Animas is macroscopic volcanic material, (Fassett and Hinds, 1971, p. 33). The Animas reaches a thickness of 2,670 feet in Colorado (Reeside, 1924, pl. 2).

SAN JOSE FORMATION

The San Jose Formation of Eocene age overlies the Nacimiento and the Animas Formations and consists of interbedded sandstone, shale, and variegated shale. The sandstones are fine- to coarse-grained, arkosic, sporadically conglomeratic, and contain silicified wood. The basal contact of the San Jose seems to be unconformable around the basin rim and conformable in the central basin area (Fassett and Hinds, 1971).

This formation was known as Wasatch for many years but in 1948 Simpson wrote: "It is at present a firmly established, almost self-evident conclusion that "Wasatch," as a stratigraphic name, is a misnomer for the beds commonly so called in the San Juan Basin." In a long and detailed exposition on the nomenclatorial history of the San Juan Basin Tertiary rocks, Simpson (1948, p. 280) recommended that the name "... San Jose Formation [which] is derived from the San Jose valley, in northwestern Sandoval County, New Mexico," be used for rocks formerly called Wasatch.

Baltz (1967) later studied the Tertiary rocks of the east-central San Juan Basin and divided the San Jose Formation into four members which he called, from oldest to youngest, the Cuba Mesa Member, the Regina Member, the Llaves Member, and the Tapacitos Member. These units are lithologically sandstone-shale-sandstone-shale, respectively. Fassett (1966), Hinds (1966), and Woodward and others (1972) had difficulty mapping these units. The writer and J. S. Hinds of the U.S. Geological Survey traced the Cuba Mesa Member a few miles west of Cuba to where it pinched out. In the subsurface, however, Brimhall (1973) was able to divide the San Jose into four sandstone-shale-sandstone-shale units which he labeled 4, 3, 2, and 1, upward. Brimhall wrote (1973, p. 202) that he had not tied his electric log section "... into outcrops; however, the numbered members correspond to 1-Tapacitos: 2-Llaves, 3-Regina and 4-Cuba Mesa Members of Baltz (1962, p. 143-163)."

Generally speaking, the San Jose thickens toward the east-central part of the basin where it reaches 2,400 feet, as depicted by Brimhall (1973, fig. 4). There is some speculation that the San Jose once completely filled the San Juan Basin. Indirect evidence for a once deeper burial of the central basin was furnished by R. H. Tschudy (personal commun., 1972). Tschudy noted that rock samples from the Gasbuggy core (Tschudy, 1973; Fassett, 1968) break down much more slowly when being processed for pollen and spore separation than would be expected for their present depth of burial.

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