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NEOGENE STRATIGRAPHY OF THE NORTHWESTERN ALBUQUERQUE BASIN

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INTRODUCTION

Stratigraphic studies of the Neogene deposits of the Albuquerque-Belen basin were initiated in the northwestern part of the basin along the Ceja del Rio Puerco, the badland escarpment carved by tributaries of the Rio Puerco, and in the adjacent terrain dissected by the Jemez River. The stratigraphic nomenclature developed in this region has been applied elsewhere in the basin, but the northwestern outcrops historically have been the source for most of our knowledge of the stratigraphy of the basin-fill deposits. The following review will focus on this region as the most influential in the development of concepts of the Neogene stratigraphy of the Albuquerque-Belen basin.

HISTORICAL REVIEW

Bryan and McCann's pioneering study, published in two parts (1937, 1938), was the first synthesis of the Cenozoic history of the Albuquerque basin. Coupled with a concurrent but unpublished study with Upson on the adjacent Santo Domingo basin, these investigators were able to establish regional relationships in stratigraphy, structure, and geomorphology across an important part of the Rio Grande depression. The term "Santa Fe Formation" that Darton (1922) had substituted for the "Santa Fe marls" of Hayden (1869) and others was used by Bryan and McCann (1937, p. 806-807) for the late Cenozoic deposits of the northern Albuquerque basin. They applied the term to rocks in the Albuquerque basin on the basis of paleontological evidence of equivalent age and continuity of outcrop with the type locality to the north. Broad similarity in lithology, depositional environments, deformation, and geological history were recognized by Bryan (1938) to link the late Cenozoic basin deposits of the Rio Grande depression from southern Colorado to Texas into one lithogenetic and tectonic entity to which he applied the term Santa Fe Formation. This concept was followed by most later workers, but the increasing awareness of the complexity of local depositional and structural settings along the depression prompted Kelley (1952), Kottlowski (1953), and Spiegel (1961) to suggest group rank for the term. Spiegel and Baldwin (1963) formally proposed that the term Santa Fe, as used by Bryan, be raised to the rank of a group in lithostratigraphy. This proposal has been further discussed by Hawley and others (1969) who recommend limiting the upper part of the group to the youngest deposits predating the initial entrenchment of the Rio Grande Valley system.

Galusha and Blick (1971) strongly objected to such an enlarged concept of the Santa Fe Group arguing that the interbasinal relationships implied by this usage were not demonstrable in the pre—Rio Grande deposits. They advocated a separate nomenclature for each Cenozoic basin and in particular would restrict the term Santa Fe Group to its type area, the Espanola basin. Such a strictly analytical approach, however, can be denoted in nomenclature by use of the formation-rank for the deposits of individual basins as has been done in recent years (see Hawley, 1978 for review). Precise linking, through correlation, of basin histories would be the most desirable way to demonstrate the stratigraphic and tectonic interrelationships along the depression. Indeed, the hypothesis put forward by Bryan (1938) of the structural linkage of the Cenozoic basins composing the Rio Grande depression has been reinforced in the ensuing years. A nomenclature that expresses this unity of overall history in the face of local diversity is thus desirable in any larger synthesis of Cenozoic geology of the region.

Bryan and McCann (1937) recognized three informal members within the "Santa Fe Formation" exposed along the Ceja del Rio Puerco and in the Rincones de Zia south of the Jemez River (fig. 1). These rocks rest unconformably on Cretaceous deposits and on the Eocene Galisteo Formation (Galusha, 1966). The older rocks were once regarded as pre—Santa Fe "andesite," "andesite tuff," and "basalt tuff," but these volcanics appear to be either clasts in the basal Santa Fe or the intrusives of the Benevides Hill diatreme (Kelley and Kudo, 1978). The three members were differentiated mainly on color into Lower Gray, Middle Red, and Upper Buff members; all are basically sandstones. The two lower units are fine- to medium-grained sand, cemented with calcite into concretionary structures; the upper member is more variable in lithology, with coarser-grained with gravelly sands and gravels interbedded with silts and clays. Judging from their lithology, the sources of these sediments lay to the northwest in the Sierra Nacimiento and San Juan Basin, but the Upper Buff also showed volcanic clasts that underlie the surface of the Llano de Albuquerque were deposited. These younger deposits are coarser grained, indicate a high-energy depositional environment, and imply a large source-area component from the San Juan Basin. The surface of aggradation, Llano de Albuquerque, is capped by a caliche.

Bryan and McCann (1937) concluded that the three members of the Santa Fe Formation may not be distinguishable in the deeper part of the basin to the east, but they predicted that they may be traced to the south along the Ceja since that escarpment is cut approximately parallel to the basin edge. Bryan's student Wright (1946) carried the stratigraphy southward into the lower Rio Puerco area and was able to trace the Lower Gray member into the Apache graben west of the Rio Puerco and just north of 1-40. Only the Middle Red and Upper Buff members were recognizable farther south. Wright (1946) recognized that episodic movement on some of the intrabasin faults (notably in the Sand Hill fault zone) interrupted deposition of the Upper Buff member and gave rise to local unconformities within that unit and in the overlying gravels. Superposed caliches were formed as alluviation and calicic-soil formation accompanied local deformation.

The 1960's brought publication of the results of the several geologists whose work concerned the Cenozoic stratigraphy of the northwestern Albuquerque basin. Spiegel (1961) studied the stratigraphy exposed along the lower reaches of the Jemez River (fig. 1). He mapped westward into the Rincones de Zia, the limit of Bryan and McCann's (1937) work. He used the term Santa Fe Group and divided the units mapped into two unnamed formations. The lower unnamed formation was, in turn, divided into two members: (1) a lower member of thick, light tan to gray sandstone bearing pumiceous ash in the upper part, and (2) an upper member of red mudstone, reddish-brown sandstone, and red silty conglomerate that interfingers with the gray sands of the lower member. Significantly, Spiegel noted that the red beds of his upper member thicken to the east and include volcanic conglomerates in outcrops on the flanks of and southwest of Santa Ana Mesa; whereas, to the west, in the Rincones, a similar thick red unit that he presumed was correlative

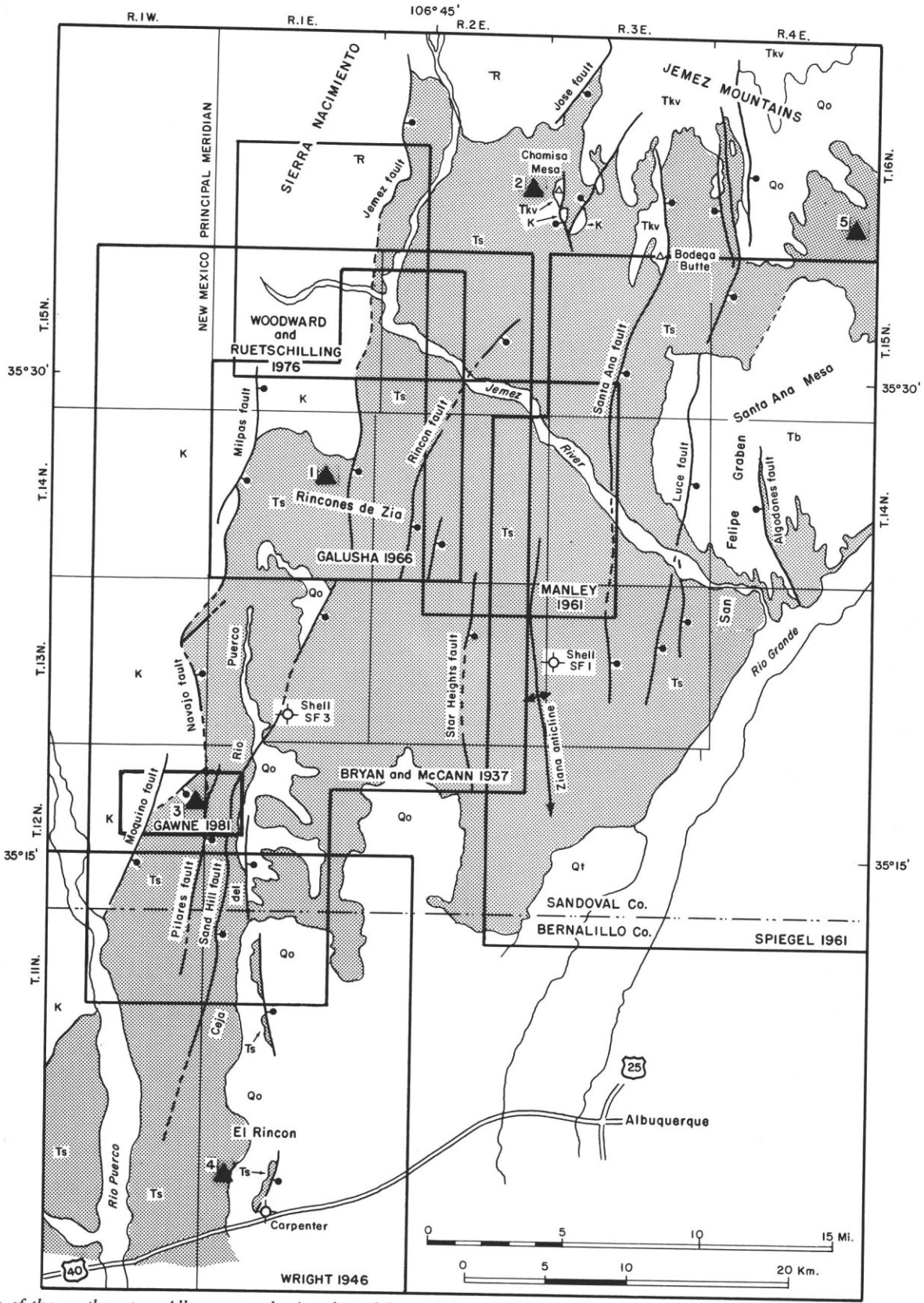

Figure 1. Map of the northwestern Albuquerque basin adapted from Kelley (1977) showing the outcrop of Neogene basin fill (Santa Fe Group shaded), prominent faults, and geographic features discussed in the text. Areas mapped by authors whose work is reviewed in this paper are outlined by heavy lines and labeled by author(s) name and date of publication. In addition, Smith and others (1970) mapped the area north of the Jemez River and beyond the limit of this figure. Type sections of units discussed in this report are indicated by black triangles and numbered as follows: (1) Piedra Parada Member, Zia Sand, and Zia Sand type section; (2) Chamisa Mesa Member, Zia Sand; (3) Cañada Pilares Member, Zia Sand; (4) Ceja Member, Santa Fe Formation; and (5) Cochiti Formation, part of the type area. Abbreviations of geologic units are: R, Triassic; K, Cretaceous and Eocene; Ts, Santa Fe Group; Tkv, Jemez Mountains volcanics, mostly Keres Group in area of map; Tb, Santa Ana basalt field; Qo, Ortiz gravel and younger deposits; Qt, Rio Grande terraces. Faults and folds shown with familiar symbols (Kelley, 1977).

lacked volcanic detritus. Spiegel (1961) correlated these units with the Lower Gray and Middle Red members of the Santa Fe Formation of Bryan and McCann as shown in Figure 2.

Spiegel correlated his upper unnamed formation with the Upper Buff member and recognized three facies within this unit: alluvial piedmont facies from the western and eastern sides of the basin, and an axial gravel facies representing the ancestral Rio Grande. Spiegel did not observe the interfingering of sands and gravels of the western-piedmont facies with the axial gravels. The western-piedmont facies alluvium contains red granite pebbles and basalt boulders that Spiegel thought were derived from the Nacimiento—San Pedro uplift and the western Jemez Mountains, respectively. He mentioned the basalt flows interbedded with the western-piedmont facies northwest of Santa Ana Mesa in the Chamisa Mesa and Bodega Butte area.

The western-piedmont facies of the upper unnamed formation of Spiegel (1961) is unconformably overlain by up to 10 m of gravelly sand, the "uppermost gravels," whose lithology closely resembles the gravels of the underlying deposits and implies the same source area. These younger gravels were equated with those deposited prior to the development of the widely identified Ortiz erosional surface (Bryan and McCann, 1938), and locally they were correlated with the formation of the basalt field of Santa Ana Mesa.

Galusha initiated his stratigraphic study of this region in 1947 upon discovery of rich fossil deposits in the Santa Fe Group in the Jemez region and along the Ceja. The geological results of Galusha's work were published in preliminary form in 1966, and further comments on the stratigraphy of the Jemez area were offered by Galusha and Blick (1971) and Hawley and Galusha (1978).

Galusha (1966) proposed the term Zia Sand Formation for outcrops in the Rincones de Zia, and he subdivided it into two members: (1) the Piedra Parada Member at the base with a type section in the Rincones de Zia (fig. 1, Arroyo Piedra Parada) and (2) the Chamisa Mesa Member above with a type section (fig. 1) on the western slope of Chamisa Mesa, 18 km to the northwest in the upper Jemez River drainage. The Piedra Parada Member is identical to the Lower Gray member of Bryan and McCann (1937) as recognized in the Rincones de Zia. Galusha was the first to note that except for local fluviatile beds, the greater part of this light gray-to-buff, medium-to-coarse sand unit is made up of eolian deposits whose large-scale crossbedding is clearly defined by the differential cementation of the deposit. The sedimentology of these deposits was later investigated in detail by Gawne (1981). Eolian crossbedded sands also occur within the Chamisa Mesa type section, but the sequence there is on the whole pinkish in color, finer grained, and thinner bedded with many greenish beds near the top. Gawne (1981) presents evidence that an important eolian component is present in this section and identifies loessic deposits as well as dune sands.

Galusha (1966) arbitrarily chose a limestone with siliceous concretions as the top of his Chamisa Mesa Member and, thus, the Zia Sand at Chamisa Mesa. This choice was based on his ability to map this limestone locally rather than on evidence of a hiatus with the overlying deposits. Gawne (1981) and Tedford (1981) have recently recommended that the contact of the Chamisa Mesa Member and younger rocks be placed at the cherty sandstone about 12 m higher in the section at Chamisa Mesa in recognition of a biostratigraphic hiatus. To the south in the Rincones de Zia, the top of the Zia Sand is a well-marked disconformity with the overlying Middle Red member of Bryan and McCann (1937). Galusha (1966) identified these overlying beds as "Santa Fe Formation equivalent" and later (Galusha and Blick, 1971) noted that their contained fossils indicate correlation with the Tesuque Formation of the Espanola basin.

Galusha (1966) mapped the "Upper Buff member" above the "Santa Fe Formation equivalent" in the Rincones de Zia and showed the Upper Buff to thicken progressively eastward, making up a greater part of the outcrop belt south of the Jemez River and east of the Rincon Fault. Bryan and McCann (1937) had correlated the "alluvial-fan deposits" of the lower Jemez River drainage with their Lower Gray member. Spiegel (1961) also had assigned these outcrops to the lower member of his lower unnamed formation, and he correlated them with the Lower Gray member. Galusha and Blick (1971) insisted that these beds "are not equivalent to the Lower Gray (Galusha, 1966) but lithologically and faunally are similar to the Ojo Caliente Sandstone Member of the Tesuque Formation." The following paragraph in their (Galusha and

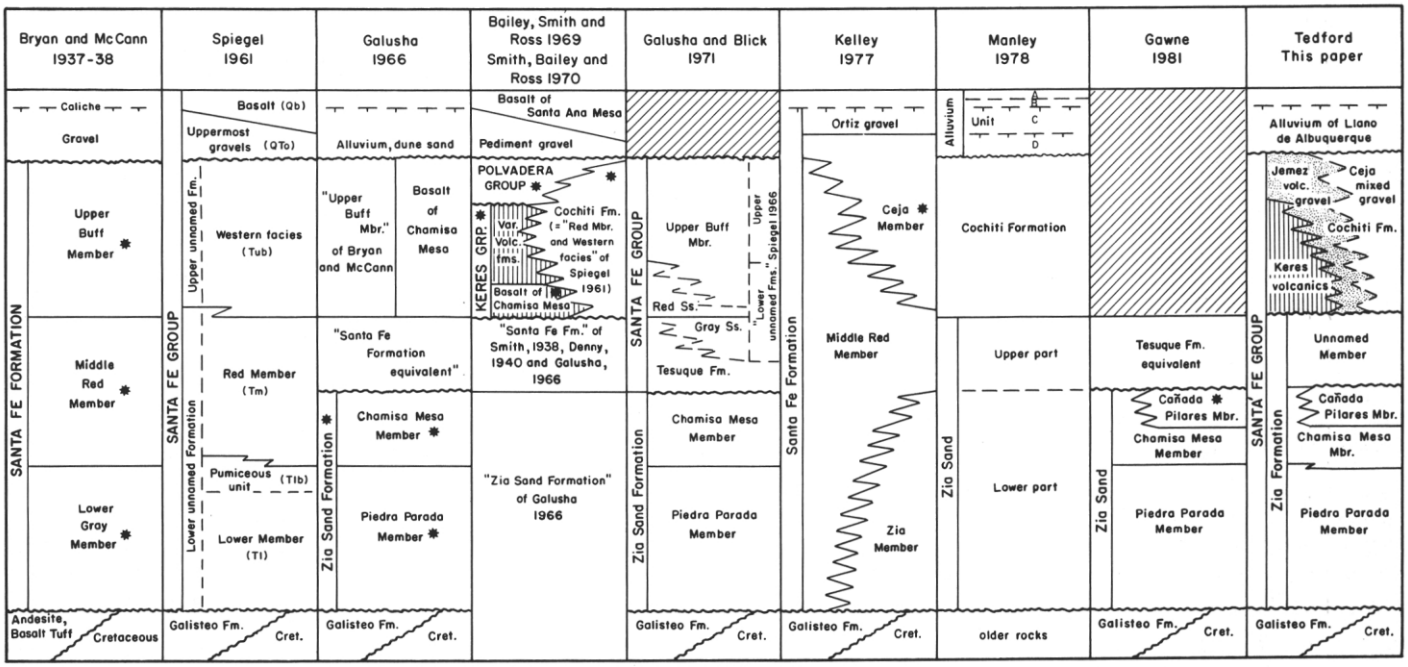

Figure 2. Comparative stratigraphic nomenclature for the Neogene rocks in the northern Albuquerque basin illustrating the concepts discussed in the text. Correlations proposed by certain authors are indicated, specifically the correlations of Spiegel's (1961) work by Bailey and others (1969) and Galusha and Blick (1971). Asterisks denote names first proposed in the papers cited.

Buick, 1971, P. 39-40) paper contains a succinct summation of their views on the correlation of the deposits exposed in the lower Jemez River area and is worth quoting in full:

> The Tesuque Formation (Middle Red of Bryan and McCann) was traced and prospected for fossils from the [Canada] Piedra Parada eastward across the various fault blocks that have successively offset the Tesuque (Middle Red Member). The gray sand beds at the top of the Tesuque Formation increase in thickness in an easterly direction, with maximum thickness exposed southwest of Santa Ana Pueblo and south of Jemez Creek where cemented dikes commonly associated with fault zones are conspicuous topographic features. The red deposits underlying Santa Ana Mesa north of Jemez Creek, and those overlying the gray sand south of Jemez Creek, mentioned above, are part of the same formation. If fossils had not been available to point the way toward investigation of the stratigraphic position of these beds, it would have been natural to assume that the gray sand was a lateral facies of the Zia Sand, an early and medial Miocene (Arikareean and Hemingfordian) formation. Actually they belong high in a set of strata of early Pliocene (Clarendonian) age. The Tesuque (Middle Red of Bryan and McCann) Formation can be shown to be faulted and buried by the Upper Buff in the Lower Jemez River region. The red deposits in the Lower Jemez area that have been confused with the Middle Red are interfingered laterally toward the west with the buff beds of the Upper Buff of Bryan and McCann and presumably are essentially a facies of the same formation.

Galusha and Blick (1971) thus correlated Spiegel's (1961) unnamed formations with part of the Middle Red and Upper Buff members of Bryan and McCann (1937), as shown in Figure 2.

By 1969 studies of the stratigraphy of the Jemez Mountains volcanic center were sufficiently advanced for a proposal of a nomenclature for the volcanic rocks (Bailey and others, 1969). This was followed by a geological map (Smith and others, 1970) in which the areal distributions of the named units were shown. Although the emphasis was on the volcanic stratigraphy, the relationship of volcanic rocks to the interfingering sediments in the Espanola, Santo Domingo, and northern Albuquerque basins also was outlined. With regard to the latter basin, these authors accepted the concepts of the Zia Sand and "Santa Fe Formation" as proposed by Galusha (1966). They extended the "Santa Fe Formation" upward to the base of their Keres Group and locally to the basalt of Chamisa Mesa, the oldest volcanic unit having a center in the Jemez Mountains. The volcanic gravels that interfinger with all the volcanics of the Keres Group (and the lower part of the succeeding Polvadera Group) were named the Cochiti Formation "for exposures in the badlands west [and] southwest of Cochiti Pueblo, in the western half of the Santo Domingo Pueblo quadrangle, and the eastern half of the Jemez quadrangle" (Bailey and others, 1969, p. 69; fig. 1). Mapping by Smith and others (1970) illustrates the distribution of the Cochiti Formation in the northern part of the Jemez River drainage from Bodega Butte south to the Santa Ana Mesa where it is in fault contact with the "Santa Fe Formation" to the west, across the Santa Ana fault of Kelley (1977), and overlain by the basalts of Santa Ana Mesa to the east. Bailey and others (1969) noted:

> the formation becomes finer grained southward from the Jemez Mountains, and under Santa Ana Mesa it grades laterally into coarse sands which become redder by inclusion of more and more granitic debris at the expense of volcanic debris. These coarse sands were mapped by Spiegel (1961) as the "red member of the Santa Fe Group" and were believed by him to be older than the Cochiti Formation, which he called the "western facies of the Santa Fe Group": Intertonguing and gradation between Jemez-derived volcanic debris and granitic debris, however, especially on the north and west side of Santa Ana Mesa, indicate that the two facies are, in large part, time equivalent.

This correlation of the Cochiti can be carried westward into the Rincones de Zia where the Upper Buff member as mapped by Bryan and McCann (1937) may be wholly or partially equivalent.

Kelley's (1977) comprehensive review of the geology of the Albuquerque basin advocated another approach to the stratigraphy of the basin fill, essentially returning to the concept of Bryan and McCann (1937). He differed in regarding the three members as facies of the basin fill for which the term "Santa Fe Formation" is used with the comment that the mapped subdivisions "are not distinctive enough to warrant more than member status" (Kelley, 1977, p. 11). Kelley critically reviews previous work on the stratigraphy of the basin fill. In his view, interfingering of lithologies is so pervasive, vertically and laterally, that the stratigraphic subdivisions of Galusha (1966) and Bailey and others (1969) cannot be mapped over the entire basin. Kelley's lithologic criteria for these units remain the color changes and the larger aspects of lithology cited by Bryan and McCann (1937). Kelley does not utilize more detailed studies of lithology, sedimentology, or provenance.

Kelley (1977) proposed the term Ceja Member "roughly the equivalent of Bryan and McCann's Upper Buff member" and designated a type section on the southern side of El Rincon, a reentrant in the Ceja del Rio Puerco, 4 km north of 1-40 (fig. I). There, 64 m of conglomerates, coarse-grained sandstone, and minor mudstone crop out above the "Santa Fe red beds." Kelley (1977) discussed the distribution and size of clasts in the Ceja Member when traced along the Ceja del Rio Puerco. Like Bryan and McCann (1937), he concluded that "the volcanic fraction increases northward with respect to other fractions" as one follows the Ceja outcrops. These lithological features, and the stated near correspondence in concept of the Ceja Member with the Upper Buff member in the northern Ceja and Rincones de Zia outcrops, indicates correlation with at least a part of the Cochiti Formation despite Kelley's (1977, p. 13) statement that the latter is "simply a volcanic-bearing facies of the Santa Fe, mostly of Middle Red member, but possibly also some of the Zia in the upper part." Remnants of the Ortiz surface are indicated on Kelley's (1977) map, but the description of the El Rincon section does not designate an "Ortiz pediment gravel," although "in general there usually is present at least a thin (less than 20 ft thick) sand or gravelly sand on the Ceja-Ortiz surface" (Kelley, 1977, p. 20).

Manley (1978) mapped the Bernalillo NW quadrangle that lies in the western part of the region mapped by Spiegel (1961), mostly south of the Jemez River and between the Rincon (west) and Santa Ana (east) faults (fig. 1). She divided the outcrops of Tertiary rocks into two formations, the Zia Sand below and Cochiti Formation above, and proposed to redefine the Zia Sand to include the Zia Sand and "Santa Fe Formation" of Galusha (1966). The latter proposal was adopted by the U.S. Geological Survey (Sohl and Wright, 1979, p. A49). Manley (1978) justified this action by noting that "the Zia Sand and Santa Fe Formation of Galusha (1966) have been combined because the lithological differences between them are minor and do not justify separation into two formations, and the unconformity separating them cannot be recognized throughout the area." Manley does not discuss the problems in correlation of the lower Jemez deposits pointed out by Galusha and Blick (1971) and Bailey and others (1969) and discussed above. The "Zia Sand-upper part" mapped by Manley (1978) in the Bernalillo NW quadrangle appears to be the "Santa Fe" or "Tesuque" formations of Galusha (1966) and Galusha and Blick (1971) and the "lower unnamed formation" of Spiegel (1961). The dominance of beds deposited by eolian processes suggested the Ojo Caliente Sands to Galusha (Galusha and Blick, 1971; Hawley and Galusha, 1978) who recognized beds of similar lithology above the red fluviatile deposits of the "Santa Fe Formation equivalent" in the Rincones de Zia and in a similar position beneath the basalt cap of Chamisa Mesa.

The most recent contribution to the Cenozoic stratigraphy of the northern Albuquerque basin accompanies Gawne's (1981) study of the sedimentology at the Zia Sand of Galusha (1966). Gawne (1981; figs. 1, 4) mapped the important Zia outcrops in the head of the Arroyo Benevides drainage (Cafiadas Pilares and Moquino). This area was mentioned by Galusha (1966) and correlated with the type section in

the Rincones to the north. Gawne recognized the eolian Piedra Parada and fluviatile Chamisa Mesa members at this locality and included the red mudstones and interbedded fluviatile sandstones above the correlated Chamisa Mesa Member in the Zia Sand as a mew member, the Canada Pilares Member. These red mudstones were assigned to the Middle Red member by Bryan and McCann (1937). They are disconformably overlain by eolian sands petrographically similar in composition to the Zia Sand but containing mica, hornblende, and better-preserved unstable mineral grains (C. G. Gawne, personal commun., 1981). The latter sands and the thick fluviatile section above them were equated by Gawne (1981) with the Tesuque Formation of the Espanola basin.

DISCUSSION

The above historical review and Figure 2 introduce several problems in lithostratigraphy in the northern Albuquerque basin. In some cases the use of the same name for units of a different conceptual basis has led to semantic as well as geological problems. The lack of published detailed lithological studies has prohibited significant evaluation of the various bases on which the Cenozoic stratigraphy of the basin has been viewed. Nevertheless, some general conclusions seem to emerge that are supported by some or most workers and that can serve as hypotheses which need further testing.

The "Zia Sand Formation" of Galusha (1966) was the first formal unit to be proposed for the sequence informally designated by Bryan and McCann (1937). Although this unit is identical to the "Lower Gray member" of the latter authors in the Rincones de Zia, Galusha included part of the "Middle Red member" when tracing the Zia Sand southward along the Ceja del Rio Puerco. He followed an unconformity within the lower part of the "Middle Red" that chronologically constituted a significant hiatus. Gawne (1981) agreed with Galusha and located a similar contact and biochronological hiatus at Chamisa Mesa (see also Tedford, 1981). She showed that the Zia Sand was predominantly an eolian sand unit containing locally important red-colored fluviatile and fioodplain facies (e.g., Canada Pilares Member).

Manley's (1979) use of the term Zia Sand included the units of Galusha and Gawne plus the overlying informally designated "Santa Fe Formation" or "Tesuque equivalent" beds. The upper boundary of this composite unit was thus raised to the unconformity at the base of the Keres Group. Manley could not follow the unconformity at the top of the Zia Sand of Galusha and Gawne eastward into the Rincones de Zia. She did not discuss the possible effect of the dominant down-to-the-east faulting in the northern Albuquerque basin that would progressively carry the top of the Zia Sand of Galusha beneath the surface east of the Rincones. Nevertheless, it seems clear that the "Zia Sand" Manley mapped in the Bernalillo NW quadrangle includes beds that lie well above the Zia Sand of Galusha (fig. 2).

The view of the above authors that the Zia Sand is an unconformity-bounded unit contrasts with that of Kelley (1977), who used the term Zia (as Zia Member of the Santa Fe Formation) for a different concept. Kelley's Zia Member comprises the light-colored sandstones of the Lower Gray member of Bryan and McCann (1937); Kelley regarded as a facies of the red-colored, more heterogeneous sediments that compose the "main body" of the "Middle Red member" of the Santa Fe. Stratigraphically, the Zia Member is confined to the lower part of the basin fill, but it grades laterally and vertically into red beds. Kelley experienced the greatest difficulty in carrying the stratigraphy of Galusha eastward from Chamisa Mesa and the Rincones de Zia. Kelley found such an interfingering of white and red sandstones as to defy consistent mapping on these criteria. This seems to be the principal basis for his proposal of the facies relationship of the units of Bryan and McCann (1937). Galusha (1966), Manley (1978), and Gawne (1981) recognized that light-colored sandstones showing eolian structure occur both at the base of the Zia Sand (Piedra Parada Member) and in the "Tesuque Formation equivalent" or "Zia Sand-upper part." Dune-sand deposits are thus a demonstrable facies of the Santa Fe deposits in the northern Albuquerque basin, but evidence for stratigraphic continuity of these dune-sand bodies or any other white sand body in the sense of Kelley's Zia Member has not been demonstrated. Kelley's concept is a generalization whose validity and utility is stratigraphic analysis remains to be tested.

All workers agree with Bryan and McCann (1937) that coarse-grained debris dominates local lithologies only in the upper part of the basin-fill. Their "Upper Buff member" was defined in this manner. They also also noticed that the Upper Buff gravels contain volcanic clasts of Jemez provenance. Kelley (1977) noted that such gravels increase in volcanic component when traced northward to the Jemez River. North of the river, Bailey and others (1969) defined the Cochiti Formation as volcanic conglomerate and sandstones coeval with the development of the earliest volcanics in the Jemez region (Keres Group). These gravels were mapped southward across the river (Spiegel, 1961) and westward (Manley, 1978) to the Rincon fault. Farther west they are continuous with the "Upper Buff member" in the Rincones de Zia (Galusha, 1966). The gravels include red beds ("Red Member of the lower unnamed formation" of Spiegel, 1961), and these red beds thin and interfinger westward with the buff or yellow colored "Upper Buff" more typical of the outcrops in the Rincones and farther south along the Ceja (Hawley and Galusha, 1978). Kelley equated the Upper Buff member along the Ceja with his "Ceja member of the Santa Fe formation" whose type section lies near 1-40. Virtual continuity of outcrops and lithological character (with observable change in frequency of clast types) unite, at least in part, the Cochiti Formation and Ceja Member as mapped by Kelley around the northwestern Albuquerque basin. Comparison of Kelley's (1977) and Manley's (1978) maps also indicates that the Ceja Member as mapped by Kelley includes unit D of the alluvium unconformably overlying the Cochiti Formation of Manley. Kelley (1977, p. 19) admits the difficulty of separating the Ceja and younger ("Ortiz") gravels at given outcrops.

CONCLUSION

A tentative nomenclature summarizing the conclusions drawn from the above lithostratigraphic analysis is given in Figure 2. I provisionally accept the enlargement of the concept of the Zia Sand proposed by the U.S. Geological Survey, but have changed the term to Zia Formation to reflect the more heterogeneous lithologies attributed to the unit by inclusion of the "unnamed member" for the "Tesuque Formation equivalent" of Gawne (1981) or "Zia Sand, upper part" of Manley (1978). In making this proposal I recognize in nomenclature the probable local nature of the unconformity with the Zia Sand of Galusha and the evidence of lithogenetic affinity noted by all authors. Informal terms are used for the gravels of different dominant constituents within the Cochiti Formation. The Ceja Member of Kelley (1977) is subsumed as an informal member of the Cochiti Formation. I suggest here that it be limited upward by the younger sediments deposited during the development of the Rio Grande drainage system. The latter proposal may apply only to the type section and mapped extensions along the Ceja. A broader concept of the term Ceja Member is used by Kelley (1977) and Tedford (1981).

ACKNOWLEDGMENTS

I wish to dedicate this highly derivative paper to the memory of Kirk Bryan, whose pioneer work together with that of his students form the foundation of all our efforts. To the late Ted Galusha, I owe my introduction to this region and my fascination with it. I am grateful to all

the geologists whose work is so freely dealt with here, and for achievements in the field that have given substance to this review.

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