The Santa Fe Group of north-central New Mexico

Brewster Baldwin, 1956, pp. 115-121

in:

Southeastern Sangre de Cristo Mountains, Rosenweig, A.; [ed.], New Mexico Geological Society 7th Annual Fall Field Conference Guidebook, 151 p.

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THE SANTA FE GROUP OF NORTH-CENTRAL NEW MEXICO

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INTRODUCTION

The Santa Fe group is a complex sequence of basin-filling sedimentary and some associated volcanic rocks deposited in the Rio Grande trough during late Cenozoic time. The work of Kirk Bryan, his students, and V. C. Kelley has clarified many of the relationships between structure, stratigraphy, and physiography of this structural trough. Recent work (Spiegel and Baldwin, manuscript) by Baldwin and Kottlowski in the Santa Fe area has led to a revision of the definition of "Santa Fe". This article is not intended as a formal publication either of the proposed revision of "Santa Fe" or of proposed formation names; the purpose is to summarize the present understanding of the Santa Fe group.

Hayden's (1869, pp. 166-170) original definition of the Santa Fe marls follows:

"From Santa Fe to the banks of the Gallisteo Creek, eighteen miles, we pass over the recent marls and sands which seem to occupy the greater portion of the valley of the Rio Grande, above and below Santa Fe, which I have called Santa Fe marls....."

"From Santa Fe to Embudo Creek, and mostly even to Taos, the Santa Fe marls cover the country. On the east side of the Rio Grande I did not observe a single dike, from the Cerillos to the mouth of the Chama Creek. North of that the melted material has been poured over the marl so as to form broad mesas. On the west side there are numerous outbursts of igneous matter. These Santa Fe marls reach a great thickness north of Santa Fe, in the Rio Grande Valley, from one thousand two hundred to one thousand five hundred feet, and have a tendency to weather into similar monumental and castellated forms, as in the "Bad Lands". The upper portions are yellow and cream colored sandstones, sands, and marls. Lower down are some gray coarse sand beds with layers of sandstone. All these marls dip from the range westward three to five degrees. The Rio Grande wears its way through these marls with a bottom about two miles wide. On the west side are distinct terraces with the summits planed off smoothly like mesas. The first one is eighty feet above the river; the second one, two hundred feet. These marls extend all the way between the margins of the Santa Fe Mountains on the east side and the Jemez Range on the west. Most of the Chama Hills, and I think the entire hills, are composed of it. ....."

Johnson (1903) demonstrated that the "Santa Fe marls" in the vicinity of the Cerrillos were in fact alluvial deposits. The marl of Hayden is now recognized as caliche. For many years, interest in the Santa Fe was confined to study of the abundant fossils collected near Espanola, until Bryan began a systematic study of the Rio Grande trough and its sediments in the 1930's. A detailed study of the Rio Puerco area by Bryan and McCann (1937, 1938) was followed by Bryan's (1938) regional study of the Rio Grande Valley, and Bryan's students mapped contiguous areas (see Stearns, 1953a, fig. 6, for map showing the areas studied). Bryan (1938) concluded that the bulk of the Santa Fe was deposited in closed structural basins; also the Santa Fe was subdivided into three units: the Lower Gray, Middle Red, and Upper Buff members of the Santa Fe formation (Bryan and McCann, 1937). These units appear to be valid today in the area of figure 1. Whereas the reports by Bryan and his students emphasized the stratigraphy and physiography, Kelly (1952, 1954) was concerned primarily with tectonics of the Rio Grande trough and its relation to stratigraphy and physiography.

The fauna collected near Espanola were studied by Cope (1874), Matthew (1909), Osborn (1918), and Simpson (1933). In the 1920's faunal collections attracted the attention of Dr. Childs Frick (1926a), and the Frick Laboratory of the American Museum of Natural History has been making careful collections and studies of the fauna to the present time. Several monographic studies of certain mammal groups have been published (Frick, 1926b, 1933, 1937), but these are not accompanied by specific statements regarding position of the collections. However, Frick (1937) appeared to be in general agreement with the upper Barstoian-lower Clarendonian (Miocene-Pliocene transition zone) age assigned by the others. It is generally believed that the collections were from the "typical Santa Fe", the main middle unit of Bryan and McCann's Santa Fe formation.

Although the Santa Fe has been subdivided in some areas, the paucity of vertebrate remains has made it difficult to correlate subdivisions from one part of the trough to another. Correlation by lithologic type and local sequence is hindered by the extreme lithologic variability of the sediments. The "Santa Fe formation" of some reports refers to all three units of the basin-filling sequence, whereas the same term in other reports is restricted to the middle unit. Incorrect correlations have further complicated the meaning, for in some reports "Santa Fe" is inadvertently used in both a restricted and unrestricted sense.

Therefore Baldwin and Kottlowski (Spiegel and Baldwin, manuscript) propose that the term "Santa Fe" be raised to

group status, and that it include all three of the units recognized by Bryan and his students. The name "Tesuque formation" is proposed for the middle unit in the Santa Fe area, the unit hitherto called "Santa Fe formation" in its restricted sense. The Santa Fe group as defined represents the basin-filling sedimentary and volcanic rocks associated with the Rio Grande trough, and it ranges in age from middle Miocene (?) to Pleistocene (?). In the Santa Fe area, the lower limit of the Santa Fe group is taken as the top of the Espinaso volcanics and Cieneguilla limburgite, and as the base of the Abiquiu(?) formation of Stearns (1953a). The upper limit of the Santa Fe group is chosen to exclude only alluvium and terraces of present drainage, and thus the basalt flows west of Santa Fe are in the upper part of the Santa Fe group. Future studies may lead to modification of these limits.

EARLY CENOZOIC HISTORY

Laramide deformation in the Santa Fe area resulted in the formation of mountains and intermontane basins. Stearns (1943) outlined the depositional basin of the Galisteo formation, generally south and southwest of the city of Santa Fe. The Galisteo formation, an Eocene alluvial deposit 900 to 4000 feet thick, is overlain conformably by a sequence of latitic to andesitic flows and flow-breccias, named the Espinaso volcanics (Stearns, 1953b). Vertebrate remains collected a few hundred feet below the top of the Galisteo formation and also in the transition interval just above the Galisteo formation have been identified as Duchesne River in age; Stearns (1943, p. 311) arbitrarily treated the Duchesne River and the Galisteo formation as Oligocene, but later (1953b, p. 430) he put the Duchesne River in the latest Eocene. Thus Espinaso volcanism began at about the beginning of the Oligocene epoch.

In the Cerrillos, 20 miles southwest of the city of Santa Fe details of the Espinaso volcanism have been clarified by Disbrow (Disbrow and Stoll, manuscript). Four periods of igneous activity are demonstrated. In each period there was near-surface intrusion of stocks, and all but the first period were marked by accompanying extrusion of flow-breccias and some flows. Five miles northwest of the Cerrillos, Sun and Baldwin (1956) have shown that two latitic flow and flow-breccia units in the Cienega area were extruded after the youngest of Disbrow and Stoll's volcanic units. Thus the Espinaso volcanics include four periods of intrusion and four or five periods of extrusion, a total of five or six distinct periods of igneous activity, with the forceful intrusion of stocks causing local but pronounced angular unconformities during Espinaso time.

The intermediate volcanics of the Cienega area are overlain, possibly with unconformity, by the flows of the Cieneguilla limburgite (Stearns, 1953b). Just west of the Cienega area limburgite flows are in turn overlain by tuffaceous and volcanic sedimentary rocks which Stearns (1953a) named the Abiquiu(?) formation and tentatively correlated with the Abiquiu tuff (Smith, 1938), the basal unit of the Santa Fe group. Indirect evidence suggests that the Abiquiu tuff and the Abiquiu(?) formation are middle Miocene in age; if so, the Espinaso volcanism occupied some or all of the interval between latest Eocene and middle Miocene. Stearns (1953a) suggests that there was a significant interval of deformation and erosion between Espinaso and Abiquiu time; the Cieneguilla limburgite was extruded at some time within this interval.

SANTA FE GROUP

Correlation

Description of the three main units of the Santa Fe group is simplified by first establishing certain correlations. Figure 2 shows the subdivisions of the Santa Fe group as used in the several reports by Bryan and his students, as well as two columns labeled "This Report" which refer to the manuscript by Spiegel and Baldwin. The correlations suggested in the figure are only incidentally based on fossils and are therefore subject to modification.

The Santa Fe group consists of three units that are fairly persistent in the area of Figure 1. Bryan and McCann (1937) named these three units the Lower Gray, Middle Red, and Upper Buff members of the Santa Fe formation. Later reports restricted the use of Santa Fe formation to the middle unit. Stearns (1953a) tentatively correlated his Abiquiu(?) formation with the Abiquiu tuff (Smith, 1938) some 60 miles to the north, and Stearns also suggested that the Lower Gray member of Bryan and McCann was equivalent to his Abiquiu(?) formation. Cabot (1938) and Smith (1938) correlated the Santa Fe formation in their areas with the similar-appearing sedimentary rocks of the Espanola Valley that contain the late Miocene-early Pliocene Santa Fe fauna. Denny (1940a) studied the Santa Fe formation near Espanola, and Stearns (1953a) correlated his Santa Fe formation with the Middle Red member and with Denny's Santa Fe formation.

Whereas correlation of the lower two units was fairly well established by Stearns and others, the uppermost unit was not correlated satisfactorily. Bryan (1938) placed the river gravel of the ancestral Rio Grande in

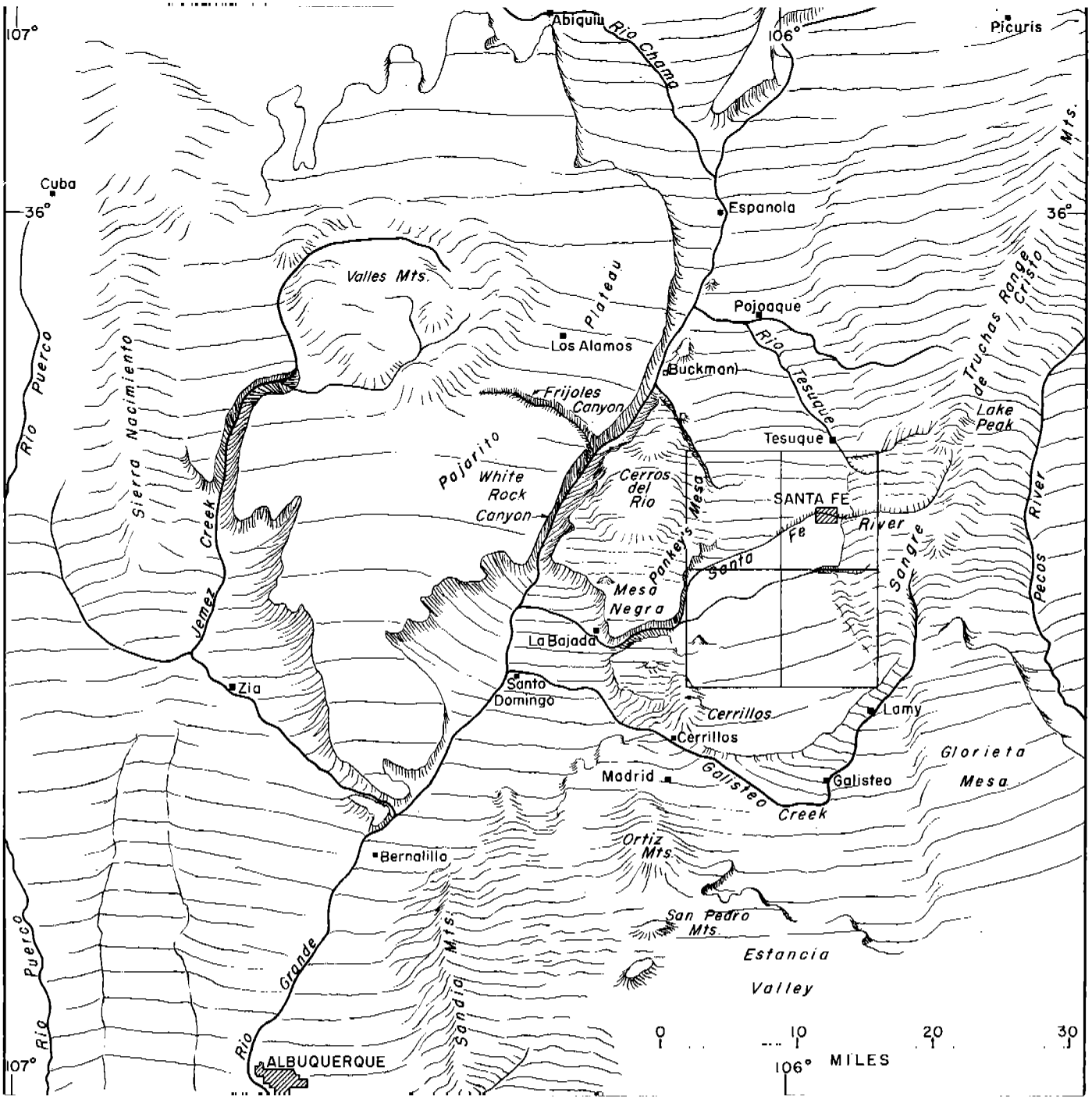

FIGURE 1. REGIONAL SKETCH MAP

the Santa Fe formation; moreover, the Upper Buff member was believed to be overlain with angular unconformity by sand and gravel (Bryan and McCann, 1937, fig. 8). Wright (1946, p. 404, 406; pl. 3, fig. 1; fig. 10) showed that the angular unconformity is within the Upper Buff member, stating that "the beds of gravel and sand interfinger with the main unit of the Upper Buff member."

Moreover, he (p. 411) suggested that the river gravel was equivalent to the Upper Buff. Unfortunately, the Tuerto gravel, which Stearns properly considered to be younger than his Santa Fe formation, is exposed in one part of his area, and the river gravel in another; the two are not seen in stratigraphic contact. So Stearns concluded, as had Denny and Wright, that the river gravel was in the

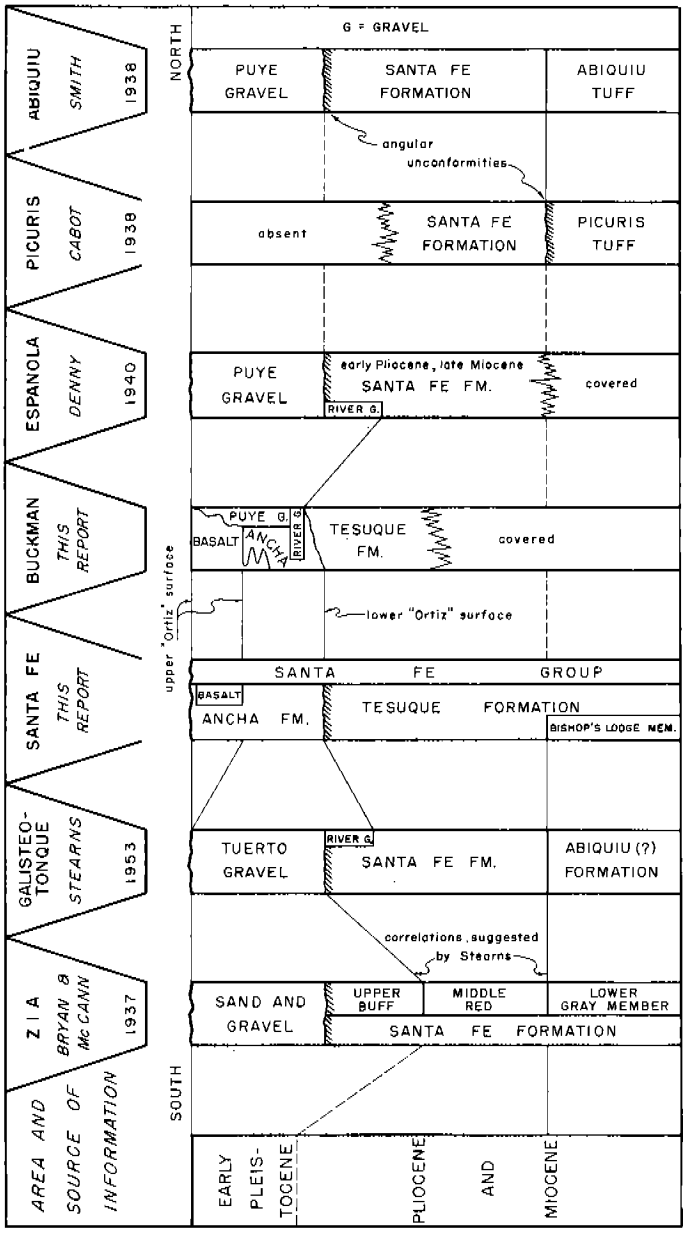

FIGURE 2. NOMENCLATURE AND TENTATIVE CORRELATIONS OF UNITS IN THE SANTA FE GROUP

upper part of the Santa Fe formation (restricted), although this was puzzling, for Denny (1940b, p. 93) and Needham (1936) had reported upper Pliocene fossils from beds equivalent to the Upper Buff member. Reconnaissance by the writer in the Buckman area (on the Rio Grande between Santa Fe and Los Alamos) suggested that the river gravel is interbedded with the Ancha and Puye gravels, and by correlation, with the Tuerto gravel; the Upper Buff member is then correlative with these gravels of the uppermost part of the Santa Fe group.

Basal unit

Smith (1938) described the Abiquiu tuff, 500 to 1200 feet in thickness, as a light-gray stream-deposited tuff and volcanic conglomerate underlying the Santa Fe formation. Because of the northward coarsening of the conglomerate, Smith stated that the Abiquiu tuff was deposited as a piedmont fan by streams draining from the north, although some contemporaneous volcanism was indicated by tuff beds and by interbedded basalt flows.

Stearns (1953a, pp. 469, 493-497; fig. 8) expanded the interpretation of the origin of the Abiquiu tuff. The fan extended south from a source in the Taos Plateau, meeting the southeast-draining master stream northwest of Bernalillo. Southwest of the master stream, sediments of the Lower Gray member were deposited by northeast-draining streams. Relief in Abiquiu time was only locally pronounced, for much of the Abiquiu tuff and Abiquiu(?) formation is fine-grained. Although the Abiquiu tuff consists largely of volcanic material, the Abiquiu(?) formation is generally non-tuffaceous. The Abiquiu(?) formation was derived primarily from the Espinaso volcanics, the Galisteo formation, and Cretaceous and Jurassic sedimentary rocks, but not from Precambrian rocks.

Sedimentary material derived from Precambrian rocks is, however, present in the tuffaceous sediments farther north. Smith (1938) mentioned a basal gravel of Precambrian granite pebbles and Precambrian pebbles are present in gravel interbedded in the water-laid Picuris tuff (Cabot, 1938, p. 91). Just north of Santa Fe, 50 to 530 feet of light-gray volcanic-derived sandstone and silt, with minor tuff beds, were measured by Kottlowski (Spiegel and Baldwin, manuscript).

This tuffaceous unit in places rests conformably on as much as 100 feet of pinkish-tan Precambrian-derived sandstone typical of the Tesuque formation. Although Cabot (1938) extended the Picuris tuff southward to include the exposures just north of Santa Fe, Kottlowski is proposing the name Bishop's Lodge member of the Tesuque formation for several reasons: (1) the Bishop's Lodge Member is interbedded with the lower part of the Tesuque formation; (2) Cabot's treatment of the Picuris tuff is generalized, whereas the study of the Santa Fe area is detailed; and (3) exact correlation with the type Picuris tuff is not possible at the present.

Middle unit

The middle unit which forms the bulk of the Santa Fe group, is a thick complex of alluvial fans, variable in sorting, source material, and cementation. North of Santa Fe, near the mountains, boulder beds are abundant in the

lower part of the Tesuque formation, but farther west, near the Rio Grande, the upper part of the formation is characterized by siltstone and fine sandstone with minor conglomeratic beds. Many of the sandstones are fairly well sorted and are cemented by crystalline calcium carbonate that gives the rock a glittering appearance. Crossbedding and linticular bedding are common. The Tesuque formation is composed almost entirely of material derived from Precambrian and Pennsylvanian rocks of the Sangre de Cristo Mountains, although correlative sedimentary rocks farther west may include other sourse materials. The Tesuque formation dips westward about 10° and it is exposed in an east-west direction for about 8 miles; thus the formation may be 7000 feet thick northwest of Santa Fe. The true thickness may be as little as half this figure, however, because of repetition of beds by unrecognized faults. For example, a peculiar occurence of 15-foot blocks of quartzite, 4 miles west of pre-Santa Fe exposures, may indicate that the basement rocks have been faulted nearly to the surface at that locality.

In the Espanola Valley (Denny, 1940a) the "typical Santa Fe" dips westward and was derived from the Sangre de Cristo Mountains. Channeling and channel breccias are fairly common, and there are many thin tuffaceous interbeds. The abundant mammal fauna collected from these beds indicates semi-arid to humid climate during late Miocene-early Pliocene time.

Upper unit

The Puye gravel (Smith, 1938), the Ancha formation, and the Tuerto gravel all rest with angular unconformity on deformed beds of the Tesuque formation. These units of gravel are 500, 300, and 150 feet in maximum thickness, respectively, and thus they are more than a pediment veneer. Both the base and the upper surfaces of the Ancha and the Tuerto were referred to indiscriminately as the "Ortiz surface" by Bryan (1938), but, as Stearns (oral communication) has pointed out, the Ortiz surface is compound. Further reference in this article to the Ortiz surface is to the "lower Ortiz surface" (the surface of angular unconformity) and the "upper Ortiz surface" (the physiographic surface).

The Tuerto gravel was derived from Mesozoic sedimentary rocks and Cenozoic volcanic rocks of the Ortiz Mountains; the Ancha formation was derived from the Tesuque formation and from Precambrian rocks of the Sangre de Cristo Mountains; the Puye gravel was derived from the volcanic rocks of the Jemez Mountains west of Los Alamos. Distinction between the Tesuque and Ancha formations in the Santa Fe area is based largely on the westward dip and the somewhat better consolidation of the former. Lithologies of the two are similar, although the Tesuque formation is commonly a very fine-grained sandstone whereas the Ancha formation contains a large proportion of gravel and coarse sand. In the Buckman area the Ancha formation appears to intertongue with Puye gravel and with river gravel that was assigned by Bryan (1938) to the ancestral Rio Grande. In this area the contact between the Tesuque and the Ancha formation is difficult to recognize, for the latter is scarcely deformed. There may have been no marked break in deposition near Buckman, which was so far from the rising mountains.

SUMMARY

The mountain-building of Laramide time formed intermontane basins, such as the one in which the Galisteo formation was deposited during the Eocene epoch. The streams that deposited the Galisteo formation were blocked by the extrusion of Espinaso volcanics at about the beginning of the Oligocene. Probably large areas were covered by tuff, flows, and breccias, though locally there was erosion of domes formed by near-surface intrusions. The five or six periods of volcanic activity assigned to the Espinaso volcanism may have continued spasmodically through the Oligocene into the Miocene. The Cieneguilla limburgite was extruded as flows in some localities, probably in the early part of the Miocene.

Although Stearns (1953a) placed a major hiatus, represented by deformation and erosion and by extrusion of limburgite, between Espinaso and Abiquiu time, only fossils will indiacate the relative lenths of time occupied by Espinaso volcanism, deformation and erosion, and Abiquiu deposition. On the other hand, it is possible that Espinaso and Abiquiu time overlapped, for there was at least minor contemporary volcanic activity during deposition of the Abiquiu tuff and Abiquiu(?) formation, and the basalt flows associated with these units might possibly be correlative with the Cieneguilla limburgite. In any event event, the Abiquiu is presumed to be middle Miocene in age, and although there may have been some warping at this time the faulting characteristic of the Rio Grande trough probably had not begun.

The Rio Grande trough probably began to form at the beginning of Tesuque time, for the Abiquiu grades up into sediments derived form Precambrian rocks, suggesting that uplift in the areas had by this time accelerated erosion, which in turn exposed the mountain core of Precambrian rocks. The structural basins, which make up the complex graben-structure of the Rio Grande trough, were apparently filled to overflowing before the end of the upfaulting of the margins, for deformation of the "typical Santa Fe" was succeeded by considerable erosion, at least

along the borders. The Tesuque formation was entirely eroded from the Cerrillos area, and erosion in the Santa Fe area may have continued from early into late Pliocene. However, farther west, deposition may have been without major interuption.

Stearns' map (1953a, fig. 9) of middle and late Santa Fe time is largely a representation of Ortiz time. The Ortiz Mountains, the Sangre de Cristo Mountains, and the majestic volcano west of Los Alamos were eroded to form, respectively, the Tuerto gravel, the Ancha formation, and the Puye gravel. These sediments were deposited on the lower Ortiz surface, beveling earlier rocks, and an ancestral course of the Rio Grande was established in about the present position of the river. Deposition may have built up the land surface considerably above the remnants of the upper Ortiz surface, for Cabot (1938) described a surface some 500 feet higher than the surface that he correlated with the upper Ortiz, and the mesa-like Cerros del Rio west of Santa Fe, which stand some 1,000 feet above the Ancha formation, may conceivably have been planed off by erosion before streams cut down to form the upper Ortiz graded surface. In any event basalt flows that issued from centers near the Rio Grande dammed the ancestral Rio Grande, buried the upper Ortiz surface and diverted the westward drainage of the ancestral Santa Fe River. Ortiz time, including the basalt flows, probably continued into the Pleistocene.

Activity of the Jemez volcano culminated in the Pleistocene about at the end of Santa Fe time. Large volumes of pumice were blown out – a line of pumice deposits extends southeast across the Santa Fe area – and then nuées ardentes spread great thicknesses of welded tuff as an apron on the east side of the volcano as the volcano collapsed. Only the base of the volcano is left, forming the ring of mountains west of Los Alamos, but the large grassed valleys inside the ring are the subdued remains of one of the largest calderas in the world. The Rio Grande, shunted eastward by the welded tuff, cut downward to form White Rock Canyon. Downfaulting near La Bajada accelerated the canyon-cutting, both of the Rio Grande and of the Santa Fe River. Although no post-Ancha faulting is recognized in the Santa Fe area, faulting in other parts of the trough continued after Ortiz time (Stearns, 1953a, fig. 10).

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