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Geology of Rincon Quadrangle, New Mexico

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Preface

This report is the second in a series on the geology of the Rio Grande rift between Las Cruces and Hatch, New Mexico. The first (Seager and others, 1971) dealt with the San Diego Mountain area about 10 miles south of Rincon, while the third (Clemons and Seager, in press) covers part of the Sierra de las Uvas south of Hatch. An eventual goal of these studies is to evaluate the effects of Laramide and Basin and Range tectonics and Cenozoic volcanism on the structure and stratigraphy of the region. Another purpose is to interpret the late Cenozoic history of the Rio Grande valley in terms of ancestral Rio Grande deposition and geomorphic development. We believe these studies will provide a geologic framework for other resource investigations involving ground water, land use, soils, minerals, oil or gas, and a variety of civil engineering projects.

The geology of the Rincon-San Diego Mountain area is critical to an understanding of regional structure and stratigraphy. A nearly complete Oligocene to Pliocene sequence of pre- and post-rifting basin sediments is present and well exposed. These strata are used as a reference section against which more incomplete Tertiary sections in nearby uplifts are compared and interpreted. Furthermore, the stratigraphic and structural features within the Oligocene-Pliocene sequence provide insight into 1) inception of Basin and Range faulting, 2) amount of contemporaneous faulting, 3) age of barite, manganese, and fluorite mineralization, 4) configuration of ancient basins and uplifts, and 5) source areas for both local and regional deposits.

Inasmuch as Quaternary deposits (Camp Rice Formation and younger units) cover more than 75 percent of the quadrangle, studies of them have been relatively detailed. Aside from their economic value as ground-water reservoirs and sources of sand, gravel and road metal, these units provide information on the geomorphic development of the Rio Grande valley, and the geologic history of the Rio Grande. Because they are primarily surficial deposits, or are widely exposed at the surface, the Quaternary units become directly involved in land-use planning or engineering studies. Consequently an effort was made to subdivide them, and older basin-fill units, into stratigraphic facies, such as basin floor (clay and silt) or piedmont (gravel) or flood plain (clay and silt) so that areas of materials with differing engineering properties would be delineated. A major purpose in mapping was to provide a map detailed enough to be useful for Soil Conservation Service investigations of soils and soil-geomorphic relationships. Such studies are currently in progress by the junior author and his associates, L. H. Gile and R. B. Grossman.

The work on the Rincon Quadrangle was done between 1967 and 1970, and partially supported by grants from the New Mexico Bureau of Mines and Mineral Resources. The authors are grateful to Noel Castle, Neil Graham, and W. A. Winder for allowing access to their land, and to Mr. Castle for permission to make detailed soil-geomorphic studies on the Rincon Surface. Acknowledgement is also made to the following persons who have contributed directly to the present study of the Rincon Quadrangle: Leland H. Gile, Robert B. Grossman and Guy D. Smith (soils); Frank E. Kottlowski (general geology); A. L. Metcalf (Quaternary molluscan faunas and stratigraphy); W. S. Strain (vertebrate paleontology and stratigraphy), W. E. King (hydrogeology), and R. E. Clemons (petrology and stratigraphy).

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Contents

FIGURES

TABLES

REAR POCKET

Abstract

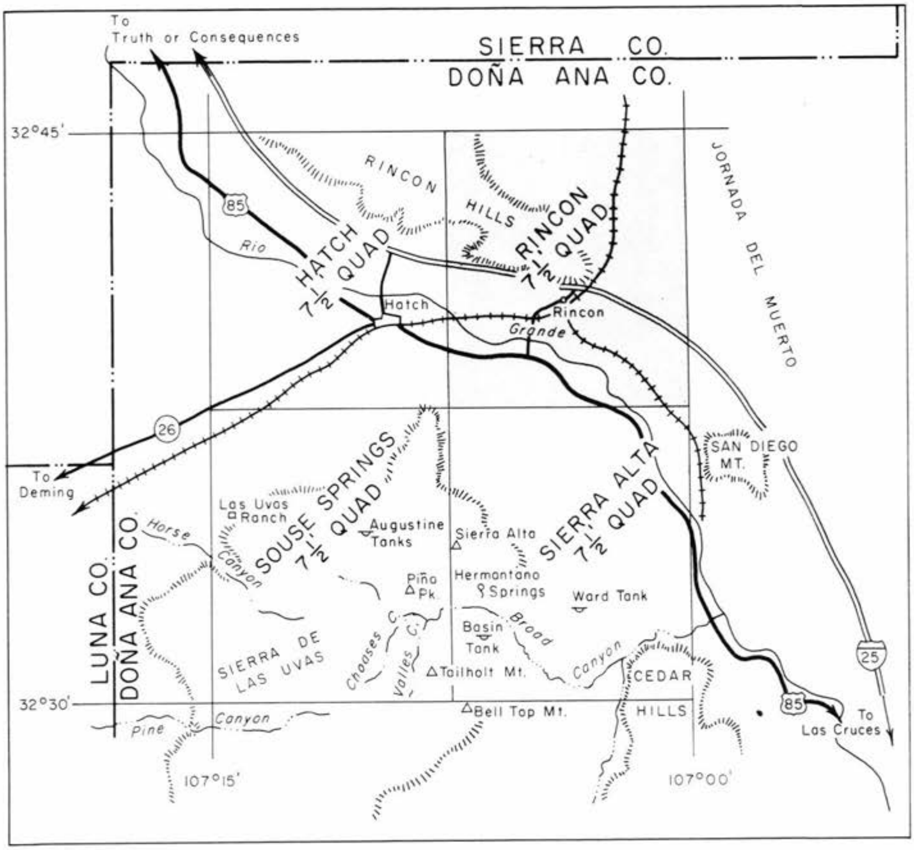
The Rincon *71/2* minute quadrangle is located in north-central Doña Ana County, New Mexico, mostly north of the Rio Grande and the towns of Hatch and Rincon. Rocks and sediments in the quadrangle range in age from Silurian to Holocene.

Paleozoic rocks, deformed during the Laramide, form much of the southern Caballo Mountains. Fusselman Dolomite, Percha Shale, Caballero Formation, Lake Valley Formation, Magdalena Group, and San Andres Formation are well exposed. In the structurally lower Rincon Hills uplift Paleozoic strata are overlain with angular unconformity by more than 7,000 ft of less-deformed Cenozoic volcanic and sedimentary rocks. These include in ascending order: fanglomeratic Love Ranch Formation, andesitic volcaniclastic Palm Park Formation (Eocene, 2,000 ft), rhyolitic volcaniclastic strata and ash-flow tuffs of the Thurman Formation, including a 400-ft thick tongue of Uvas Basaltic Andesite (Oligocene to Miocene, 2,000 ft) and Santa Fe Group (Miocene to Pleistocene, 3,600 ft). The Santa Fe Group is locally conformable with older rocks.

The Santa Fe Group comprises bolson and valley-fill deposits subdivided into **4** formations. Fanglomeratic to basinal bolson deposits of Miocene and Pliocene age comprise the basal unnamed transitional unit, Hayner Ranch Formation, and Rincon Valley Formation. The Camp Rice Formation (Pleistocene, 300 ft) consists of deposits of the ancestral Rio Grande and adjacent piedmont slopes. The Camp Rice overlaps all older rock units with angular unconformity.

Middle to late Quaternary deposits are those of the present Rio Grande system. "Older" valley-fill alluvium, formed during middle to late Pleistocene cycles of valley cutting and backfilling, include arroyo terrace, fan, and rock-veneer deposits together with flood-plain and fluvial deposits and slope colluvium. "Younger" late Pleistocene to Holocene deposits are mainly those formed by the present cycle of cutting and backfilling by the Rio Grande and its tributaries.

Major structural features in the quadrangle are high-angle normal faults of Miocene to Pleistocene age that border uplifts and adjacent grabens. Economic deposits in the area include: barite and manganese of Miocene age; clay, sand and gravel of Pliocene to Holocene age; and ground water.



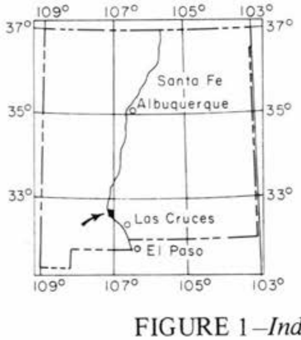


FIGURE 1–*Index map showing location of study area.*

Introduction

The Rincon 71/2-minute quadrangle in north-central Doña Ana County, New Mexico is located in the Rio Grande trough between the villages of Hatch and Rincon (fig. 1). The area mapped includes all of the Rincon quadrangle plus about 3 square miles in the northeast corner of the Hatch 71/2-minute quadrangle adjacent west. This area is in the northern part of the Mexican Highland section of the Basin and Range physiographic province (Fenneman, 1931; Thornbury, 1965). The quadrangles include the northern part of the Rincon segment of the Rio Grande valley, the northern edge of the piedmont slopes bordering the Sierra de las Uvas, a small part of the Jornada del Muerto Basin, and the foothills of the Caballo Mountains, which extend a few miles into the area from the northwest (fig. 2). Mesa, terrace, fan, and badland topography along the river valley gives way northward along faults to the Rincon Hills, a broad expanse of low mountains, hogbacks, cuestas, and badlands that extend from Rincon to Palm Park. This landscape, in turn, changes abruptly to the more rugged narrow ridges and steep canyons of the Caballo Mountains fault block. Elevations range from about 4,000 ft on the flood plain to 5,200 ft in the Caballos, but local relief does not exceed more than a few hundred feet.

FIGURE 2–*Rincon Hills landscape looking northwest from microwave tower in southern Rincon Hills. Cuesta and badland topography in middle distance is developed on Thurman and Palm Park strata. Slopes in foreground are on Hayner Ranch Formation, while Camp Rice basin-fill underlies the nearly level Rincon Surface at the foot of the Southern Caballos in the upper right. Black Range is on the skyline in the upper right, rising above the Rio Grande valley.*

TABLE 1—*Annual averages of selected climatological data, Doña Ana County, New Mexico, for the period of record through 1960*

		Temperatures °F		Precipitation (in.)			Average dates 32°F		
Station	Elevation	Mean max.	Mean min.	Yrs. of record	Mean annual	Yrs. of record	Last in spring	First in fall	Avg. Frost-free days
Hatch	4,042	78	42	27	8.96	30	Apr 10	Oct 24	197
Jornada Experimental Range	4,265	76	41	42	8.91	47	Apr 22	Oct 25	186
State University	3,881	76	44	62	8.41	103	Apr 9	Oct 28	202

TABLE 2—*Monthly temperatures and precipitation, State University, Doña Ana County, New Mexico, for period of record through 1960*

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperatures °F												
Average daily maximum	57	62	69	77	85	94	94	92	87	78	66	57
Average daily minimum	26	29	34	42	49	59	65	64	56	44	31	26
Daily mean	42	46	52	59	67	77	79	78	71	61	49	42
Extreme maximum	78	86	90	94	103	107	109	103	102	93	83	78
Extreme minimum	-8	2	12	20	27	36	42	44	30	22	5	1
Precipitation												
Average rainfall (inches)	.34	.45	.32	.20	.30	.52	1.64	1.70	1.26	.72	.49	.47
Average number days 0.10 inch or more (1936 to 1965)	1	1	1	<½	1	1	4	3	3	2	1	2
Average snowfall (inches)	.5	.4	.2	<.05	0	0	0	0	0	0	.4	.9

The following paragraph on climate was extracted from a section on the climate of Doña Ana County by Frank E. Houghton, New Mexico Climatologist, National Weather Service (Maker and others, 1971).

The Rincon area is arid. The rainy season occurs in the summer with the remainder of the year being dry. Table 1 shows selected climatological data for Doña Ana County localities including Hatch. Annual precipitation and temperature patterns for University Park (30 miles SE of Rincon) are shown in table 2. These are generally representative of other county localities, with the exception of the higher and more massive mountain uplands such as the Organ and San Andres ranges and the Sierra de las Uvas, all outside the mapped area. Rainfall is highly variable, however, and annual local totals as low as 3.4 inches or as great as 19.6 inches have been recorded. One month totals range from no precipitation to 7.5 inches and a 24-hr rainfall of 6.5 inches was measured during an intense storm at University Park. An average of 42 thunderstorms occur per year, mostly during the period of April through October; a few are accompanied by hail. Dust storms are most frequent in the spring when strongest winds blow and dry soils are most common. Dry blowing dust may also occur briefly in advance of thunderstorms.

With the exception of one ranch headquarters, the area is unpopulated away from the inner valley of the Rio Grande. The flood plain supports intensive irrigated farming with cotton, vegetables, and alfalfa comprising the major crops. Adjacent valley slopes, basin surfaces and uplands are used mainly for grazing and generally support a sparse cover of vegetation. Shrubs are dominant, mainly creosote bush, with lesser amounts of mesquite, snakeweed, yucca, tarbush and various cacti. Grass cover is fair in widely scattered areas. Soil and land resources of the area have been recently summarized by Maker and others (1971).

The first geologic studies in Rincon-Caballo Mountain area were primarily concerned with water resources investigations, including the location of dam sites for the (then proposed) Elephant Butte Irrigation Project. The major effort in this direction was conducted by W. T. Lee (1907) who generally presented a very good account of the later Cenozoic geology and geomorphic evolution of the region. The geomorphology of the intermontane basins and the Rio Grande drainage system near Rincon received the attention of a number of workers in addition to Lee, including Hill (1900), Keyes (1903, 1904, 1905), Herrick (1904), and Tight (1905). Hill and Tight effectively introduced the term "bolson" to modern geomorphic literature.

The earliest accounts of the economic geology of the area are reports by Wells (1918), Harley (1934), Dunham (1934), and Russell (1947). Wells, Dunham and Russell described the general rock types and the manganese mineralization near Rincon. In 1938 Kirk Bryan presented a detailed summary of 3 decades of work on the late Cenozoic geology, geomorphology and ground-water resources of the Rio Grande region. Kelley and Silver (1952) described parts of the two quadrangles in their study of the Caballo Mountains and presented an excellent summary of the geology of the region including a review of all previous geologic investigations. Kottlowski (1953) mapped and described the Cenozoic rock units that underlie most of the area, and integrated them into a regional synthesis. More recent studies of the Cenozoic rock units and resources of the area have been published by Kottlowski and others (1956), Hawley (1965, 1970), Kottlowski (1965), Hawley and Kottlowski (1969), Ruhe (1962, 1967), Kottlowski and others (1969), King and others (1969), and Seager and others (1971). Special studies on fossil plant and snail faunas in late Cenozoic basin and valley fills have recently been published by Metcalf (1967) and LeMone and Johnson (1969).

Stratigraphy

Stratigraphic units exposed in the quadrangles range in age from Silurian to Holocene (Geologic map, sheet 1 in pocket). Outcrops in the Caballo Mountains to the north show that Precambrian granitic rocks, Ordovician Bliss Sandstone, El Paso Group and Montoya Group underlie the region but these units are not exposed in the Hatch•Rincon quadrangles. Late and middle Paleozoic shelf strata form the Caballo Mountain fault block east of the Palm fault. With the exception of the Abo Sandstone and Yeso Formation which are covered, all late and middle Paleozoic rock units present in the area are well exposed, although the Magdalena and San Andres Formations are incomplete. About 860 to 930 ft of Paleozoic strata crop out.

Early to late Cenozoic rock units form downfaulted blocks around the southwestern side of the Caballo Mountains. The Rincon Hills block contains about 7,500 ft of volcanic and volcaniclastic rocks and fanglomerate of Eocene to Pliocene age, the upper 5,200 ft of which record essentially uninterrupted deposition from middle Oligocene to middle or late Pliocene time. The type sections for two Tertiary formations originally identified by Kelley and Silver (1952) in this area are described in this report.

Quaternary elastic deposits, locally more than 300 ft thick, are well exposed in the bluffs and badlands along the Rio Grande and its major tributaries. These strata in large part are deposits of the ancestral Rio Grande. They overlap all older rock units with angular unconformity and probably buried much of the Rincon Hills and southern tip of the Caballo Mountains within the last half million years.

PALEOZOIC UNITS

FUSSELMAN DOLOMITE (105 + ft exposed, lower and upper parts not exposed)

The Fusselman Dolomite (Richardson, 1908; Kelley and Silver, 1952) of Silurian age crops out at two places in the footwall block of the Palm fault in the southeastern Caballo Mountains. Light-gray to light-olive-gray, fine-grained, hard, cherty dolomite comprises the formation. Patchy brecciation and silicification is common, and, in Thurman Canyon small amounts of barite-fluorite mineralization along faults is present. Bedding is very thick and massive, and the formation forms cliffs and benches beneath Percha slopes.

PERCHA FORMATION (180 ft thick)

Overlying the Fusselman disconformably are dark-gray to greenish-gray fissile, micaceous shales of the Percha Formation of Upper Devonian age (Gordon, 1907; Kelley and Silver, 1952). Interbedded yellowish-gray micaceous siltstones become more numerous toward the top of the formation. The soft unit is poorly exposed because of the debris from limestone cliffs above. Nevertheless, the Percha is an easily identified unit owing to its broad, slope-forming character between cliff-forming strata.

CABALLERO FORMATION (90 ft thick)

The Percha Formation is succeeded conformably (?) by the Caballero Formation of Kinderhookian age (Laudon and Bowsher, 1941). Most of the formation is comprised of yellowish-gray, micaceous, calcareous siltstone in thin to medium beds. Pale reddish-purple patches are conspicuous in some strata and pale-red, fine-grained sandstone with comminuted fossils is present near the top. The Caballero forms steep slopes beneath cliffs of the Lake Valley Formation. The basal contact of the Caballero Formation with the Percha is not exposed, but siltstones in the Percha and Caballero appear identical, thus a conformable contact is suggested. Identification of the Caballero Formation in the southern Caballos is based on correlation of the unit with lithologically similar beds containing an Early Mississippian fauna at the same stratigraphic position in the northern Robledo Mountains (F. E. Kottlowski, letter, Dec. 1970). An erosion surface with 2 ft of relief is present at the top of the formation.

LAKE VALLEY FORMATION (to 67 ft thick where present)

The Alamogordo and Nunn Members of the Lake Valley Formation (Cope, 1882; Laudon and Bowsher, 1941, 1949) of Osage age have been recognized in the map area. Pre-Pennsylvanian erosion has removed one or both members in many places so that the distribution of the formation is spotty and discontinuous.

The Alamogordo Member, where present, overlies the Caballero Formation unconformably, forming a prominent limestone ledge to 30 ft thick that thickens and thins along strike. The limestone is medium- to light-gray micrite in even, parallel beds 1 to 3 ft thick. Banded chert lenses 4 to 5 in. thick and 2 ft in diameter are conspicuous; sparse silicified crinoids and corals are present. Where the overlying Nunn Member is present, the upper contact is an abrupt change from hard, gray limestone to softer, lighter-colored fossiliferous limestone that forms slopes.

The Nunn Member consists of soft, marly, argillaceous crinoidal biomicrite in thin, uneven, nodular beds. Light-pink, tan and white strata containing a profusion of bryozoans, crinoids, brachiopods and corals is characteristic. Maximum thickness in the map area is about 37 ft. The upper contact of the Lake Valley is an erosion surface that truncates both members and continues into the Caballero Formation locally.

MAGDALENA GROUP (374 to 381 ft exposed, upper part not exposed)

Strata of Pennsylvanian age are included in the Magdalena Group (Gordon, 1907b; Kelley and Silver, 1952) in the Caballo Mountains. They overlie Mississippian formations disconformably and form the upper slopes, ridge tops and back slopes of the highest peaks and ridges in the area. Kelley and Silver (1952) subdivided the Magdalena into three formations (in ascending order): Red House, Nakaye, and Bar B. In the Rincon and Hatch quadrangles only the Red House and Bar B Formations are exposed. These were not mapped separately owing to the scale of the map and the relatively small exposures of the Bar B Formation.

The Red House Formation forms the upper ledgy slopes and dip slopes of the fault block mountain terrain east of the Palm fault. The base of the formation is marked by 3 to 10 ft of conspicuous white to light-gray chert pebble-boulder breccia that may overlie any of the Mississippian strata. Northward, Kelley and Silver (1952) report complete overlap of Mississippian strata by Pennsylvanian, resulting in Red House overlying Percha on an unconformity with 500 ft of relief. Thin- to medium-bedded, ledge-forming biomicrite comprises most of the Red House Formation in the map area, but locally massive cherty, cliff-forming strata and interbedded soft, nodular, thin-bedded limestone is present. Siltstone beds with convolute structures occur in the lower part, and thin intraclastic zones alternating with crinoidal biosparite appear cyclically throughout the rest of the formation. Light- to dark-gray beds with yellow or purple casts or mottle patterns are typical. Many limestone beds contain abundant fusulinids, brachiopods, corals and bryozoans.

The Bar B Formation is present only in faulted slices along the Palm fault. No good estimate of its thickness can be made. It consists mainly of thin-bedded limestone and gray calcareous shale that weathers to rounded, gray hills or hogbacks. Much of the limestone is cherty and highly fossiliferous, and weathers brown to shades of yellow-gray or light-gray.

The middle and uppermost part of the Magdalena Group and the overlying Abo Sandstone and Yeso Formation are not exposed in the map area. However, they presumably occur in the subsurface in the northern part of the Rincon quadrangle between outcrops of the Magdalena and San Andres; they are covered by Quaternary colluvium-alluvium, Santa Fe Group, Palm Park and Love Ranch strata.

SAN ANDRES FORMATION (300 ft exposed, top and base not exposed)

A small outcrop of San Andres Formation (Lee, 1909), isolated by alluvium, occurs in sec. 17, T. 18 S., R. 2 W. in the Rincon quadrangle. The vertical strata appear to be part of the nearly continuous outcrop band of San Andres Formation that forms the eastern edge of the Caballo Mountains (Kelley and Silver, 1952). The exposed part of the formation consists of even, parallel-bedded, medium- to thick-bedded, fetid micrite and dolomite. Alternating light- and dark-gray layering or laminated bands and lack of chert are characteristic. At least one bed of soft, yellow-brown, fine-grained sandstone is interbedded. Brachiopods and gastropods are common at a few horizons. The formation is overlain with angular unconformity by limestone boulder conglomerate of the Love Ranch Formation.

TERTIARY UNITS

LOVE RANCH FORMATION (to 50 ft thick where present, top not exposed)

Three small exposures of limestone boulder conglomerate that form the base of the Cenozoic section in the southern Caballo Mountains have been mapped. These conglomerates appear similar to Love Ranch Formation at San Diego Mountain (Seager and others, 1971) and in the San Andres Mountains (Kottlowski and others, 1956) and are tentatively correlated with it. The formation consists of cobbles and boulders of Paleozoic limestones, mainly Magdalena Group, in a matrix of reddish-brown sandstone and mudstone. From a distance the formation is distinctly light-reddish-gray. No stratification was seen in the limited exposures.

The Love Ranch Formation overlies the San Andres Formation in easternmost exposures in the quadrangle. Westward, near the Palm fault, the formation was deposited on the Magdalena Group. These relations indicate that the formation was deposited across the truncated edges of successively older Paleozoic strata from east to west; angular relations with the Paleozoic rocks are conspicuous at all exposures. The Love Ranch is considered to be an orogenic deposit that resulted from erosion of Laramide structures (Seager and others, 1971). It is probably early Tertiary in age (Kottlowski, and others, 1956). Outcrops along the Palm fault show that the Love Ranch is succeeded by the Palm Park Formation, but the nature of the contact is not clear.

PALM PARK FORMATION (2,000[1 ft thick)

Several hundred to 2,000 (?) ft of varicolored volcaniclastic strata crop out in Johnson Spring Arroyo and west of the Palm fault. These strata were named Palm Park Formation by Kelley and Silver (1952) for exposures in Palm Park valley, but no type section was described. (The writers follow Kelley and Silver, 1952, in designating this valley Palm Park; but the correct name, according to Yeo, 1952, is Palmer Park after a ranching family in the area.) Because exposures in Palm Park are poor, a type section from Johnson Spring Arroyo, 21/2 miles southeast of Palm Park was measured and is included in the Appendix (section la- lb). Although only the upper 556 ft of the formation is present at Johnson Spring Arroyo, the variety of lithologies characteristic of the formation are well displayed. A supplementary section containing freshwater limestone beds that occur locally is also presented in the Appendix (section lc). Kottlowski (1953) has presented a brief description of a Palm Park section in Apache Valley (fig. 1) and has discussed (1963) the freshwater limestones that occur locally. The formation has eroded to badland topography in slopes beneath mesas or cuestas capped by Santa Fe sandstones or basal Thurman ash-flow tuff. Good exposures are limited mainly to small draws on these slopes or to the banks of the larger washes.

The Palm Park Formation contains a varied lithology. Grayish-red tuffaceous mudstone and siltstone, purple andesite boulder-cobble conglomerate and brown to gray andesite-plagioclase sandstone are cyclically interbedded throughout the formation. Lenticular freshwater limestone and associated travertine deposits are locally conspicuous in the middle (?) of the formation. The lithologic assemblage suggests hot spring, stream, flood-plain and possibly mudflow deposition on piedmont slopes draining andesitic volcanic highlands.

An unconformity separates the Palm Park Formation from the overlying Thurman Formation. Evidence bearing on this relationship comes from the Sierra de las Uvas and vicinity where several generations of rhyolitic domes, flows, cones and associated unconformities occur between the Palm Park Formation and ash-flow tuffs correlative with those at or near the base of the Thurman Formation. A K-Ar date of 43 m.y. from a similar andesitic sequence near Las Cruces (Kottlowski and others, 1969), suggests that the Palm Park Formation is substantially older than the Thurman. Undated gastropods and palm fronds (?) from freshwater limestones may eventually yield a reliable age for the Palm Park in the Rincon Hills.

THURMAN FORMATION-UVAS BASALTIC ANDESITE (2,241 to 2,395 ft)

The Thurman Formation was named by Kelley and Silver (1952) from Thurman Arroyo southwest of Palm Park. They designated sec. 35 and 36, T. 18 S., R. 3 W. near Johnson Spring as the type locality but did not describe a type section. A complete section of Thurman Formation, including a medial unit of Uvas Basaltic Andesite, was measured during the present study and is included in the Appendix as the type section (section 2a-2g). The Thurman is well exposed in Kelley and Silver's (1952) type locality in the Black Hills half graben (fig. 3) and southeastward toward Rincon. The white to light-gray outcrops, interbedded dark basaltic andesite flows, and badland-forming topography are its most distinctive features. The Thurman is unconformable with the underlying Palm

FIGURE 3—*"Upper Thurman clastic unit" about 1 mile west of Johnson Spring.*

Park Formation, and locally is conformable with the overlying Santa Fe Group.

The Thurman has been subdivided into four map units which include the formally named Uvas Basalt or Uvas Basaltic Andesite (Kottlowski, 1953). The basal part of the formation is clearly marked by a widespread resistant crystal-pumice ash-flow tuff about 50 ft thick designated on the geologic map "basal ash-flow tuff" (sheet 1 in pocket). The brown to cream crystal ash-flow tuff forms a prominent cuesta partly surrounding Palm Park valley and extending southward toward Johnson Spring and beyond in faulted outcrops. Locally, the ash-flow tuff is underlain by up to 150 ft of rhyolitic tuffaceous sedimentary rocks and a thin discontinuous ash-flow tuff considered to be the oldest parts of the Thurman Formation in this area (see section 2a, Appendix).

Above this basal sequence, 526 ft of interbedded tuffaceous clastic strata and air-fall and ash-flow tuffs are called "lower Thurman clastic section" on the geologic map. The lower part of this unit consists of reddish, orange or gray andesite cobble conglomerate, andesite sandstone and pink mudstone similar to Palm Park rocks. Thicker beds of white, even-bedded tuffaceous sandstone, andesite cobble conglomerate, and locally two ash-flow tuffs comprise the upper part. About 400 ft of dark to light-gray, amygdaloidal basaltic andesite flows containing two thin tuffaceous clastic tongues overlie "lower Thurman clastic section." Basaltic andesites of similar lithology and thickness occur above tuffaceous sandstones along the summit of the Sierra de las Uvas south of Hatch. Clearly, the basaltic andesites in the Rincon Hills are part of the Uvas Basalt rock unit, and intertongue with the Thurman Formation. Consequently Uvas terminology is applied to the medial Thurman basaltic andesite. Above the Uvas, 1,311 ft of Thurman is designated on the geologic map "upper Thurman clastic section" (fig. 3). It consists of interbedded gray to pink tuffaceous lithic sandstone and pink claystone. Most sandstone units consist of thick to thin, even, parallel-bedded strata, but occasional tangential cross-bedding in sets 4 in. to 5 ft thick is present. Abundant white clay, altering from pumice fragments, glass shards and crystals, constitute the matrix of sandstone beds. Cobbles and pebbles of Uvas Basaltic Andesite, andesite, or siliceous rocks, are scattered throughout the unit. Locally, thin beds of breccia, similar to the thick rhyolite pebble breccia described at San Diego Mountain (Seager and others, 1971) occurs near the base of the unit. Southeast of Johnson Spring, silification and reddish color of some beds is present in the lower part of the unit. The Thurman strata probably formed on a broad alluvial plain that occasionally was covered by shallow lakes. Eruption of ash-flow tuffs and basaltic andesites from vents in the Sierra de Las Uvas area inundated the plain periodically.

The formation is Oligocene to early Miocene in age. A potassium argon date of 34 m.y. for the basal ash-flow tuff in Apache Valley has been reported (Kottlowski and others, 1969). Uvas Basaltic Andesites, however, are Miocene as indicated by a date of 26 m.y. from basal Uvas flows in the Sierra de las Uvas (F. E. Kottlowski, letter, 1970). All four ash-flow tuffs present in the Thurman sequence below the Uvas Basaltic Andesite have been identified within the Bell Top Formation (Kottlowski, 1953) of the Sierra de las Uvas, where, however, each is thicker and more widespread. Correlation of the Thurman, Uvas and Bell Top Formations between the Sierra de las Uvas and Rincon Hills is illustrated in fig. 4.

From Johnson Spring southeastward, the Thurman is conformably overlain by the basal transitional unit of the Santa Fe Group, but west of Johnson Spring Arroyo the Thurman is overlapped with angular unconformity by the Rincon Valley Formation.

SANTA FE GROUP *(Tertiary and Quaternary)*

The general composition of the Santa Fe Group in the south-central New Mexico border region has been described by Hawley and others (1969); the three major formations comprising the group near San Diego Mountain have been discussed by Seager and others (1971). The expanded Santa Fe concept of Spiegel and Baldwin (1963) has been followed in southern New Mexico in general accord with stratigraphic usage established by Dunham (1935), Bryan (1938), Kelley and Silver (1952), and Kottlowski (1953, 1958, 1960).

A restricted concept of the Santa Fe Group recently has been proposed by Galusha and Blick (1971). They would limit the use of Santa Fe terminology to a relatively small geographical area (in and contiguous to Denny's, 1940, "type" Santa Fe area) north of Santa Fe, New Mexico, and to pre-Rio Grande alluvial and eolian deposits of middle Miocene to middle to upper Pliocene age. The Galusha and Blick proposal is contained in a very well written and comprehensive report on rock-stratigraphic and biostratigraphic aspects of the Santa Fe Group in northern New Mexico. The report constitutes a major advance in research on basin-fill geology and represents more than 4 decades of work by the staff of Frick Laboratory of the American Museum of Natural History on the late Tertiary stratigraphy and vertebrate paleontology of the area between Santa Fe and Abiquiu-Ojo Caliente. The proposal to limit the Santa Fe Group in space and time, however, comes after long established usage in a broader sense in the upper and middle Rio Grande region. Since 1935, every major work on the geology and natural resources of the Rio Grande valley of southern and central New Mexico has used the term Santa Fe to describe the bulk of late Cenozoic intermontane basin-fill deposits. In particular, the more general Santa Fe terminology has been found to be useful in the major studies of the ground-water

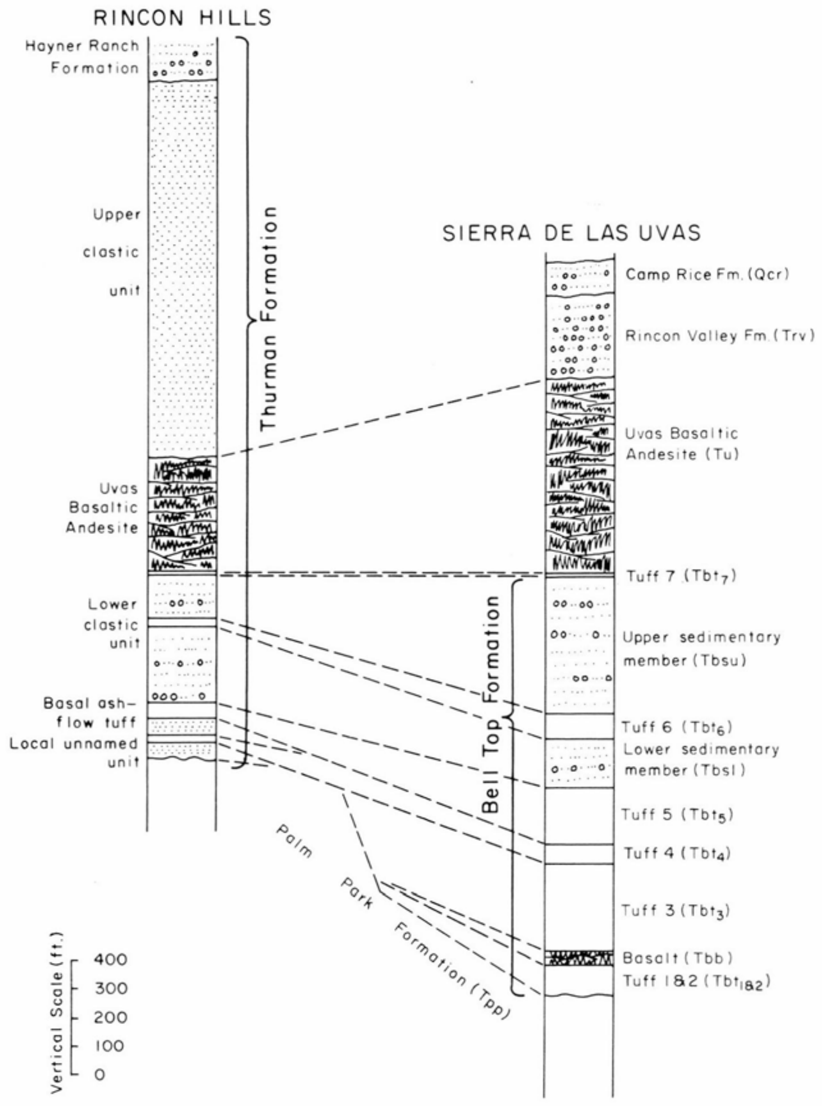


FIGURE 4–*Correlation of Thurman Formation of Rincon Hills area with Bell Top Formation of Sierra de las Uvas area.*

resources of the Elephant Butte Irrigation Project (Sayre and Livingston, 1946; Conover, 1954, Leggat and others, 1962; Davie and Spiegel, 1967; and King and others, 1971). Abandoning the term Santa Fe and introducing a new group name would lead to unnecessary confusion; a change is deemed unwarranted.

The Santa Fe Group in northern Doña Ana County consists of thick deposits of mainly locally derived clastics that filled major complex grabens of Miocene to Pleistocene age. Uplift and erosion continuing into late Quaternary time in the Rincon Hills area has resulted in exposures of Santa Fe strata that formed along or overlapped the graben margins. Where conformable with the underlying Thurman, the base of Santa Fe strata is marked by the appearance of conglomerate. The upper part of the Santa Fe includes all of the Pleistocene basin-fill deposits that pre-date entrenchment of the present Rio Grande valley system.

In the Rincon Hills the Santa Fe is at least 3,625 ft thick and includes four formations (in ascending order): unnamed transitional unit, Hayner Ranch Formation, Rincon Valley Formation, and Camp Rice Formation. At least locally the first three formations comprise a conformable sequence of coarse- to fine-grained clastics that represent essentially uninterrupted bolson deposition from Miocene through Pliocene time. Elsewhere within the area, however, angular relations exist between the Rincon Valley and older formations of the Santa Fe Group or the Thurman Formation. These unconformities probably resulted from faulting and tilting along basin margins while Santa Fe deposition was in progress. The youngest stage of basin filling, represented by deposits of the ancestral Rio Grande and alluvium of adjoining piedmont slopes, is included here in the Camp Rice Formation. These strata overlap all older rock units down to the Paleozoic with pronounced angular unconformity.

UNNAMED TRANSITIONAL UNIT (about 430 ft thick)

Strata transitional with the Thurman and Hayner Ranch Formations form a distinctive unit that has been mapped separately. In the Tonuco uplift, Seager and others (1971) did not include the transitional beds in either the Thurman Formation or the Santa Fe Group. However, because of similarities of texture and composition with the Hayner Ranch Formation, the transitional beds are now considered the basal part of the Santa Fe Group. The unit is probably Miocene in age, and the conglomeratic strata may mark initial Basin and Range faulting in northern Doña Ana County (Seager and others, 1971). The unit is well exposed in the cliffs and slopes west of the microwave station near Rincon, and also within the Johnson Spring Arroyo drainage. The base of the unit is marked by the first appearance of conglomerate or conglomeratic sandstone above the white, tuffaceous sandstones of the "upper Thurman clastic sequence."

The transitional unit consists predominantly of interlensing yellow-brown or pale-red conglomeratic sandstone, mudstone and conglomerate of fluvial origin. The sandstones are calcareous, coarse- to medium-grained lithic varieties that occur in even, parallel beds. Internal cross-stratification is common. Conglomeratic zones consist of well-rounded pebbles and cobbles of Uvas Basaltic Andesite, ash-flow tuff, and andesite. Three pinkish-gray laminated, dense micrite beds, each about 6 to 18 in. thick, occur within the unit. They contain numerous thin siliceous flakes and filaments that may be algal in origin. The limestones are distinctive and apparently widespread and have allowed recognition of the transitional strata in faulted outcrops in the Tonuco uplift and in the Rincon Valley area. The transitional unit weathers to ledgy slopes, cliffs, and dip slopes above the low, whitish badlands of the Thurman Formation. North of Rincon the unit is conformably overlain by the Hayner Ranch Formation but near Johnson Spring the unit is succeeded unconformably by a fanglomeratic facies of the Rincon Valley Formation.

HAYNER RANCH FORMATION (about 2,500 ft thick)

The Hayner Ranch Formation comprises the main part of the Santa Fe Group in the Rincon Hills area. The unit forms and is well exposed in the red hills north of Rincon, although it is faulted, silicified and mineralized at many places. The reddish strata weather to rounded hills and ledgy slopes, but are more resistant than underlying units. A Miocene and possibly early Pliocene age for the Hayner Ranch is indicated by its position between formations that have yielded K-Ar ages of 26 m.y. (Uvas Basaltic Andesite) and 9 m.y. (Selden Basalt) (Seager and others, 1971). The stream-laid strata accumulated as piedmont and basin floor deposits that filled grabens bordering fault-block uplifts formed during this time.

The Hayner Ranch Formation can be divided into an upper part distinguished by small quantities of granite, chert and limestone clasts mixed with volcanic cobbles and pebbles, and a lower part that lacks granite, chert and limestone fragments but contains thick tongues of volcanic-derived boulder conglomerate. The contact of the lower part with the underlying transitional unit appears conformable and is taken to be a well-indurated red sandstone ledge that separates predominantly red strata above from brown beds below. Above this ledge about 2,125 ft of interbedded conglomeratic sandstone, mudstone, sandstone and conglomerate comprise the lower part of the Hayner Ranch. The sandstones and conglomeratic sandstones generally are weak-red to reddish-brown, ferruginous, poorly sorted lithic types that are locally silicified. Well-rounded pebbles and cobbles of Uvas Basaltic Andesite, ash-flow tuff, and andesite comprise either discontinuous zones within the sandstones or are "floating" in a matrix of finer material. Bedding and internal cross-stratification is generally weakly expressed or lacking, although some even beds 1 to 4 ft thick occur. At least 4 dark-grayish-brown, non-bedded conglomerate tongues 30 to 335 ft thick are interbedded with the sandstone units. Poorly sorted boulders and cobbles of Uvas Basaltic Andesite to 18 in. in diameter are most conspicuous, but ash-flow tuff cobbles are common. The conglomerates are noncalcareous, variably indurated, and locally grade to conglomeratic sandstone and mudstone. The upper part of the Hayner Ranch Formation does not contain thick conglomerate beds, but consists, instead, of about 375 ft of weak-red, reddish-brown to gray sandstone, conglomeratic sandstone and, near the top, mudstone. The content of mixed clasts is the main distinction between upper and lower sandstone beds, which otherwise are similar in bedding, sorting, color and clast content.

In exposures due north of Rincon, the upper part of the Hayner Ranch Formation appears to grade conformably upward into the soft mudstones, siltstones and claystones, of the Rincon Valley Formation. A few miles west, however, near the Morgan manganese claims, outcrops of lower Hayner Ranch appear to be unconformably overlain by the Rincon Valley Formation.

RINCON VALLEY FORMATION (about 400 ft exposed; top eroded)

The barren, reddish badlands and bluffs near Rincon and along the Rio Grande from Hatch to San Diego Mountain are carved on the Rincon Valley Formation. Although locally appearing conformable on the Hayner Ranch

Formation, the Rincon Valley Formation progressively overlaps, with increasing angular discordance, the Hayner Ranch, transitional strata, and the Thurman units, from the manganese mines northwestward to Johnson Spring Arroyo. Where the base is conformable, the formation consists of gypsiferous basin-floor strata representing a late stage in the uninterrupted filling of Miocene-Pliocene grabens. Overlap, on the other hand, is accompanied by the appearance of fanglomeratic strata in the formation which coarsen and thicken in the direction of greater angular discordance. The overlap and fanglomerate facies are interpreted as resulting from erosion caused by faulting or warping of basin margins during Santa Fe deposition. Thicker sections than the 400+ ft measured near the basin margin may be expected in the subsurface toward basin centers. The Rincon Valley Formation is probably late Miocene and Pliocene. The 9 m.y. old Selden Basalt Tongue occurs in the lower part of the formation south of San Diego Mountain in Selden Canyon (Seager and others, 1971).

The lithology of the Rincon Valley Formation is distinctive. The basin-floor facies is well exposed north of Rincon, where it comprises laminated to thin-bedded, slightly conglomeratic siltstone, sandstone, claystone and gypsum beds. The soft, reddish, poorly lithified strata weather to rounded badlands devoid of vegetation. The fanglomeratic basin-margin facies forms steep canyon walls or round-topped cuestas in the lower part of Johnson Spring Arroyo. The brown fanglomerate consists of massive, poorly stratified pebbles, cobbles and boulders of Paleozoic limestone, Abo Sandstone, and to a lesser extent, andesite, rhyolite and Uvas Basaltic Andesite. High percentage of Paleozoic clasts distinguishes the Rincon Valley Formation from older Santa Fe conglomerates in this area. In canyons east of Johnson Spring Arroyo, intertonguing of the two facies of the Rincon Valley is clearly displayed on the walls of numerous gulches. Both facies are separated from the overlying widespread Camp Rice Formation by a major angular unconformity of regional extent.

QUATERNARY UNITS

CAMP RICE FORMATION (330 ft exposed, base buried in area of maximum thickness)

The youngest unit of the Santa Fe Group in southern New Mexico and western Trans-Pecos Texas has been designated the Camp Rice Formaton by Strain (1966, 1969). Seager and others (1971) have formally extended the Camp Rice terminology into the Rincon Valley area, described a composite reference section southwest of San Diego Mountain, and discussed the reasons for the Camp Rice designation in the area. W. S. Strain of the University of Texas at El Paso, who first defined the Camp Rice and its vertebrate faunas, has visited a number of sections in the Rincon-San Diego Mountain area and concurs with the writers.

Two distinct facies subdivisions of the Camp Rice Formation are recognized, both regionally and within the map area: 1) a basin-floor facies, primarily ancestral Rio Grande (fluvial) deposits, that intertongues laterally with 2) a piedmont-slope facies, mainly fan alluvium derived from adjacent uplifts. The bulk of the formation in northern Doña Ana County is considered to have been deposited over a rather long span of early and middle Pleistocene time (throughout parts of the Blancan and Irvingtonian land-mammal ages) by river distributaries fanning out from a narrow basin floor in the Palomas basin above Hatch. The locus of active deposition appears to have shifted widely during aggradation of the broad central plain of the southern Jornada del Muerto located south of Point of Rocks and between piedmont slopes flanking the Sierra de las Uvas and San Andres Range.

The basin floor facies "Qcrf" consists primarily of channel and flood-plain deposits of a Major perennial river system, but locally may include some minor eolian and lacustrine deposits. Petrified wood, horse teeth and a number of miscellaneous tooth and bone fragments of large vertebrates have been recovered from this facies at several localities in the map area. Horse teeth of probable early to middle Pleistocene age have been found in similar beds near San Diego Mountain (Seager and others, 1971). Occurrences of volcanic ash and fossil plant materials are discussed below.

Light-gray to brown sand, gravel, sandstone, and conglomerate make up the river-channel subfacies. Individual medium- to very thick bedded units are internally cross-stratified. Individual sand strata are moderately well sorted and range from fine to coarse grained. Sands are arkosic. Gravel clasts are generally subrounded to rounded and in the pebble size range, but cobbles are locally present, particularly in very gravelly zones in the upper part of the unit. Gravel lithology is mixed, with volcanics (including wide range of welded tuff and lava types) being dominant. However, significant amounts of siliceous sedimentary rocks and granite are also present. Limestone gravel is commonly absent or only present in trace amounts. Nonindurated brown-to reddish-brown silt-clay clasts, often in the form of armored mud balls, are present in some zones. Rounded pebbles of resistant rock types, notably quartzite, chert, granite, and traces of obsidian, derived from source areas other than the local uplands are almost always present. The fluvial facies of the upper Santa Fe Group can be traced far upstream of the Rincon area in the Rio Grande trough; some of the observed gravel types could only come from northerly source areas (Hawley and others, 1969).

Channel units normally grade upward into finer-textured flood-plain deposits comprising light-brown to reddish-brown sand-silt-clay (loamy) or silt-clay mixtures, and in places, their indurated, muddy sandstone to mudstone equivalents. Graded channel to flood-plain depositional sequences, no more than 30 to 40 ft thick, are stacked in multiple units, with as many as 6 "cycles" observable in a single vertical section. Paleosol zones developed in the upper parts of the graded sequences are often present. They are usually several ft thick and are characterized by reddish-brown (clay-enriched and partly leached) horizons that grade down into very light colored horizons of carbonate accumulation. Laterally the individual graded sequences appear to be lenticular, but are often essentially sheet-like over outcrop areas several miles in extent.

Induration of the fluvial facies varies considerably. For example, strong induration of sand and coarser-grained beds is relatively common, while finer-grained materials are usually not, or only slightly, indurated. Calcium carbonate is the dominant cementing agent, but cementation by silica and iron-manganese oxides occurs locally, particularly in the vicinity of faults bounding the Rincon Hills uplift. Selenite-cemented sandstones have been observed only in the extreme southeast corner of the map area (NE1/4 sec. 26, T. 19 S., R. 2 W.) near faults bounding a northwestern extension of the Tonuco (San Diego Mountain) uplift.

In various parts of the map area the fluvial facies has been informally subdivided into subunits differentiated on the basis of major changes in texture and/or a degree of induration. Because shifts in lithologic character are often gradual, vertically as well as horizontally, some subunit boundaries are rather arbitrarily placed in transition zones. Future detailed studies will certainly result in some shifts of subunit boundaries and probably also will lead to recognition of additional subunits or some revisions of present subunit concepts.

South of Interstate 25 and east of the Rio Grande, the following three major subunits are distinguished: 1) an upper, erosion-resistant gravel to gravelly sand subunit (designated by the subscript "u") probably the youngest member of the fluvial facies; 2) a medial (< 15 percent gravel) sand subunit (designated by "m") with occasional interbedded loamy strata in which paleosols have developed, and local indurated zones; and 3) a lower sandstone to conglomeratic sandstone subunit (designated by "1") exposed in low bluffs northeast of the flood plain. Subunit "u" grades upward into sandy to loamy beds comprising the youngest "Qcrf' sediments that floor the Jornada del Muerto plain and form the parent materials of the thick soils of the La Mesa geomorphic surface discussed in the following section. The gravelly facies of subunit "u" continues north of Interstate 25 to the NW part of sec. 25, T. 18 S., R. 2 W. and forms the uppermost slopes and benches east of Rincon Arroyo (fig. 5). The gravelly facies also includes as many as three graded channel to flood-plain depositional sequences occurring in vertical succession. North of sec. 25, gravels in subunit "u" appear to wedge out and the "Qcrf/u" symbol designates sandy to clayey basin fill with prominent zones of secondary lime accumulation. These nongravelly to slightly

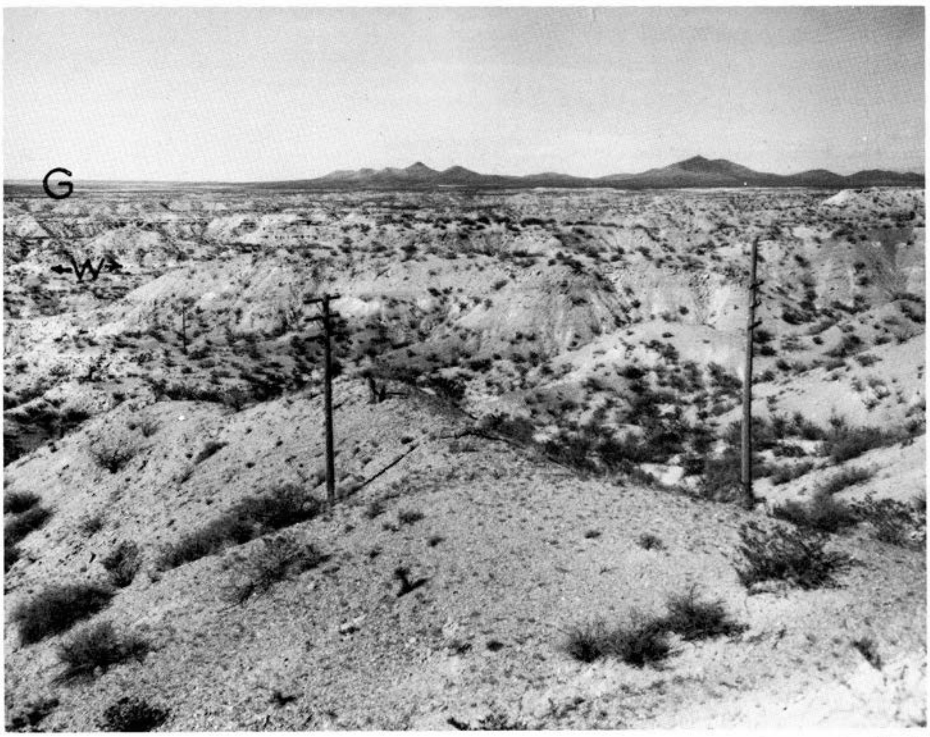


FIGURE 5—*About 200 ft of Camp Rice beds exposed in Rincon Arroyo badlands between Interstate Highway 25 and Grama, "G." Telephone poles in foreground in upper fluvial gravel and sand subunit. White marker zone in middle part of formation designated with "W." Point of Rocks hills rise on northern skyline above Jornada del Muerto plain (La Mesa Surface).*

gravelly beds are tentatively regarded as basin-floor sediments deposited just outside the area of very active flood-plain build-up (main part of "Qcrf/u"). They may include some eolian and lacustrine materials. Subunit "m" is the major former of valley slopes, and is generally very poorly exposed. It is usually covered by an unmapped veneer of sandy colluvium and alluvium (general equivalent of "Qvy" unit on sheet 1 in pocket) that rarely exceeds 4 ft in thickness. North of Interstate 25 (fig. 5), indurated beds occur throughout the exposed thickness of middle to lower (?) subunits of the fluvial facies and increase in frequency as the Rincon Hills are approached. However, the indurated beds apparently never comprise more than one third of the unit. The subscript "ml" designates area of most common occurrence of sandstone to sandy mudstone. Multiple paleosol zones are locally prominent in subunit "Qcrf/ml."

A number of distinctive but thin lithologic units recognized over relatively large areas, occur in the fluvial facies. These appear to have been emplaced over fairly short spans of geologic time. The most prominent units have been mapped in the valley of Rincon Arroyo and serve as marker beds or zones useful for local stratigraphic correlation as well as development of working hypotheses of depositional history and structural evolution of the area. Dashed lines just below the east valley rim marked with the letter "g" show the basal position of one or two channel gravel deposits at the base of subunit "u". The letter "w" marks the outcrop pattern of two white marker beds (1 to 4 ft thick) that locally contain abundant opalized plant materials (fig. 5). Near the east Rincon Hills fault (NE1/4 sec. 4, T. 19 S., R. 2 W. and SE1/2 sec. 33, T. 18 S., R. 2 W.) these markers are partly to completely opalized. Elsewhere they appear to be primarily cemented with lime. The letter "a" shows the approximate position of a sequence of sandy channel to clayey flood-plain deposits that, in one area, near the upper end of Grama Gully (SW corner SE1/4 sec. 14, T. 18 S., R. 2 W.) are capped with a thin layer of volcanic ash (fig. 6). The "a" and "w" beds occur in the middle to upper part of the medial or "m" subunit, and just above bed "c", the basal conglomeratic sandstone zone of a graded sandstone to loam sequence that immediately underlies the ash-bearing sequence at the lower end of Grama Gully. Zone "c" has been traced to the southern Rincon Arroyo Valley to an area where zone "c" is separated from the northernmost recognized segment of bed "w" by about 40 ft of sandstones to sandy mudstone and loams comprising 2 or 3 possible graded sedimentation sequences capped with paleosols. The "w" beds thus appear to be slightly younger (and are certainly no older) than sequence "a".

The ash found at the top of marker zone "a" in Grama Gully is an air-fall unit no more than 1 ft thick composed mainly of silt-size glass shards with a refractive index of about 1.5. This ash appears to have been deposited in a flood plain characterized by local ponding and sedimentation of very fine grained materials. The younger Camp Rice beds have been eroded from the area of exposure, and post-Santa Fe units rest disconformably on the sequence of beds including the ash. The basal ash zone locally contains a very thin bed of clay, identical to flood-plain deposits immediately underlying the entire unit (fig. 6, lower view). This interstratification supports the hypothesis that the ash was deposited penecontemporaneously with this part of the Camp Rice section and not at a much later date subsequent to erosion of upper Camp Rice strata by tributaries of Rincon Arroyo. Possible correlatives of the ash have been described in the type area of the Camp Rice Formation (Strain, 1966) in El Paso Canyon, and in fluvial facies deposits in Selden Canyon (Hawley and others, 1969). Samples of the ash have been submitted to the U.S. Geological Survey, Denver, for study. In a preliminary written communication dated July 21, 1971, Ray Wilcox of the

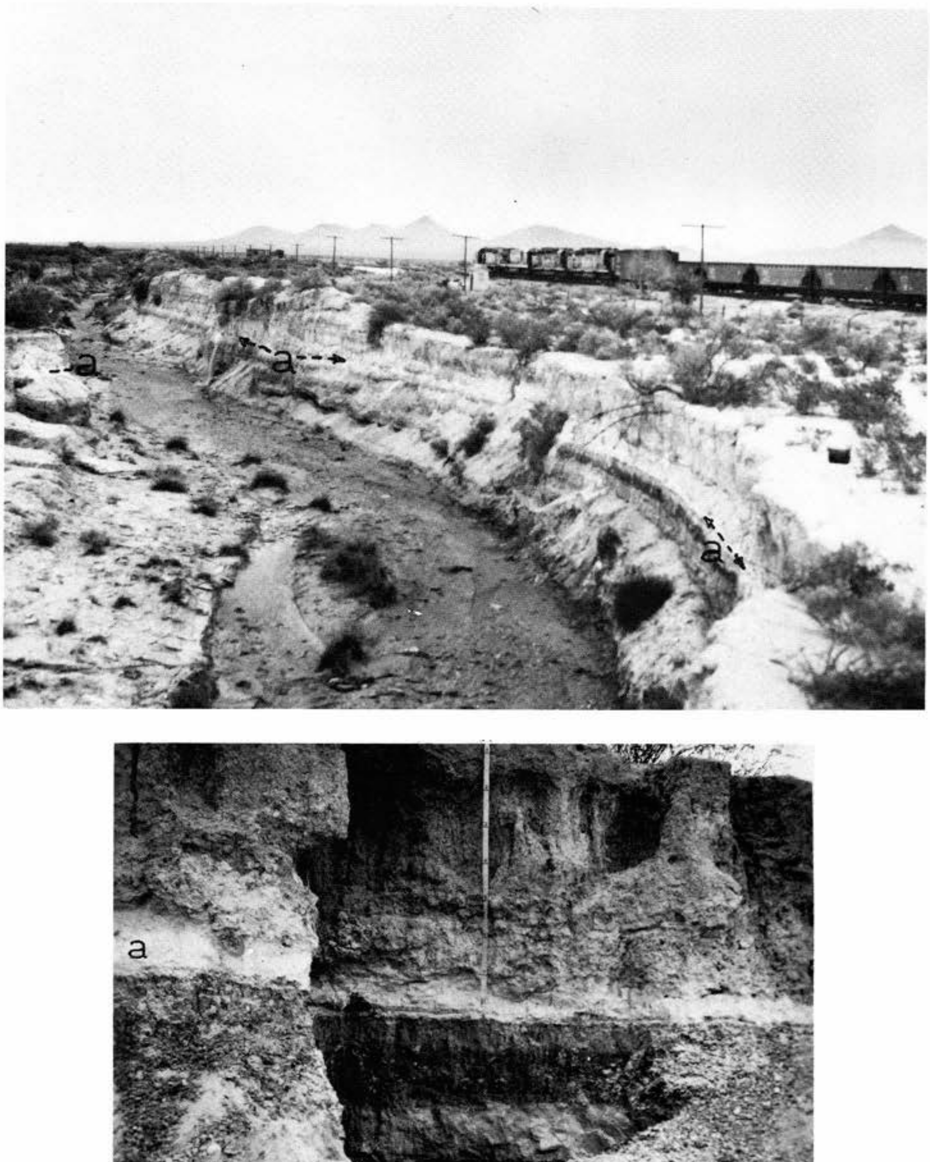


FIGURE 6–*Exposures in Grama Gully of Camp Rice fluvial sand to clay sequence with interbedded Pearlette-like volcanic ash "a" in upper part. Upper 5 to 6 ft of sediments exposed in gully walls appear to correlate with "older basin-fill alluvium."* **Upper view** *shows Jornada del Muerto landscape with Point of Rocks on northern skyline.*

Lower view *is west gully wall showing two ash layers below the 7 ft mark on tape. The thin lower layer is interbedded with light-gray clay, which grades down into interbedded light-reddish-brown clay and brownish-gray sand with selenite crystals.*

U.S.G.S. states that the ashes so far sampled from the Camp Rice Formation in its type area, at El Paso, and in Selden Canyon are probably like Pearlette ash beds derived from one or more of the three caldera-forming eruptions of the Yellowstone Tuff in Yellowstone National Park. Studies by Izett and others (1971) and Naeser and others (1971) indicate that these eruptions occurred, respectively, about 2.0, 1.2, and 0.6 million years ago. Reynolds and Larsen (1972) have recently correlated the Selden Canyon ash with the 0.6 million-year-old Pearlette type-0 member.

LeMone and Johnson (1969) have studied the opalized and locally well-preserved fossil flora contained in the white (w) marker beds. They have described a number of genera and species associated with marshy environments and postulate that the area at the time of white marker bed deposition was a spring-fed cienega, presumably located at or near the edge of an ancestral river flood plain.

The piedmont-slope facies consists primarily of alluvial-fan and coalescent fan deposits, but includes thin alluvial and colluvial veneers on erosion sufaces (in part rock pediments) cut on Rincon Valley Formation and older formations along the mountain fronts. Exposed thickness of the entire facies is generally less than 100 ft. A basal conglomerate to conglomeratic sandstone (in part fan-glomerate) subunit "Qcrc" with some interbedded, usually nonindurated, finer-grained zones, is overlapped by lower to medial fluvial-facies subunits along the margins of the ancient basin floor. This basal unit is relatively thin, probably rarely exceeding 30 ft in thickness. An upper (younger) piedmont-slope facies "Qcrp" has a very wide textural range (from coarse gravels to silt-clay mixtures) and is generally nonindurated. This areally extensive subunit, generally less than 70 ft thick, intertongues with and overlaps medial to upper fluvial facies subunits. A combined "Qcrp/Qcrc" mapping unit symbol has been used on piedmont slopes, upslope from the wedge-out zone of the fluvial facies, to designate areas where the lower and upper piedmont facies have not been differentiated.

Composition of the gravel fraction varies greatly from place to place in the two piedmont facies subunits. However, the rock types present invariably reflect the lithologic character of older formations exposed in adjacent uplands that comprise the three major sources of piedmont alluvium in the map area. On the partly dissected piedmont slope of the Sierra de las Uvas, southwest of the Rio Grande, boulder- and cobble-size clasts of Uvas Basaltic Andesite and Bell Top rhyolitic volcanics are abundant in both the "Qcrc" and the "Qcrp" alluviums; and fine- to medium-grained interbeds are uncommon. The relatively undissected piedmont slope in the Jornada del Muerto east of the southern Caballo Range appears to be primarily underlain by pebble to cobble gravels commonly interbedded with low gravelly, loamy to silty zones. Limestone, chert, and siltstone are the dominant rock types in the gravel fraction, and the finer-textured materials are highly calcareous. The Rincon Hills formed the third major source area for piedmont-slope alluvium during Camp Rice deposition, but due to much less mass and lower relief, this uplift did not contribute nearly as much material to the basin fill as was derived from the Uvas and Caballo uplifts. Coarse, cobbly to bouldery conglomerate and gravel zones are generally confined to a narrow belt along the front of the uplift. Interbedded loam, sand and minor pebbly strata of the "Qcrp" mapping unit nowhere extend more than 1/2 to 3/4 mile from the base of the Rincon Hills. Basinward, they appear to intertongue with, and definitely overlap, upper beds of the "Qcrf/ml" mapping unit. In sections 21 and 28, T. 18 S., R. 2 W., the piedmont slope facies appears to have been at least partly derived from erosion of older Camp Rice units exposed by uplift of the western part of the Jornada Basin along the northern extension of the East Rincon Hills fault zone in early to middle Pleistocene time.

RINCON, LA MESA, AND JORNADA I GEOMORPHIC SURFACES

Large remnants of 3 major relict surfaces marking in various places the culmination of early to middle Pleistocene basin aggradation (cessation of Camp Rice Formation deposition) are delineated by lined overprint patterns on the geologic map (sheet 1 in pocket).

The Rincon Surface of early to middle Pleistocene age comprises several segments of the ancient Jornada Basin floor (and small adjoining piedmont-slope areas) that appear to have been raised relative to the main part of the Jornada Basin during the late movements along faults bounding the Rincon Hills uplift. The Rincon surface possibly stabilized soon after deposition of marker beds "w" and "a". The La Mesa and Jornada I geomorphic surfaces are developed, respectively, on the Camp Rice basin-floor "Qcrf/u" and piedmont-slope "Qcrp" facies. They represent remnants of the youngest constructional basin surfaces predating cutting of the Rio Grande valley. Studies in the Mesilla Valley area (Gile and others, 1970; Hawley and Kottlowski, 1969) indicate that at least the younger part of the La Mesa surface stabilized during the Irvingtonian (middle Pleistocene) land-mammal age, and that this surface is somewhat older than large parts of the Jornada I piedmont slope.

The Camp Rice basin-floor deposits "Qcrf/m" beneath the Rincon surface are cemented with calcium carbonate and minor amounts of silica into a nearly continuous, well-indurated and dense caliche caprock from 20 to 30 ft thick. The upper 10 to 12 ft of the caprock is clearly pedogenic in origin, consisting of illuvial horizons of carbonate accumulation; the lime cement was derived primarily from leaching of overlying soil materials that received atmospheric additions of calcareous sediments over a very long span of time. Morphological features of this upper zone include multiple laminar and pisolitic (or rockhouse) structures very similar to those described in southern High Plains caliche caprock units of Pliocene and early Pleistocene age by Swineford and others (1958) and Bretz and Horberg (1949). Lower indurated layers may have been cemented by diagenetic processes unrelated to pedogenesis, perhaps prior to uplift of the Rincon Hills fault blocks when these basin-floor sediments were still saturated, or occasionally saturated, with ground water. A detailed study of soils and soil-geomorphic relationships on this very ancient landscape by the Soil Survey Investigation staff of the U.S. Soil Conservation Service is currently in progress.

The youngest Camp Rice basin-floor "Qcrf/u" and piedmont-slope "Qcrp" facies associated with stable remnants of the La Mesa and Jornada I surfaces generally contain prominent zones of secondary carbonate accumulation 4 to 8 ft thick, beginning within 1 to 3 ft of the ground surface. Horizons comprising the upper 2 to 4 ft of these zones are commonly indurated, being hardest and most dense at the top. They are transitional to underlying nonindurated, but still carbonate-impregnated, horizons. The basal horizons, in turn, grade downward into unaltered Camp Rice beds that are often noncalcareous. Investigations by Gile and associates (Gile, 1961, 1967; Gile and others, 1965, 1966, 1970, 1971) have conclusively demonstrated that near-surface accumulations of this type are pedogenic in origin and comprise the most commonly occurring variety of caliche in the region. The horizons are primarily illuvial accumulations resulting from downward transfer of calcium carbonate in solution from surface horizons. When other soil-forming factors are kept constant, geomorphic surface age correlates directly with degree of development of these horizons. In most instances, accumulation has taken place well above any capillary fringe or ground-water zones (King and others, 1971), and atmospheric additions are apparently the major source of carbonates observed in many soils of the region.

POST-SANTA FE VALLEY AND BASIN FILLS

The Camp Rice Formation represents the culmination or near culmination of intermontane basin filling in many parts of south-central New Mexico, particularly those areas immediately adjacent to the deeply entrenched Rio Grande valley system. Studies by Kottlowski (1958), Ruhe (1962, 1967), Strain (1966), Metcalf (1967, 1969), Hawley and Kottlowski (1969) show that initial valley entrenchment occurred in late middle Pleistocene (latest Kansan to Illinoian), apparently as the result of integration of ancestral upper and lower Rio Grande systems and development of through drainage to the Gulf of Mexico. These studies also demonstrate that valley evolution during middle to late Quaternary was characterized by several episodes of major valley incision, each followed by intervals of partial backfilling and valley-floor stability. Evidence of episodic cutting, filling, and conditions approaching a graded state is preserved in Rincon Valley, as well as in the valleys of major tributary arroyos, in the form of a stepped sequence of graded valley-border surfaces, both erosional and constructional. The surfaces include alluvial terraces and fans and erosional backslopes and footslopes. Concurrent with evolution of the Rio Grande valley system, large areas of the Jornada del Muerto piedmont slope east of the Caballos continued to be modified by gradational processes in drainage systems still unaffected by episodes of valley entrenchment and backfilling.

Seven major geomorphic surface units that post-date La Mesa and Jornada I surface development have been formally defined in the valley and basin areas between Caballo Reservoir and El Paso (Ruhe, 1964, 1967; Hawley, 1965; Hawley and Gile, 1966; Gile and Hawley, 1968; Gile and others, 1970). These surfaces (in order of decreasing age) are: the Tortugas, Picacho, Leasburg and Fillmore surfaces in the Rio Grande valley system, and the Jornada II-Petts Tank, Isaacks' Ranch, and Organ surfaces in closed basin areas. Fills associated with constructional parts of these surfaces have been formally designated as morphostratigraphic units (Metcalf, 1967; Hawley and Kottlowski, 1969; Gile and others, 1970) generally following procedures recommended by Frye and Willman (1962). This detailed subdivision of post-Santa Fe units is based primarily on the relative position in the landscape and primary surface form of deposits rather than on variations in lithology, and has been done as a part of soil-geomorphology studies by the Soil Survey Investigations staff of the U.S. Soil Conservation Service. While these units have been recognized throughout the region, they have only been mapped on large scale (1:16,000 to 1:8,000) airphoto maps, in the 400 square-mile study of the SCS Desert Project around Las Cruces (Gile and others, 1971). Their major characteristics are outlined in table 3.

In mapping post-Santa Fe deposits of the Rincon area, emphasis to date has been placed on defining the occurrence of major lithologic units as well as in determining general age relationships. Eight map units comprising informal rock-stratigraphic units, and one undifferentiated alluvial-colluvial unit have been delineated on the geologic map (sheet 1 in pocket). Four major facies and two general ages of fill materials are recognized. The facies units are: 1) valley-slope alluvium, 2) valley-floor deposits, 3) piedmont-slope alluvium, and 4) basin-floor sediments. The time divisions comprise an "older" middle to late

TABLE 3—*Post-Santa Fe Group morphostratigraphic units in south-central New Mexico*

RIO GRANDE VALLEY FILLS

Fort Selden Group Deposits

Rio Grande (fluvial) and tributary arroyo (alluvial) deposits, and alluvial-colluvial veneers, generally < 4 ft thick, on erosion surfaces; associated with landscapes graded to local base levels ranging from as much as 30 ft above to 80 ft below present river valley floor. Maximum thickness: 50 to 80 ft beneath Rio Grande flood plain; as much as 110 ft beneath toes of valley side slopes along flood-plain borders; generally less than 15 ft on main part of valley slopes. Late Wisconsinan thru Holocene. Sediments locally inset against or overlap Picacho and older deposits, and are differentiated into the following three units in basins of tributary arroyos:

Arroyo (channel and fan) alluvium. Maximum thickness: 10 to 15 ft in small fans along flood-plain border, generally < 4 ft on valley slopes. Historical age < 400 yr. Sediments partly fill channels cut into:

Fillmore alluvium and colluvium. Fan and terrace deposits associated with constructional parts of the Fillmore geomorphic surface, and erosion surface veneers, graded to local base levels near the present flood-plain level. Thickest and most extensive fills of this unit are located on lower slopes of major arroyo systems, max. thickness about 45 ft, generally < 15 ft. Middle to late Holocene, <7,500 yr B. P. to prehistorical. Sediments locally inset against or overlap:

Leesburg alluvium. Fan and terrace deposits associated with constructional parts of the Leasburg geomorphic surface graded to local base levels slightly above present river-valley floor. Maximum thickness probably more than 15 ft. Late Wisconsinan to early Holocene, < 22,000? to > 7,500 yr B. P. Sediments locally inset against or overlap:

Picacho sediments

Fan and terrace deposits associated with constructional parts of the Picacho geomorphic surface, and erosion-surface veneers, with upper surfaces in most areas graded to local base levels 60 to 80 ft above the present river flood plain. Thickest (max. about 70 ft) and most extensive fills occur in lower parts of major tributary drainage basins, near the flood-plain margins, and locally include tongues of ancient Rio Grande (fluvial) deposits. Early (?) to middle Wisconsinan, > 22,000 yr B. P., partly fills valleys cut into:

Tortugas sediments

Fan and terrace deposits associated with constructional parts of the Tortugas geomorphic surface, and erosion-surface veneers, with upper surfaces graded to local base levels 100 ft or more above the present river flood plain, but below Jornada I and La Mesa surfaces. Thickest fills (as much as 125 ft) occur in lower parts of major tributary basins and locally contain tongues of ancient Rio Grande deposits; they are associated with ancient flood-plain stability levels less than 130 ft above the present river flood plain. Middle to late Pleistocene (Illinoian to earliest Wisconsinan?). Sediments partly fill valleys cut into Camp Rice and older formations.

BASIN FILLS IN AREAS UNAFFECTED BY RIO GRANDE ACTIVITY

Ephemeral-lake-plain (playa) sediments

Basin-floor sediments, fine-grained, primarily lacustrine; maximum thickness 15 ft. Youngest deposits associated with Lake Tank (late Holocene) geomorphic surface, but unit probably includes sediments of middle to late Quaternary age associated with older ephemeral and perennial(?) lakes.

Arroyo and gully (channel and fan) alluvium

Piedmont-slope channel fills, including arroyo- and gully-mouth fans, and sediments derived from broad belts of erosional scarplets. Thickness generally < 4 ft. Historical age. Sediments locally inset below or overlap:

Organ alluvium

Piedmont-slope deposits, including fan, terrace and undissected drainageway fills; associated with the Organ geomorphic surface. Maximum thickness about 12 ft. Middle to late Holocene, < 6,500 yr B. P. to prehistorical. Sediments locally inset against or overlap:

Isaacks' Ranch alluvium

Piedmont-slope deposits, including fan, terrace and undissected drainageway fills, associated with the Isaacks' Ranch geomorphic surface. Maximum thickness about 10 ft. Late Wisconsinan to early Holocene < 17,000? to > 6,500 yr B. P. Sediments locally inset against or overlap:

Jornada II alluvium

Piedmont-slope deposits associated with constructional parts of the Jornada II geomorphic surface, including 1) fan, terrace and undissected drainageway fills, and 2) undifferentiated but very extensive sheets of alluvium. Maximum thickness probably about 15 ft. Middle (?) to late Pleistocene > 22,000 yr B. P.?. Sediments locally inset against or overlap the Camp Rice and older formations, and grade laterally into:

Petts Tank sediments

Basin-floor deposits; silty, very calcareous; associated with the Petts Tank geomorphic surface including broad alluvial flats grading to playa-lake depressions in parts of the southem Jornada del Muerto Basin; primarily alluvium, but possibly including some ancient lacustrine sediments. Maximum thickness about 10 ft. Middle (?) to late Pleistocene, general age equivalent of Jornada Il alluvium.

TABLE 4—*Correlation of morphostratigraphic units with informal rock-stratigraphic units in the Rincon area*

	Rock-stratigraphic Units	General morphostratigraphic equivalents and age ranges (yr B. P.)		
Qvy & Qvyf	Younger valley-slope alluvium & Younger valley-floor deposits	Fort Selden Group	Historical Fillmore Leasburg	<400 >400 to <7,500 >7,500 to <22,000
*Qvo & Qvof	Older valley-slope alluvium & Older valley-floor deposits	Picacho Tortugas		>22,000 to <100,000? >100,000 to <250,000?
Qpy	Younger piedmont-slope alluvium	Organ and Historical Isaacks' Ranch		<6,500 >6,500 to <17,000?
Qpo & Qbf	Older piedmont-slope alluvium & Basin-floor sediments (older)	Jornada II, Petts Tank, and possibly other unnamed units		>22,000 to <250,000?

*Where Qvo and Qvof are complexly intertongued, they are shown as Qvou on geologic map (sheet 1).

Pleistocene (Illinoian? to middle Wisconsinan) subdivision and a "younger" latest Pleistocene (late Wisconsinan) to Holocene subdivision. The information presented here represents the first step in setting up at least two formally named rock-stratigraphic subdivisions of formation rank (generally conforming to the "Qvo-Qvof-Qpo-Qbf" and "Qvy-Qvyf-Qpy-QL" groupings) that would comprise the major mappable units of middle to late Quaternary age in the south-central New Mexico region. Limitations on time available for field study in the later Quaternary units near Rincon, as well as those due to airphoto and topographic base map scales, prevented separation of geomorphic surfaces and morphostratigraphic units at the level of detail done near Las Cruces. However, the morphostratigraphic subdivisions do comprise members of lithologic units defined in the following paragraphs. A correlation of morphostratigraphic and rock-stratigraphic units is given in table 4. The dual type of stratigraphic classification being developed will provide a sound and flexible base for future investigations by workers from a variety of scientific and engineering disciplines, notably those interested in proper management of land and waters resources of the region.

Arroyo-valley and piedmont-slope facies units "Qvo, Qvy, Qpo, Qpy" are similar in composition to the Camp Rice Formation piedmont facies in that they include a very wide range of textures and rock types reflecting lithologies exposed in local sediment source areas. *Valley-floor (fluvial) facies units "Qvof, Qvyf" are* similar in composition to the Camp Rice fluvial facies in that they consist of deposits of sand and rounded gravel that often grade upward into loamy to clayey sediments. The gravel clasts consist mainly of resistant, often siliceous, rock types in part derived from older units cropping out upstream from the Rincon Valley. Sands are relatively clean and well sorted, and both sand and gravel beds are often internally cross-stratified. These post-Santa Fe units are areally limited to narrow strips that cross, and are commonly inset below, more widespread lithologic units of the Camp Rice and older formations. The valley-floor materials are confined to the low bluffs flanking the inner Rincon Valley and the river flood-plain area. Fossil snail shells have been noted in finer textured strata, and are locally of common occurrence in the fluvial facies. Distinguishing characteristics of these units follow.

Older Valley-Slope Alluvium "Qvo"—Major arroyo terrace and fan deposits and minor (< 5 ft thick) veneers on erosion surfaces. Unit may be as much as 50 ft thick in the bluffs flanking the inner Rio Grande valley and along lower valleys of major arroyos (e.g., Rincon, Angostura), but is generally less than 20 ft thick. Coarsest deposits, gravels (pebble to small boulder size with sandy to loamy matrix) with minor amounts of interbedded gravelly (<35 percent) to low gravelly (<15 percent) sand to loam strata, crop out in watersheds heading in the Sierra de las Uvas southwest of the Rio Grande. Elsewhere in the map area bouldery zones are rare and low gravelly beds are commonly present. These fan and terrace deposits occupy topographic positions ranging from several ft to about 120 ft above floors on the river and larger arroyo valleys. Alluvial fills representing at least two distinct episodes of valley aggradation are often present, and comprise the middle to late Pleistocene, Tortugas and Picacho morphostratigraphic units (excluding their fluvial facies) of Metcalf (1967, localities 2, 13, 19-21, 25) and Hawley and Kottlowski (1969, type sections 1 through 4). Prominent but relatively thin (generally < 3 ft thick) zones that are almost continuously impregnated with illuvial carbonate occur, in association with overlying soil horizons in an A and B position, in the uppermost beds (upper 3 to 5 ft) below stable Tortugas and Picacho geomorphic surface remnants. These strong pedogenic accumulations, which are absent in younger units, usually include indurated horizons in their upper parts where they have developed in very gravelly parent materials. A diagonal-line (NW-SE) overprint pattern on the geologic map (sheet 1 in pocket) shows most areas of occurrence of such accumulations below large remnants of Picacho-Tortugas surface complexes above the mouths of Angostura, Reed, and Bignell Arroyos. Toward the ancient river-valley axis, fan alluvium intertongues with and overlaps older valley-floor (fluvial facies) deposits "Qvof" below elevations of about 4,160 ft.

Older Valley-Floor Deposits—Fluvial Facies "Qvof"—River channel and flood-plain deposits. This unit may be as much as 50 ft thick in the bluffs forming the margins of the inner Rincon Valley. Gravel is generally in the pebble range, but cobbles and widely scattered small boulders are present in some strata. Discontinuous zones of calcite cementation occur locally but the unit is generally nonindurated. Deposits crop out at elevations ranging from several ft to about 120 ft above the Rio Grande flood plain. These ancient river-terrace deposits, with original surfaces either obliterated or locally buried, were laid down during at least two distinct episodes of valley aggradation, the Tortugas and Picacho. The fluvial facies of the Tortugas and Picacho morphostratigraphic units have been described by Metcalf (1967, localities 1-12, 14-18, 22-24, 26-27) and Hawley and Kottlowski (1969, type sections 1 to 3). Complexly intertonguing fluvial and arroyo fan deposits are mapped as an undifferentiated older valley-fill unit "Q vou."

Younger Valley-Slope Alluvium "Qvy"—Arroyo channel, terrace and fan deposits. The maximum thickness may approach 50 ft just above the zone where fan deposits merge with Rio Grande deposits, but the unit thins rapidly upstream in the arroyo valleys, and appears to be generally less than 15 ft thick throughout much of the map area. The base of the unit is usually buried. As in the case of older alluvial deposits on the piedmont and valley slopes, "Qvy" fills exhibit an extremely wide compositional range including: 1) bouldery, volcanic-derived gravels in valleys heading in the Sierra de las Uvas, and derived mainly from reworking of "Qvo" and "Qcrp/Qcrc" deposits in the same area; 2) silty to clayey alluvium in smaller areas of the fine-grained facies of the Rincon Valley Formation; 3) sandy sediments derived mainly from Camp Rice fluvial facies sand and sandstone notably south and east of Rincon Arroyo; and 4) mixed texture (cobble gravel to loam range) and rock type units in arroyo systems draining the Rincon Hills areas. These deposits are nonindurated. Zones of secondary carbonate accumulation are generally limited to thin coatings on gravel clasts and to scattered soft filamentary bodies and nodules. Surfaces of terrace and associated fan fills are commonly within 10 ft, and rarely more than 15 ft of present channel floors and are graded to local base levels approximating that of the present Rincon Valley floor. Alluvial fills represent one major and one or two minor episodes of valley aggradation. The last episode of arroyo incision appears to be of very recent (perhaps historical) age. The bulk of the materials outside of active channel areas consists of the Fillmore morphostratigraphic unit (middle to late Holocene) of Metcalf (1967, localities 28, 30-33, 38-46) and Hawley and Kottlowski, 1969, (type sections 5 and 6). However, alluvium of the Leasburg morphostratigraphic unit (late Wisconsinan to early Holocene age) of Hawley and Kottlowski (1969, p. 98) is also locally present. As shown in tables 3 and 4, the arroyo channel, Fillmore, and Leasburg alluviums together comprise the valley-slope alluvial facies of the Fort Selden morphostratigraphic group. Along the Rio Grande flood-plain border, "Qvy" fan alluvium intertongues with and overlaps younger valley-floor (fluvial-facies) map unit "Qvyf."

Younger Valley-Floor Deposits—Fluvial Facies "Qvyf"—River flood-plain and channel deposits. Studies by Conover (1954) and King and others (1971) indicate that this unit ranges in thickness from about 55 to 70 ft beneath almost the entire area occupied by the floors of Rincon and Palomas valleys. Exposures are limited to the banks of the river channel, irrigation canals, and drain ditches, and to a few scattered shallow excavations. Surficial deposits are generally gravel-free and range from sand to clay. Water well logs (drillers data in Conover, 1954, and King and others, 1971) indicate that the bulk of the inner valley fill below depths of 10 to 20 ft consists of sand and gravel with some interbedded clays. The unit is nonindurated. Zones of secondary lime accumulation appear to be limited to soft, scattered filamentary bodies and nodules. Regional studies (Hawley and Kottlowski, 1969) indicate that the bulk of the "Qvyf" unit was deposited in late Wisconsinan time after an episode (or episodes) of deep valley incision that generally coincided with the last major glacial maximum (Pinedale Stadial) in the southern Rocky Mountains. Recent studies (S.C.S.) and Carbon 14 dating of wood buried in Historical meander belt deposits at Las Cruces show that the river has at least locally reworked valley fills to depths of about 25 ft below present channel levels within the past several hundred years. The "Qvyf" mapping unit is equivalent to the "Rio Grande valley-floor deposits" subdivision of the Fort Selden morphostratigraphic unit (tables 3 and 4).

Older Piedmont-Slope Alluvium "Qpo"—Fan deposits, fills of shallowly incised drainageways, and erosion surface veneers. This mapping unit generally is less than 10 ft thick, and textures range from gravel to loam. Gravelly to very gravelly materials are predominant and are derived from the carbonate rock terrane of the southern Caballos. The unit appears to correlate with Jornada II morphostratigraphic unit of middle to late Pleistocene age described by Gile and others (1970, stops 5, 7, 9, and 10) at the south end of the Jornada del Muerto Basin. Prominent horizons of soil carbonate accumulation, similar to those described in the surficial zone of "Qvo" alluvium are almost always present within 2 or 3 ft of the surface in the "Qpo" mapping unit. "Qpo" deposits appear to intertongue with finer-grained basin-floor sediments of the "Qb' mapping unit in the area of mergence of piedmont-slope and basin-floor surfaces near Grama Siding (sec. 15, T. 18 S., R. 2 W.).

Younger Piedmont-Slope Alluvium "Qpy"—Fills of shallowly incised drainage-ways. Maximum thickness of this mapping unit does not appear to exceed 10 ft, and the alluvium is commonly less than 7 ft thick. Textures range from loamy (commonly silty) to gravel; however, low (<15 percent) gravelly loamy materials are dominant. Very gravelly beds are generally restricted to areas near the mountain fronts, and elsewhere to basal parts of deposits. Gravel type and the strongly calcareous nature of the sand-to-clay fraction reflects the predominantly limestone composition of the Caballo Mountain source for alluvium in this particular area. Alluvial fills represent at least one major episode of valley aggradation and probably several additional minor episodes. The bulk of the materials outside of active channels consist of the Organ morphostratigraphic unit (middle to late Holocene) of Hawley and Kottlowski (1969, type sections 7 and 8). However, alluvial fills of the late Wisconsinan-early Holocene Isaacks' Ranch morphostratigraphic unit (Gile and others, 1970, stops 5, 7, and 9) are also locally present.

Basin-floor units "Qbf and QL" occupy a very small percentage of the map area. These fine- to medium-grained sediments were deposited in one small Jornada del Muerto sub-basin east of Grama and in several small depressions on the Rincon and La Mesa geomorphic surfaces. Because of lack of good exposures, these units have not been mapped or otherwise described in detail in most areas, but do have some distinguishing features.

Basin-floor sediments "Qbf" include loamy to clayey alluvium in a basin area that is still unaffected by arroyo valley incision (even though located in an upper reach of the Rincon Arroyo system). The deposits are either nongravelly or contain only scattered gravel clasts and probably do not exceed 7 ft in thickness. A strong, but still nonindurated, horizon of soil carbonate accumulation is usually present in the upper part of the unit. "Qbf' sediments appear to be transitional to "Qpo" alluvium in the area of mergence of piedmont-slope and basin-floor near Grama; and they may be partly correlative with the Petts Tank Morphostratigraphic unit (tables 3 and 4).

Ephemeral-Lake Sediments "QL" comprise mainly clayey fill of small playa-lake depressions, and generally is less than 10 ft thick. The playas in this area occur several hundred ft above the water table. Occasionally they contain standing water but may not flood for several years. Surficial sediments are of Holocene age, but sediments of middle to late Pleistocene age probably occur at depth in many of the depressions. The fill of a playa on the Rincon Surface (SE1/4 sec. 24, T. 18 S., R. 3 W.) has been trenched and sampled as part of the Soil Survey Investigation's study of soil-geomorphic relationships on that ancient basin landscape. A detailed description of the playa fill will be included in a future Soil Conservation Service report.

Structure

The map area includes part of the Rio Grande depression (Kelley, 1955) and the Caballo-Rincon Hills fault blocks which border the depression on the north (fig. 7). The major strutural features in the area are north- and northwest-trending, high-angle, normal faults that border and divide the uplifts and separate them from the Rio Grande and Grama (Jornada del Muerto) grabens. The uplifts are relatively simple tilted fault blocks. Dips, for the most part, are gentle to moderate and homoclinal, except for drag along faults and moderate folding of Paleozoic strata. The Rio Grande and Grama depressions appear to be steep-sided complex grabens filled with several thousand ft of elastic debris derived mainly from adjacent uplifts. The great volume of fill in many places exceeded the confines of the graben, resulting in overlap and burial of parts of adjacent uplifts. The unconformities formed in this way are of several ages and have proved useful in dating fault movements.

The high-angle faults that dominate the structure of the area are clearly Miocene to Pleistocene in age, and some may have been active into Recent time. The episodes of faulting that can be inferred or proved from lithologies, and the relationships of rock units and unconformities with fault surfaces are summarized in table 5.

Pre-Miocene periods of deformation have little expression in the modern topography of the area. Repeated epeirogenic uplift during the Paleozoic and Mesozoic resulted in the numerous disconformities between Paleozoic rock units, and the absence of the entire Triassic-Jurassic systems (Kelley and Silver, 1952). Effects of the Laramide orogeny, clearly in evidence in the Caballo Mountains to the north (Kelley and Silver, 1952), are not conspicuous in the Hatch-Rincon quadrangles. However, Laramide folding is indicated by the widespread overlap of Love Ranch Formation on an erosion surface that truncates tilted upper Paleozoic rock units in the northern part of the area. The nature of the Laramide deformation is not clear but probably involves mainly broad folding and associated marginal thrusting and overturning as reported elsewhere (Kelley and Silver, 1952; Seager and others, 1971).

LATE CENOZOIC HIGH-ANGLE, NORMAL FAULTS

The large area of Cenozoic and Paleozoic strata that form the Caballo Mountains and Rincon Hills in the map area have been broken into major structural blocks by the Palm fault, East and West Rincon Hills faults, Central fault, Johnson Spring fault, and Yucca fault (fig. 7). These and numerous smaller faults can be classed in two groups: those with north trends and east downthrows, and those with northwest strike and southwest downthrows. In plan the intersection of these sets of faults has created a network of branching and anastomosing faults that enclose grabens, horsts, and half grabens, the most imposing of which is the Caballo Mountain fault block.

Near the northern margin of the map area, movement on the Palm fault elevated the block of Paleozoic strata that forms the southern end of the Caballo Mountains, the structurally highest part of the map area. Stratigraphic separation of 2,500 to 3,000 ft is indicated by the fault contact betweeen lower Palm Park and Fusselman Formations. The fault, like most others in the area, dips 50 to 65

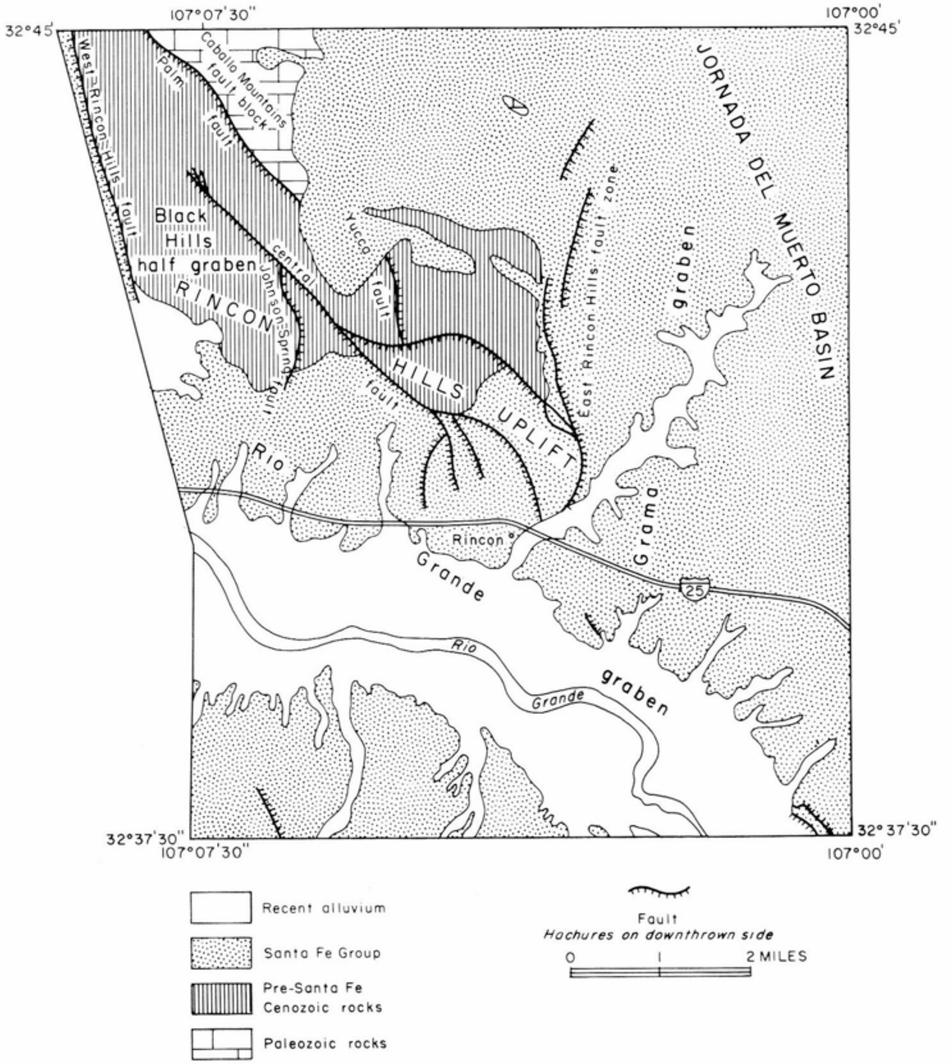


FIGURE 7–*Structure map.*

degrees; slickensides rake 65 to 70 degrees indicating oblique slip during the latest episode of faulting. Paleozoic strata in the footwall, gently to moderately folded during the Laramide, are broken into a mosaic of blocks bounded by faults that parallel the Palm fault and by those that strike obliquely across the range. Northward, the Palm fault continues as a major feature bordering Red House Mountain (Kelley and Silver, 1952); but to the southeast the fault and the strata on either side are overlapped by unbroken Camp Rice Formation (sheet 1 in pocket). Cenozoic strata in down faulted blocks around the southern sides of the Caballo Mountain block form the Rincon Hills.

Although the Rincon Hills are structurally lower than the Caballo Mountain block, they stand thousands of ft higher than the same rocks in the Rio Grande and Grama grabens. In this respect the Rincon Hills uplift consists of an intermediate step-like series of half grabens that rise structurally both by faulting and dip of beds from the Rio Grande and Grama grabens toward the Caballo block *(D-D'* and *F-F'*, sheet 2 in pocket). South of the Caballo block the Rincon Hills uplift is essentially a stair-stepped horst between the bordering depressions *(H-H',* sheet 2).

The major faults that separate the Rio Grande and Grama grabens from the Rincon Hills uplift are the East and West Rincon Hills faults and the Central fault. In the western part of the uplift, the West Rincon Hills fault and Central fault, both of which are down to the southwest, are arranged en echelon and border the south-tilted Black Hills half graben. Stratigraphic separation on the West Rincon Hills fault, which defines the block on the west, is about 5,000 ft as indicated by the juxtaposition of Rincon Valley Formation and basal Thurman ash-flow tuff. Southward, throw diminishes rapidly before the fault is buried by alluvium. The Central fault borders the northeastern side of the Black Hills block where the fault is continuously exposed in varied terrain for nearly 5 miles. Maximum stratigraphic separation may be near 2,000 ft east of Johnson Spring. To the southeast the Central fault divides into 4 smaller segments each of which loses throw rapidly and disappears in the incompetent Rincon Valley Formation near Rincon (sheet 1). The fault terminates similarly to the northwest in the basal Thurman ash-flow tuff. Along the eastern side of the Black Hills block a narrow, wedge-shaped graben is formed by the Central and Johnson Spring faults. Fanglomerate strata of the Rincon Valley Formation extend unbroken across basal Santa Fe beds in the graben, the Johnson Spring fault, and Thurman Formation outside the graben *(G-G'*, sheet 2). Inasmuch as stratigraphic separation on the Johnson Spring fault is about 500 ft, these relations illustrate the importance of major faulting that was penecontemporaneous with deposition of the Santa Fe Group. Along the eastern margin of the Rincon Hills uplift the East Rincon Hills fault comprises a 1/3-mi.-wide zone of short, over-lapping faults. The faults are all downthrown to the east, involve mainly Camp Rice units, and display stratigraphic separation of only a few 10's to 100 ft. The amount of pre-Camp Rice displacement is unknown but presumed to be important.

TABLE 5–*Dates and evidence for late Cenozoic block faulting in the Hatch-Rincon quadrangles*

Episode No.	Date	Evidence
4	post-Camp Rice (middle to late Pleistocene)	Small offset (few 100's to 10's of ft) of Camp Rice units along major boundary faults
3	late Pliocene	Major offset (few 1,000's to 100's of ft) of the Rincon Valley Formation along uplift boundary faults
2	late Miocene(?)–early Pliocene(?)	Angular unconformity between Hayner Ranch and Rincon Valley fanglomerate facies. The fanglomerate overlaps faulted "transitional unit" strata (Miocene) without itself being displaced (see cross section *G-G'*. sheet 2)
1	early Miocene	Coarse boulder-conglomerate wedges in the "transitional unit" and Hayner Ranch Formation

Economic Deposits

Manganese and Barite

Mineralization in the Rincon quadrangle is restricted to scattered, low-grade barite and manganese. The largest area of barite mineralization is northeast of Palm Park in the NW1/4 sec. 14, T. 18 S., R. 3 W. The barite occurs as bedded deposits, open space filling and replacement of fault breccia in the Fusselman Dolomite. Small faults have been prospected with open cuts, but the width of the veins appears to average only 1 to 3 ft, although some pods 5 ft thick were mined. The mineralization continues northward into the Upham quadrangle but does not increase in importance.

Manganese mineralization, reported on by Wells (1918), occurs in the Rincon area to the south. The Morgan group of claims 11/2 mi northwest of Rincon contains psilomelane in northwest-trending fissure veins within the Hayner Ranch Formation. The veins are 1/2 to 11/2 ft wide and have been prospected in open cuts to a depth of about 30 ft. Wad and limonite accompany the psilomelane. The presence of numerous fragments of red sandstone in the veins resulted in ore containing only 30 to 40 percent manganese. Total production from the Morgan claim to 1918 was 471 tons (Wells, 1918). Considerable placer psilomelane derived from the Morgan veins is contained in the Camp Rice and possibly the Rincon Valley Formations just south of the Morgan properties. The placer deposits do not appear thick or rich enough to be economic. Three quarters of a mile north of Rincon, psilomelane replacing fault breccia occurs in the Hayner Ranch Formation at the Rincon Mine. The deposit has been explored by a 30-ft tunnel; although much manganese staining is present, little primary mineralization is visible now. Elsewhere in the area thin veinlets (1/2 to 2 in. thick) of psilomelane are scattered in basal Thurman ash-flow tuff, basal transitional unit of the Santa Fe Group, and within the Hayner Ranch Formation. Locally these veinlets are associated with small quantities of barite, but none of the mineralization is widespread or high grade enough to constitute a workable deposit.

The age of the barite-manganese mineralization is Miocene (Seager and others, 1971). Stratigraphic relations near the Morgan claims indicate mineralization accompanied the faulting that occurred between Hayner Ranch and Rincon Valley deposition. In this area mineralized Hayner Ranch is overlain unconformably by unmineralized Rincon Valley Formation that contains clasts of altered Hayner Ranch strata, and possibly placer psilomelane. The Camp Rice Formation (Pleistocene) which overlies the Rincon Valley Formation also contains placer psilomelane.

Sand, Gravel, Caliche

Coarse-grained parts of the Camp Rice and Rincon Valley Formations and the various valley-fill units are extensively used for construction material. Well-graded (poorly-sorted) alluvial materials, as well as the better-sorted, more siliceous gravel and sand of fluvial facies, are used in various types of construction, from road fill to concrete aggregate. Information on engineering properties of surficial geologic deposits and soils is included in New Mexico State Highway Department reports (1964, sections 25-2 & 3; 1966, p. 103-115) and

Maker and others (1971). In particular, the Camp Rice fluvial facies appears to contain enough good quality sand and gravel to meet the demand for many years. Caliche forming the caprock of the La Mesa geomorphic surface remnant at the east edge of the map area has been locally quarried for road metal and fill material. This unit comprises the partly indurated horizon of soil carbonate accumulation described in the youngest basin-floor facies "Qcrf/u" of the Camp Rice Formation. The physical and chemical properties of this type of soil material have been reported by Gile (1961) and Gile and others (1965). The well-indurated, denser and thicker caprock unit on the Rincon Surface has not yet been utilized, mainly due to absence of roads into the area of exposure.

Clay

Partly gypsiferous clay to silty clay deposits in beds 3 to 8 ft thick are extensively exposed north and west of Rincon in the Rincon Valley Formation. Clays with some gypsum also crop out at the north end of Grama Gully in the Camp Rice Formation. The Grama beds are river flood-plain deposits that interfinger with sand and silt, while the Rincon Valley clays were probably deposited in fairly large ephemeral lakes in a closed basin environment. Some commercial clay production has come from "bentonite" beds in the Camp Rice Formation 8 miles west of Hatch in a section similar to that exposed near Grama. The "bentonite" was processed for drilling mud in the 1930's and early 1940's (Patterson and Holmes, 1965). Detailed mineralogical studies of clays have yet to be undertaken other than some investigations of clays in soils developed on Camp Rice and younger sediments in the Las Cruces area (Gile and others, 1970). Existing information does indicate, however, that the clay mineral suite is dominated by 2:1 lattice clays, ranging from fairly well-ordered calcium montmorillonites to a variety of interlayered types, with minor amounts of kaolinite, attapulgite and sepiolite also present.

The gypsiferous clay and associated fine-grained facies of the Rincon Valley Formation exert a negative influence on various aspects of land use in the area. For example, special precautions must be taken during installation of major engineering works across the formation (particularly in the emplacement of highway fills and embankments) to prevent differential subsidence and heaving. Adverse effects on ground-water production and quality are caused by the impermeable and gypsiferous character of the formation (King and others, 1971). Other detrimental aspects include rapid runoff and erosion and sedimentation hazards in areas where the unit, or fine-grained valley fills derived from the unit, crop out.

Ground Water

The late Quaternary gravel and sand deposits that form the lower part of the younger valley-fill fluvial facies "Qvyf' constitute the major producing aquifer in the study area. All irrigation and domestic wells in the Rincon Valley are apparently completed in this unit. Depths to the water table are usually 5 to 15 ft below the flood-plain surface (cross section *C-B*, sheet 1, in pocket; Conover, 1954; King and others, 1971). Elsewhere in the region, the Camp Rice fluvial facies is also a major aquifer (King and others, 1971). In or adjacent to the map area, however, the only wells completed, or at least partly developed, in Camp Rice beds are the Rincon community-Santa Fe Railroad well (NE corner NW1/4 sec. 3, T. 19 S., R. 2 W.) and two stock wells (SE1/4 SE1/4 sec. 11, T. 18 S., R. 2 W.; NE1/4 NW1/4 NW1/4 sec. 35, T. 18 S., R. 2 W.) all located east of Rincon Arroyo in the Grama Graben. The general water-table configuration near Rincon Arroyo is shown in cross sections *A=A'* and *B-B'* on sheet 2 in pocket. West of the Grama Graben, the Camp Rice Formation, where present, appears to be entirely above the water table except possibly in the area just upstream of Ralph Arroyo Dam (sec. 6, T. 19 S., R. 2 W.) where the formation is depressed along the axis of a syncline. The younger valley-fill "Qvyf" aquifer in most places rests directly on the fine-grained facies of the Rincon Valley Formation (Conover, 1954). Away from the inner river valley, little is known about the disposition of any saturated zones that might occur in the relatively impermeable Rincon Valley Formation and older units. The only well outside the valley is located at Johnson Spring, the site of a small spring or seep as late as 1932 (Yeo, 1952). The well is apparently developed in shattered Thurman sandstones along the Johnson Spring fault, and produces small quantities of stock water from a very shallow depth. Among the various Tertiary rocks, several units in the Thurman Formation appear to be the best candidates for future development of at least small ground-water supplies. The Uvas Basaltic Andesite and the basal welded tuff member should locally contain significant fracture porosity; certain sandstones may also contain a considerable amount of recoverable water. The Palm Park, Hayner Ranch and Rincon Valley fanglomerate facies, while coarse grained, are also characterized by the presence of a fine-grained matrix, and are thus relatively impermeable.

References

Bryan, K., 1938, Geology and ground-water conditions of the Rio Grande depression in Colorado and New Mexico, **in** Rio Grande Joint Investigations in the upper Rio Grande basin in Colorado, New Mexico and Texas: Washington, National Resources Commission, Regional Planning, pt. 6, p. 196-225.

Clemons, R. E. and Seager, W. R., in press, Geology of Souse Springs quadrangle, New Mexico: New Mexico Bur. Mines Mineral Resources Bull. 100.

Conover, C. S., 1954, Ground-water conditions in the Rincon and Mesilla Valleys and adjacent areas in New Mexico: U. S. Geol. Survey Water-Supply Paper 1230, 200 p. Cope,

E. D., 1882, Geological age of the Lake Valley mines of New Mexico: Eng. Mining Jour., v. 34, p. 214.

Davie, W. and Spiegel, Z., 1967, Geology and Water Resouces of Las Animas Creek and vicinity, Sierra County, New Mexico: Santa Fe, New Mexico State Engineer, Las Animas Creek Hydrographic Survey Rept., 44 p.

Denny, C. S., 1940, Santa Fe Formation in Espanola Valley, New Mexico: Geol. Soc. America Bull., v. 51, p. 677-693.

Dunham, K. C., 1935, The geology of the Organ Mountains: New Mexico Bur. Mines Mineral Resources Bull. 11, 272 p.

Fenneman, N. M., 1931, Physiography of western United States: McGraw-Hill, New York, 510 p.

Frye, J. C., and Willman, H. B., 1962, Morphostratigraphic units in Pleistocene stratigraphy: Am. Assoc. Petrol. Geologists Bull. 46, p. 112-113.

Galusha, T. and Blick, J. C., 1971, Stratigraphy of the Santa Fe Group, New Mexico: Am. Mus. Nat. Hist. Bull., v. 144: Art. 1, 127 p.

Gile, L. H., 1961, A classification of Ca horizons in the soils of a desert region, Dona Ana County, New Mexico: Soil Science Soc. America Proc. v. 25, p. 52-61.

, 1967, Soils of an ancient basin floor near Las Cruces, New Mexico: Soil Science, v. 103, p. 265-276.

Gile, L. H., and Hawley, J. W., 1968, Age and comparative development of desert soils at the Gardner Spring Radiocarbon Site, New Mexico: Soil Science Soc. America Proc., v. 32, no. 5, p. 709-719.

Gile, L. H., Hawley, J. W., and Grossman, R. B., 1970, Distribution and genesis of soils and geomorphic surfaces in a desert region of southern New Mexico: Soil Science Soc. America Guidebook, Soil Geomorphology Field Conf., 155 p.

, 1971, The identification, occurrence and genesis of soils in an arid region of southern New Mexico: Soil Survey Inv., Soil Cons. Service, Unpub. Training Bull., Desert Soil-Geomorphology Project, 117 p.

Gile, L. H., Peterson, F. F., and Grossman, R. B., 1965, The K Horizon: a master soil horizon of carbonate accumulation: Soil Science, v. 99, p. 74-82.

, 1966, Morphological and genetic sequences of carbonate accumulation in desert soils: Soil Science, v. 101, p. 347-360.

Gordon, C. H., 1907a, Lower Paleozoic formations in New Mexico, review: Jour. Geology, v. 15, p. 91-92.

, 1907b, Notes on the Pennsylvanian formations in the Rio Grande valley, New Mexico: Jour. Geology, v. 15, p. 805-816.

Harley, G. T., 1934, The geology and ore deposits of Sierra County, New Mexico: New Mexico Bur. Mines Mineral Resources Bull. 10, 220 p.

Hawley, J. W., 1965, Geomorphic surfaces along the Rio Grande valley from El Paso, Texas to Caballo Reservoir, New Mexico, **in** Guidebook of southwestern New Mexico II: New Mexico Geol. Soc., 16th Field Conf., p. 188-198.

Hawley, J. W., ed., 1970, Cenozoic stratigraphy of the Rio Grande valley area, Dona Ana County, New Mexico: E1 Paso Geol. Society, Fourth Annual Field Conf., 49 p.

Hawley, J. W., and Gile, L. H., 1966, Landscape evolution and soil genesis in the Rio

Grande region, southern New Mexico: Friends of the Pleistocene, Rocky Mountain Sec., Guidebook, 11th Field Conf., 74 p.

Hawley, J. W., and Kottlowski, F. E., 1969, Quaternary geology of the south-central New Mexico border region, in Border Stratigraphy Symposium: New Mexico Bur. Mines Mineral Resources Circ. 104, p. 89-104.

Hawley, J. W., Kottlowski, F. E., Strain, W. S., Seager, W. R., King, W. E., and LeMone, D. V., 1969, The Santa Fe Group in the south-central New Mexico border region, in Border Stratigraphy Symposium: New Mexico Bur. Mines Mineral Resources Circ. 104, p. 52-79.

Herrick, C. L., 1904, The clinoplains of the Rio Grande: Am. Geologist, v. 33, p. 376-381. Hill, R. T., 1900, Physical geography of the Texas region: U.S. Geol. Survey, Topog. Atlas, U.S. Folio 3, 12 p.

Izett, G. A., Wilcox, R. E., Obradovich, J. D., and Reynolds, R. L., 1971, Evidence for two Pearlette-like ash beds in Nebraska and adjoining areas (abs.): Geol. Soc. America Program, 1971 Ann. Mtg., Washington, D.C., p. 610.

Kelley, V. C., 1955, Regional tectonics of south-central New Mexico: New Mexico Geol. Soc. 6th Ann. Field Conf., Guidebook of south-central New Mexico, p. 96-104.

Kelley, V. C., and Silver, C., 1952, Geology of the Caballos Mountains: Univ. New Mexico Pub., Geol. Ser., No. 4, Albuquerque, Univ. New Mexico Press.

Keyes, C. R., 1903, Geological structure of New Mexico bolson plains: Am Jour. Science, v. 15, p. 207-210.

, 1904, Bolson plains and the conditions of their existence: Am. Geologist, v. 34, p. 160-164.

, 1905, Geology and underground water conditions of the Jornada del Muerto, New Mexico: U.S. Geol. Survey Water-Supply Paper 123, 42 p.

King, W. E., Hawley, J. W., Taylor, A. M., and Wilson, R. P., 1971, Geology and ground-water resources of central and western Dona Ana County, New Mexico: New Mexico Bur. Mines Mineral Resources Hydrologic Report 1, 64 p.

Kottlowski, F. E., 1953, Tertiary-Quaternary sediments of the Rio Grande valley in southern New Mexico: New Mexico Geol. Soc., 4th Ann. Field Conf., Guidebook of southwestern New Mexico, p. 30-41.

, 1958, Geologic history of the Rio Grande near El Paso: West Texas Geol. Soc. Guidebook, Field Trip, Franklin and Hueco Mountains, Texas, p. 46-54.

, 1960, Reconnaissance geologic map of Las Cruces 30 minute quadrangle: New Mexico Bur. Mines Mineral Resources Geol. Map 14.

, 1965, Middle Oligocene fluorite-barite mineralization in New Mexico (abs.): Geol. Soc. America Program, 1965 Ann. Mtg., p. 90.

Kottlowski, F. E., Flower, R. H., Thompson, M. L., and Foster, R. W., 1956, Stratigraphic studies of the San Andres Mountains, New Mexico: New Mexico Bur. Mines Mineral Resources Mem. 1, 132 p.

Kottlowski, F. E., Weber, R. H., and Willard, M. E., 1969, Tertiary intrusive-volcanic-mineralization episodes in the New Mexico region (abs.): Geol. Soc. America Program, 1969 Ann. Mtg., p. 278.

Laudon, L. R., and Bowsher, A. L., 1941, Mississippian formations of Sacramento Mountains, New Mexico: Am. Assoc. Petrol. Geologists Bull., v. 25, p. 2107-2160.

, 1949, Mississippian formations of southwestern New Mexico: Geol. Soc. America Bull., v. 60, p. l-87.

Lee, W. T., 1907, Water resources of the Rio Grande valley in New Mexico and their development: U.S. Geol. Survey Water-Supply Paper 188, 59 p.

1909, The Manzano Group of the Rio Grande valley, New Mexico: U.S. Geol. Survey. Bull. 389, p. 5-40.

Leggat, E. R., Lowry, M. E., and Hood, J. W., 1962, Ground-water resources of the lower Mesilla Valley, Texas and New Mexico: Texas Board Water Engineers Bull. 6203, 191 p.

LeMone, D. V., and Johnson, R. R., 1969, Neogene flora from the Rincon Hills, Dona Ana County, New Mexico, in Border Stratigraphy Symposium: New Mexico Bur. Mines Mineral Resources Circ. 104, p. 77-88.

Maker, H. J., Neher, R. E., Derr, P. S., and Anderson, J. U., 1971, Soil associations and land classification for irrigation, Doña Ana County: New Mexico State Univ. Agr. Expt. Sta. Research Rept. 183, 41 p.

Metcalf, A. L., 1967, Late Quaternary mollusks of the Rio Grande valley, Caballo Dam, New Mexico to El Paso, Texas: Univ. Texas (El Paso) Sci. Series no. 1, UTEP Press.

, 1969, Quaternary surfaces, sediments and mollusks: Southern Mesilla Valley, New Mexico and Texas: New Mexico Geol. Soc., 20th Ann. Field Conf., Guidebook of the Border Region, p. 158-164.

Naeser, C. W., Izett, G. A., and Wilcox, R. E., 1971, Zircon fission-track ages of Pearlette-like volcanic ash beds in the great plains (abs.): Geol. Soc. America Program, 1971 Ann. Mtg., Washington, D.C., p. 657.

New Mexico State Highway Dept., 1964, Aggregate resources and soil study, New Mexico Interstate Route 25, sections 25-2 and 3: Materials and Testing Lab., New Mexico State Highway Dept., Santa Fe.

, 1966, Aggregate resources study. Highway District 1: Materials and Testing Lab., New Mexico State Highway Dept., Santa Fe.

Patterson, S. H., and Holmes, R. W., 1965, Clays in Mineral and Water Resources of New Mexico: New Mexico Bur. Mines Mineral Resources Bull. 87, p. 312-320.

Reynolds, R. L., and Larsen, E. E., 1972, Paleomagnetism of Pearlette-like air-fall ash in the midwestern United States: a means of correlating Pleistocene deposits (abs.): Geol. Soc. America, Abstracts with programs, Ann. Mtg., Rocky Mountain Sect., p. 405.

Richardson, G. B., 1908, Paleozoic formations in trans-Pecos, Texas: Am. Jour. Sci. (4), v. 25, p. 474-484.

Ruhe, R. V., 1962, Age of the Rio Grande valley in southern New Mexico: Jour. Geology, v. 70, p. 151-167.

, 1964, Landscape morphology and alluvial deposits in southern New Mexico:Annals Assoc. Am. Geographers, v. 54, p. 147-159.

, 1967, Geomorphic surfaces and surficial deposits in southern New Mexico: New Mexico Bur. Mines Mineral Resources Mem. 18, 65 p.

Russell, P. L., 1947, Manganese Products Corporation's Morgan group, Dona Ana County, New Mexico: U.S. Bur. Mines Rept., Inv. 4021.

Sayre, A. N. and Livingston, Penn, 1945, Ground-water resources of the El Paso area, Texas: U.S. Geol. Survey Water-Supply Paper 919, 190 p.

Seager, W. R, Hawley, J. W., and Clemons, R. E., 1971, Geology of the San Diego Mountain area, Dona Ana County, New Mexico: New Mexico Bur. Mines Mineral Resources Bull. 97, 36 p.

Spiegel, Z. and Baldwin, B., 1963, Geology and water resources of the Santa Fe area, New Mexico: U.S. Geol. Survey Water-Supply Paper 1525, p. 2189.

Strain, W. S., 1966, Blancan mammalian fauna and Pleistocene formations, Hudspeth County, Texas: Texas Memorial Museum, Austin, Bull. 10, 55 p.

, 1969a, Late Cenozoic strata of the El Paso area **in** Border Stratigraphy Symposium: New Mexico Bur. Mines Mineral Resources Circ. 104, p. 122-123.

, 1969b, Late Cenozoic strata of the El Paso-Juarez area: New Mexico Geol. Soc., 20th Ann. Field Conf. Guidebook of the Border Region, p. 155-157.

Thornbury, W. D., 1965, Regional Geomorphology of the United States: John Wiley & Sons, Inc., New York, 609 p.

Tight, W. G., 1905, Bolson Plains of the southwest: Am. Geologist, v. 36, p. 27-284.

Wells, E. H., 1918, Manganese in New Mexico: New Mexico Bur. Mines Mineral Resources Bull. 2, 85 p.

Yeo, H. W., 1948, Data on archaeological evidences in Palmer Park and Johnson Canyon and in Indian Canyon near Rincon and at San Diego Mountain in Archaeology of Dona Ana County, New Mexico, Part I, evidences in Rincon Valley: Unpublished manuscript, New Mexico State Museum archives, Santa Fe, p. 32-45.

Appendix—Measured Sections

Note: Color code is in accordance with the Munsell Color Co., Inc. soil color charts. Locations of measured sections are plotted on sheet 2.

PALM PARK FORMATION

Type section is in Johnson Spring Arroyo. Descriptions begin at the top of the formation in NE¼ NE¼ sec. 36, T. 18 S., R. 3 W. The measured section proceeds northeast from the base of the Thurman Formation up the arroyo and down section.

SECTION 1a

Begin section at base of Thurman Formation NE¼ NE¼ sec. 36, T. 18 S., R. 3 W.

Unit No.	Lithology	Thickness (ft)
	Base of *Thurman Formation*	
	Palm Park Formation (partial thickness, 566 ft)	
14	Mudstone, gray-red 5R5/2, 5R6/2, 5R4/2; silty, tuffaceous; white clay lumps, weathered biotite and andesite grains are common; bedding in discontinuous, uneven layers 4 to 6 inches thick with blocky fracture; yellow-gray 5Y6/2 friable to well-cemented andesite sandstone weathering yellow brown 10 YR6/2 forms numerous gradational interbeds up to 30 ft thick; minor lithologies include weathered volcanic ash pellets in layers 6 inches to 1 ft thick and moderate-orange-brown 10R4/6 claystone	180
	Offset section 200 yds north to best exposures	
13	Mudstone, gray-red 10R4/2, silty, contains disseminated white clay lumps 2 to 5 mm in diam.; fissile, blocky, indistinct bedding	36
12	Andesite boulder-cobble conglomerate, gray-orange-pink 5YR7/2, well-rounded boulders to 2 ft diam. in matrix of volcanic-derived sand and pebbles; unit fills channel	4
11	Like unit 13	75
10	Like unit 12	4
9	Like unit 13	53
8	Sandstone, pale-yellow-brown 10YR6/2, coarse-grained, pebbly, no mudstone partings; clasts are all andesite-derived; thin-bedded, upper and lower contacts gradational	4
7	Mudstone, pale-red 5R6/2, silty, in beds ½ to 1 inch thick or with blocky, indistinct bedding	24
6	Like unit 12	6
5	Mudstone, grayish-red 5R5/2; contains discontinuous lenses of pebbly sandstone and much disseminated clay lumps 1 to 10 mm in diam. (weathered volcanic ash)	50
4	Sandstone, pale-yellow-brown 10YR6/2; pebbly, thin bedded; contains much red mudstone similar to unit 1	5
3	Like unit 13	10
	Fault	

SECTION 1b

Offset section about 1,000 ft east to best exposures. Section 1b begins at base of unit 3 which has been repeated by fault noted above.

Unit No.	Lithology	Thickness (ft)
2	Interbedded andesite pebble conglomerate and lithic sandstone, pale-red-purple 5RP6/2 to 5RP7/2 to pale-purple 5P7/2; poorly sorted, very immature; sandstone is very coarse grained and contains many andesite cobbles; bedding 1 to 3 inches to 4 ft thick; some red tuffaceous mudstone interbeds. Upper 10 to 15 ft is andesite boulder conglomerate in channel fill; boulders are well rounded, up to 4 ft diam. and embedded in coarse-grained lithic sandstone matrix	50
	Fault, unknown (small?) thickness missing	
1	Mudstone, siltstone, pale-red-brown 10R5/4-10R6/4; locally pebbly, tuffaceous (pumice weathering to clay lumps); beds 2 inches to 1 ft thick with blocky fracture	65

SECTION 1c

Section 1c is typical of those parts of the Palm Park Formation that contain limestone. Location: SE¼ SW¼ sec. 24, T. 18 S., R. 3 W.

Unit No.	Lithology	Thickness (ft)
	Palm Park Formation (partial thickness, 145 ft)	
	Top of hill	
3	Limestone and travertine, dark-yellow-brown 10YR6/6-10YR6/2 to light-brown-gray 5YR6/1 to white N9, locally moderate-pink 5YR7/4; sucrosic texture to dense, hard; beds 1 to 4 ft thick; locally contains algal filaments and gastropod remains; unit represents upper deposits of travertine mounds	50
2	Travertine, white N9 weathering grayish-orange 10YR7/4; very porous, vuggy, banded calcite, siliceous laminae, and intraclastic debris; numerous palm(?) frond impressions, twigs, and tubular casts and molds; massive beds 6 ft thick; lenticular unit pinches out along strike	20
1	Interbedded andesite cobble-boulder conglomerate, lithic sandstone and mudstone, light-blue-gray 5B7/1; very immature, poorly sorted, entirely andesite-derived clasts; boulders to 3 ft in diam.; tuffaceous; poor, indistinct bedding; poorly exposed	75+
	Base of *Camp Rice Formation*	

THURMAN FORMATION

Type section is in the Black Hills area. Lowest Thurman strata exposed in the Rincon Hills area are of local extent and overlie the type section of the Palm Park Formation in Johnson Spring Arroyo. They are described in section 2a. Elsewhere, the base of the Thurman is marked by a prominent ash-flow tuff described in section 2b. The rest of the Thurman is well-exposed in a nearly continuous section in the Black Hills and is described in sections 2c-2g.

SECTION 2a

Pre-basal ash-flow tuff clastic section. NE¼ NE¼ sec. 36, T. 18 S., R. 3 W.

Unit No.	Lithology	Thickness (ft)
	Thurman Formation (full thickness, 2,241 ft incl. *Uvas Basaltic Andesite)*	
	Thurman Formation, thickness 154 ft, below basal Thurman ash-flow tuff	
	Prominent cuesta formed by basal ash-flow tuff	
8	Mostly covered; probably red to gray mudstone and sandstone with discontinuous zones of andesite cobbles	66
7	Breccia, pale-red-brown 10R5/4; contains red mudstone, ash-flow tuff clasts to 4 inches diam.; well-bedded, graded beds	5
6	Mostly covered; red-brown tuffaceous mudstone	10
5	Ash-flow tuff; pale-red 5R6/2 to 5R7/2; lithic, pumice rich with minor crystals; moderate to densely welded; well-developed eutaxitic texture in welded areas; lithic content is dark brown, dense angular volcanic fragments; single flow; ash-flow tuff 4 of Bell Top Formation in Sierra de Las Uvas	10
4	Brecciated ash-flow tuff; pale-red 10R6/2; grades laterally into ash-flow tuff (unit 5, described above) in one direction along strike and into stream conglomerate in other	3
3	Siltstone, mudstone, pale-yellow-brown 10YR6/2 weathers gray N7; tuffaceous; numerous 6 to 8 inch thick interbeds of pebbly volcanic sandstone	25
2	Sandstone, very-light-gray, N8, weathers moderate brown 5YR4/4; clasts consist of quartz, feldspar and andesite, tuffaceous; well-cemented; numerous "floating" cobbles and boulders; pebbly zones and local lenses of andesite boulder conglomerate; unit is channel fill extending 300 yds along strike	25
1	Sandstone, gray-orange-pink, 10R7/2; clasts consist of andesite, biotite, and feldspar; tuffaceous; pebbly in zones; thin-bedded, weathers to corrugated appearance, identical to Thurman sandstones	10
	Base of Thurman Formation, top of *Palm Park Formation*	

SECTION 2b

Basal Thurman ash-flow tuff. Section is located on the south side of Palm Park SW¼ NW¼ sec. 23, T. 18 S., R. 3 W.

Unit No.	Lithology	Thickness (ft)
	Thurman Formation, basal ash-flow tuff, 55 ft	
1	Crystal-pumice ash-flow tuff, very-light-gray N8, weathers light brown 5YR6/4; moderately welded; biotite, sanidine, quartz phenocrysts; much white flattened pumice fragments to 2 inches diam.; resistant single flow, forms cuesta; ash-flow tuff 5 of Bell Top Formation in Sierra de las Uvas	55

SECTION 2c

"Lower Thurman clastic section." Section begins at top of unit approximately in NE¼ NW¼ sec. 26, T. 18 S., R. 3 W.

Unit No.	Lithology	Thickness (ft)
	Base of *Uvas Basaltic Andesite*	
	Thurman Formation, "lower Thurman clastic section," 471 ft	
13	Conglomeratic sandstone, pale-reddish-brown 10R6/4 baked red at Uvas contact; very coarse grained, poorly sorted, lithic; cobbles and boulders of andesite in channel-fill lenses; indistinct bedding 4 inches to 1 ft thick	8
12	Sandstone and conglomeratic sandstone, pale-orange 10YR8/2 to pale-reddish-brown 10R5/4; grades laterally to white tuffaceous well-sorted sandstone; unit poorly exposed	24
11	Like unit 9; cobbles consist of andesite and basal Thurman ash-flow tuff	10
10	Mudstone and siltstone, very-pale-orange 10YR8/2; very tuffaceous (white clay fragments); siltstone weathers to ledges 1 to 3 ft thick, mudstone to "popcorn" soil	22
9	Interbedded andesite pebble-cobble conglomerate and conglomeratic lithic sandstone, pale-yellow-brown 10YR6/2; coarse-grained, poorly sorted, immature; numerous well-rounded andesite boulder and cobble lenses fill channels; thin- to medium-bedded	20
8	Sandstone, white N9, weathers pale-grayish-orange 10YR8/4; very fine grained; tuffaceous; thin-bedded; weathers to small fragment-covered slope	18
7	Like unit 9	45

SECTION 2d

Continuation of "lower Thurman clastic section." Offset 1/3 mi NW across fault and continue at top of cliff-forming ash-flow tuff (unit 6 below); SE¼ SW¼ sec. 23, T. 18 S., R. 3 W.

Unit No.	Lithology	Thickness (ft)
6	Crystal ash-flow tuff, grayish-orange-pink 10R8/2, weathers 10R8/2 to moderate orange-pink 5YR 8/4; biotite, sanidine, quartz phenocrysts, no lithic fragments; moderate to poorly welded; single resistant unit, forms cliff; ash-flow tuff 6 of Bell Top Formation in Sierra de Las Uvas	35
5	Sandstone, pinkish-gray 5YR8/1 to pale-orange 10YR7/2-10YR8/2 to white N9; well-sorted, fine- to very coarse grained in different beds; lithic grains predominate; tuffaceous; medium-bedded (6 to 18 inches); some laminations, blocky fractures	84
4	Mudstone, pale-yellow-brown 10YR6/2, weathers 10YR7/2; silty, weathers to "popcorn" soil	25
3	Interbedded sandstone and andesite pebble-cobble conglomerate, pale-red 10R6/2-10R5/4, to grayish-orange-pink 10R8/2 to white N9; poorly sorted, very immature, poorly lithified; tuffaceous; much biotite and feldspar crystals; some cross-bedding; local andesite cobble-boulder lenses and few interbeds of pale-red 10R6/2 mudstone-siltstone	100
2	Rhyolite air fall(?) breccia, grayish-orange-pink 10R8/2 in lower 5 ft, white N9 in upper 10 ft; crystal ash-flow(?) tuff fragments 1 to 2 cm long in tuffaceous matrix; sandy and thin-bedded in upper 3 ft; unit is a marker bed where preserved between younger Thurman channel fills	15
1	Sandstone, pale-red-brown 10R5/4, pebbly, poorly sorted, tuffaceous, cross-bedded, locally containing lenticular pale-red 10R6/2 andesite-pebble conglomerate; interbedded with friable, very fine grained	

	pale-red 10R6/2 sand and silt that weathers to moderate orange-pink 10R7/2 "popcorn" soil. At base of unit is a prominent andesite cobble-boulder conglomerate a few ft thick with well-rounded clasts in rhyolitic, tuffaceous matrix	65
	Base of "lower Thurman clastic section," top of *basal Thurman ash-flow tuff*	

SECTION 2e

Uvas Basaltic Andesite. Begin section at top of Uvas Basaltic Andesite in NE¼ SW¼ sec. 26, T. 18 S., R. 3 W.

Unit No.	Lithology	Thickness (ft)
	Base of "upper Thurman clastic section"	
	Uvas Basaltic Andesite, 404 ft	
6	Basaltic andesite, brownish-gray 5YR4/1-5YR5/1, medium-gray N5-N6, greenish-gray 5GY5/1, olive-black 5Y2/1, dark yellowish-brown 10YR4/2-10YR6/2; flows 10 to 80 ft thick, lenticular, scoriaceous tops and bases; flow breccia common at base of flows; locally amygdaloidal; dense interiors with platy jointing; red oxidation and green deuteric alteration common	105
5	Sandstone, grayish-orange-pink 5YR7/2, weathers grayish-orange 10YR6/4, lithic, tuffaceous, well-cemented, hard, massive, contains few cobbles of Uvas Basaltic Andesite	5
4	Sandstone, white N9, fine- to medium-grained, well-sorted, tuffaceous; tangential cross-bedding; thin, wavy bedding with solution pits along bedding; fills cracks in underlying basalt; conspicuous marker bed	30
3	Like unit 6	205
2	Sandstone, light-brown 5YR6/4, medium-grained, well-sorted, friable, poorly exposed	24
1	Like unit 6	35
	Base of *Uvas Basaltic Andesite,* top of "lower Thurman clastic section"	

SECTION 2f

"Upper Thurman clastic section." Section begins at top with contact of Rincon Valley Formation in NE¼ NW¼ SE¼ sec. 35, T. 18 S., R. 3 W.

Unit No.	Lithology	Thickness (ft)
	Base of *Rincon Valley Formation*	
	"Upper Thurman clastic section," 1,311 ft	
8	Claystone (like unit 6) grayish-orange-pink 5 YR 7/2, and coarse-grained, lithic sandstone, moderately sorted, little tuffaceous material, friable; unit soft, poorly exposed, mostly claystone in lower half, sandstone in upper half	350
7	Sandstone, pinkish-gray 5YR8/1, weathering grayish orange pink 5YR7/2; coarse to fine-grained, well-sorted, tuffaceous (pumice weathered to clay), lithic, occasional "floating" cobbles and boulders of Uvas Basaltic Andesite and welded tuff; some low-angle, thin cross-beds;	

	bedding ranges from thick (4 to 5 ft) to characteristic very thin even beds ½ to 1 inch thick; minor 1 to 4 ft thick interbeds of claystone; unit forms hogbacks and strike valleys	430
6	Claystone, grayish-orange-pink 5YR7/2, with few siltstone layers 1 inch thick; weathers to "popcorn" soil and strike valley	20
5	Sandstone, very-light-gray N8, fine to medium-grained, tuffaceous, thin- to medium-bedded; 4 ft claystone layer 30 ft above base	57

SECTION 2g

Continuation of "upper Thurman clastic section." Offset 200 ft east along strike to best exposures, SE¼ NE¼ sec. 35, T. 18 S., R. 3 W.

Unit No.	Lithology	Thickness (ft)
4	Claystone, grayish-orange-pink 5YR7/2; fine sand layers 1 to 3 inches thick gives thin-bedded appearance to claystone; claystone beds 5 to 15 ft; interbedded, fine- to medium-grained, pinkish-gray 5YR8/1, tuffaceous sandstone with thin "corrugated" bedding; unit forms strike valley and small ledges	55
3	Sandstone, pinkish-gray 5YR8/1 to very light gray N8, weathers pale yellow brown 10YR7/2, fine- to medium-grained, local coarse-grained zones a few inches thick, well-sorted, lithic, very tuffaceous (pumice weathered to clay); minor thin sets of cross-beds; massive, thick to very thin bedding, some of which is indistinct, some well, even bedded; minor interbeds of sandy tuff and a few 1 to 5 ft thick beds of grayish-orange-pink 5YR7/2, claystone and siltstone that weathers to "popcorn" soil; unit forms small hogbacks and strike valleys	234
2	Sandstone, white N9, weathers pale orange 10YR8/2, fine- to medium-grained, well-sorted, lithic, tuffaceous; few cobbles and pebbles of Uvas Basaltic Andesite "floating" in sandstone; massive, indistinct bedding, weathers with pitted surface	70
	Fault, unknown amount of section missing (probably small)	
1	Sandstone, very light gray N8, to yellow-gray 5YR8/1, lithic, mostly well-sorted, very tuffaceous (pumice fragments weathering to clay); some scattered granules and cobbles of Uvas Basaltic Andesite, and several poorly sorted basalt pebble-cobble conglomerate lenses; 15 ft of silty pumice tuff at base; indistinct, crumbly, thin (1 to 3 inches) bedding; forms ledges and slopes	95
	Base of "upper Thurman clastic section," top of *Uvas Basaltic Andesite*	

Type Faces: Composed on Fototronic 600 and IBM MT/ST
Text 10 pt. Times Roman leaded one point
Display heads 18 pt Times Roman
Subheads 12 pt Times Roman
Tables in 8 pt Press Roman leaded one point

Presswork: Miehle Single Color Offset
Harris Single Color Offset

Paper: Cover on 10 pt C2S Supertuff
Body on 70# Mead Matte
Pocket maps on 20# Map Bond

Index

Numbers in **boldface** indicate main sections

HOLOCENE

Qvy — Younger valley-slope alluvium

Arroyo, fan, and terrace deposits (boulder gravel to silt-clay), associated with graded surfaces formed during the last major episode of valley entrenchment and backfilling; intertongues with and overlaps Qvyf

Qvyf — Younger valley-fill fluvial facies

River flood-plain and channel deposits (clay to sand in upper part grading to basal gravel and sand) beneath Rincon Valley floor

Qpy — Younger piedmont-slope alluvium

Fills (silty to gravelly) of shallow drainageways cut below older (Pleistocene) fan and erosion surface

Ql — Ephemeral-lake sediments

Deposits (clay-silt) beneath the floors of small closed depressions on ancient basin-floor surfaces

Qca — Colluvium-alluvium (undifferentiated)

Erosion surface veneers, and thin colluvial and alluvial fills on arroyo valley sideslopes, in mountain canyons and on piedmont slopes

MIDDLE TO LATE PLEISTOCENE

Qvo / Qvou / Qvof

Qvo — Older valley-slope alluvium. Arroyo fan and terrace deposits, and erosion surface veneers (boulder gravel to silt-clay), associated with graded surfaces formed during at least two major episodes of valley entrenchment and partial backfilling. Uppermost beds beneath relatively stable geomorphic surface remnants (Picacho and Tortugas Surfaces, NW-SE diagonal line pattern) often contain indurated zones, as much as 2 ft thick, cemented with pedogenic lime

Qvou — Complexly intertonguing arroyo fan (Qvo) and river deposits (Qvof)

Qvof — Older valley-fill-fluvial facies. River channel and flood-plain deposits (sand to cobble gravel, with minor silt-clay) at elevations ranging from a few ft to as much as 120 ft above the present river flood plain. At least two distinct "Qvof" terrace-fill units intertongue with "Qvo" arroyo-fan alluvium

Qpo — Older piedmont-slope alluvium

Fan deposits, piedmont valley fills and erosion surface veneers (gravelly to loamy), associated with surfaces graded to Jornada del Muerto Basin floor, and apparent age equivalent of "Qvo" units. Uppermost beds often contain indurated zones, as much as 2 ft thick, cemented with pedogenic lime

Qbf — Basin-floor sediments

Dominantly non- to low-gravelly alluvium in an area of the Jornada Basin still unaffected by arroyo valley incision. Main part of unit appears to grade to "Qpo" unit in piedmont toe-slope position

Rincon, La Mesa, and Jornada I surfaces

Extensive remnants of 3 major relict surfaces that, in various places, mark the culmination of basin aggradation (Camp Rice deposition). Diagonal lines designate the Rincon surface (early (?) Pleistocene); horizontal (E-W) lines denote the La Mesa (basin-floor) surface; and vertical (N-S) lines show a number of remnants of the Jornada I piedmont-slope surface (late middle Pleistocene).

"Qcrf (m)" strata beneath the Rincon surface are cemented into a complex caliche caprock unit as much as 30 ft thick. "Qcrf (u)" and "Qcrp" strata, respectively, beneath the La Mesa and or Jornada I surfaces, usually contain near surface indurated horizons ranging up to 4 ft thick cemented with pedogenic carbonate.

Areas of discontinuous eolian sand cover, mainly in the form of mesquite coppice dunes, commonly occur in and adjacent to extensive areas of Qcrf mapping units, particularly subunit m. Areas with thickest and most widespread dune deposits occur on and adjacent to: 1) the La Mesa remnant in sections 13, 14, 23, 24, T. 18 S., R. 2 W., 2) the Rincon surface remnant in south part sec. 20 and north part sec. 29, T. 18 S., R. 2 W., 3) Qca mapping unit in NE ¼ sec. 30, T. 18 S., R. 2 W., and 4) south slope of Rincon Arroyo valley opposite Rincon in sec. 8 & 9, T. 19 S., R. 2 W.

Santa Fe Group

EARLY TO MIDDLE PLEISTOCENE

Qcrp, Qcrc, Qcrf (u, g, a & w, c, m, l) — Camp Rice Formation

Intermontane basin fill with 2 major facies subdivisions: A piedmont-slope alluvial facies, and a basin-floor fluvial facies; the latter being deposited by an ancestral Rio Grande prior to incision of the present valley system

Fluvial facies (Qcrf). Sand, gravelly sand, gravel, sandstone and conglomeratic sandstone (major); clay-silt and mudstone (minor). Subscript "u" denotes upper very gravelly subunit; subscript "m" designates a medial sand, loam, sandstone and mudstone subunit with multiple paleosols developed in finer textured zones; and subscript "l" denotes lower sandstone to conglomeratic sandstone subunit. Degree of induration of the middle and lower units increases from south to north, with the area of common sandstone and sandy mudstone designated by the subscript "ml". The symbol "g" marks position of one or two channel-gravel deposits at the base of the upper subunit (u); the symbol "a" shows the position of a sequence of sand to clay beds containing a volcanic ash layer at Grama; and "w" designates outcrops of one or two white marker beds containing opalized plant fossils; "a" and "w" occur in about the same stratigraphic interval. The symbol "c" shows the position of a conglomeratic sandstone at the base of a graded sandstone-to-loam sequence that immediately underlies sequence "a" near the lower end of Grama Gully and is about 40 ft below bed "a" 1 mile to the south. Towards adjacent mountain uplifts "Qcrf" intertongues with:

Piedmont-slope facies (Qcrp, Qcrc). Fan gravel and fanglomerate with interbedded sandy to clayey zones; includes thin erosion-surface veneers near mountain fronts. Basal cemented gravelly zone (Qcrc) overlapped by lower to medial (l-u) "Qcrf" subunits. Upper, piedmont-slope facies (Qcrp), characterized by interbedded gravel, sand and loam strata, with multiple paleosol zones, including strong horizons of lime accumulation; overlaps and appears to intertongue with upper to medial (u-m) "Qcrf" subunits

ANGULAR UNCONFORMITY

PLIOCENE & MIOCENE(?)

Trv, Trvc — Rincon Valley Formation

Bolson-fill deposits with two major facies: 1) a basin center facies (Trv) that includes reddish, slightly conglomeratic siltstone, sandstone and gypsum beds which erode to barren badlands, and 2) a fanglomeratic basin margin facies (Trvc) consisting of massive poorly sorted red-brown conglomerate derived largely from Paleozoic rocks. About 400 ft thick

LOCAL ANGULAR UNCONFORMITY

MIOCENE & PLIOCENE(?)

Thr — Hayner Ranch Formation

Bolson-fill deposits that consist primarily of reddish-brown to gray conglomeratic stream-deposited sandstone. Several thick tongues of volcanic-derived boulder conglomerate are interbedded in the lower two-thirds; small quantities of granite, chert and limestone clasts distinguish the upper one third. About 2,500 ft thick

MIOCENE

Tst — Unnamed transitional unit

Stream-deposited bolson conglomeratic sandstone, mudstone and conglomerate. Yellow brown to pale red; even, parallel bedding; 3 thin algal limestone beds distinguish this unit from overlying Hayner Ranch. About 430 ft thick

OLIGOCENE & MIOCENE

Ttu, Tu, Ttl, Tta — Thurman Formation and Uvas Basaltic Andesite

Thurman Formation consists of 4 informal map units including a medial tongue of Uvas Basaltic Andesite. Basal ash-flow tuff unit (Tta) consists of a light-tan crystal-vitric ash-flow tuff about 50 ft thick. Tuffaceous sandstone, conglomerate, mudstone and a thin ash-flow tuff occur locally beneath, but were not mapped separately. Lower clastic section (Ttl) is comprised of about 525 ft of white to gray tuffaceous sandstone and mudstone, red andesite-cobble conglomerate, and 2 ash-flow tuffs

About 400 ft of Uvas Basaltic Andesite (Tu) flows occur between the lower and upper Thurman clastic sections. Upper clastic section (Ttu) includes about 1,300 ft of white to light-gray even-bedded tuffaceous lithic sandstone and pink mudstone

DISCONFORMITY

EOCENE

Tpp — Palm Park Formation

River, flood-plain, spring, and mudflow deposits, mainly andesitic in composition. Varicolored tuffaceous mudstone, siltstone, sandstone and boulder-cobble conglomerate are cyclically interbedded. Local travertine mounds and associated freshwater limestone beds present. About 2,000 ft thick

EARLY TERTIARY

Tlr — Love Ranch Formation

Massive, poorly sorted limestone boulder-cobble fanglomerate derived from underlying Paleozoic formations. To 50 ft thick where present

ANGULAR UNCONFORMITY

PERMIAN

Psa — San Andres Formation

Alternating light- and dark-gray, medium- to thick-bedded, fetid limestone. 300 ft exposed

PENNSYLVANIAN

IPm — Magdalena Group

Thin- to thick-bedded cherty, fossiliferous limestone, minor siltstone and gray calcareous, shaley limestone constitute much of the unit. Conspicuous light-gray chert-pebble breccia at the base. Only about 380 ft of upper and lower parts exposed

DISCONFORMITY

MISSISSIPPIAN

M — Lake Valley and Caballero Formations

Lake Valley Formation consists of 2 members: 1) the lower Alamogordo Member consisting of up to 30 ft medium- to light-gray, even-bedded, dense limestone that forms a conspicuous cliff, and 2) the Nunn Member, consisting of up to 37 ft of soft fossiliferous light-colored marly limestone

The Caballero Formation is comprised of yellowish-gray micaceous siltstone and fine-grained sandstone, and is about 90 ft thick beneath the Alamogordo Member of the Lake Valley Formation

DEVONIAN

Dp — Percha Formation

Dark-gray to greenish-gray fissile shale and thin interbedded siltstone

DISCONFORMITY

SILURIAN

Sf — Fusselman Dolomite

Thick-bedded, dense, gray, cherty dolomite

1 ½ 0 1 MILE

INDEX MAP OF NEW MEXICO

TRUE NORTH
MAGNETIC NORTH
12°

APPROXIMATE MEAN DECLINATION, 1971

Geologic contact, dashed where approximately located, dotted where concealed

Normal fault, dashed where inferred or approximately located, dotted where concealed. Arrows show direction of dip. Ball on downthrown side

Landslide block, arrows on hanging wall

Strike and dip of beds

Strike and dip of vertical beds

Horizontal beds

Strike and dip of overturned beds

Apparent dip of beds

Anticlinal axis

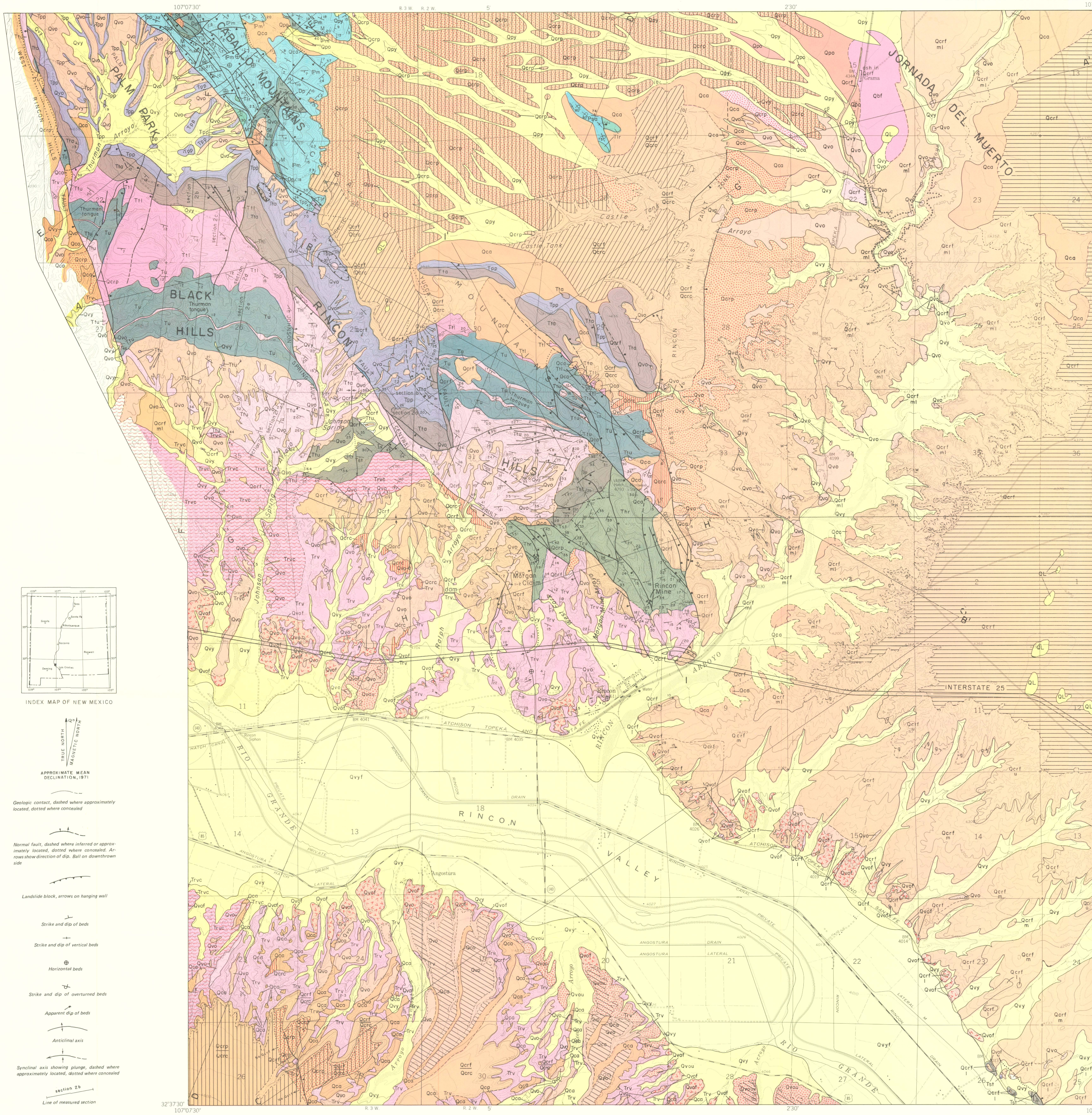
Synclinal axis showing plunge, dashed where approximately located, dotted where concealed

section 2b

Line of measured section

Manganese mines

Structure sections presented on Sheet 2

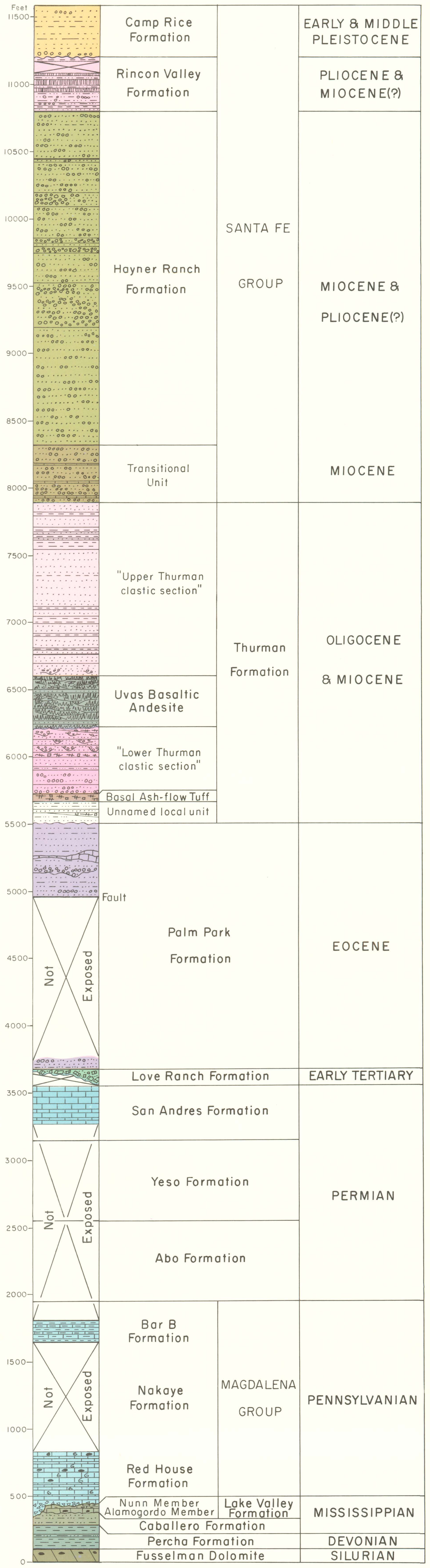


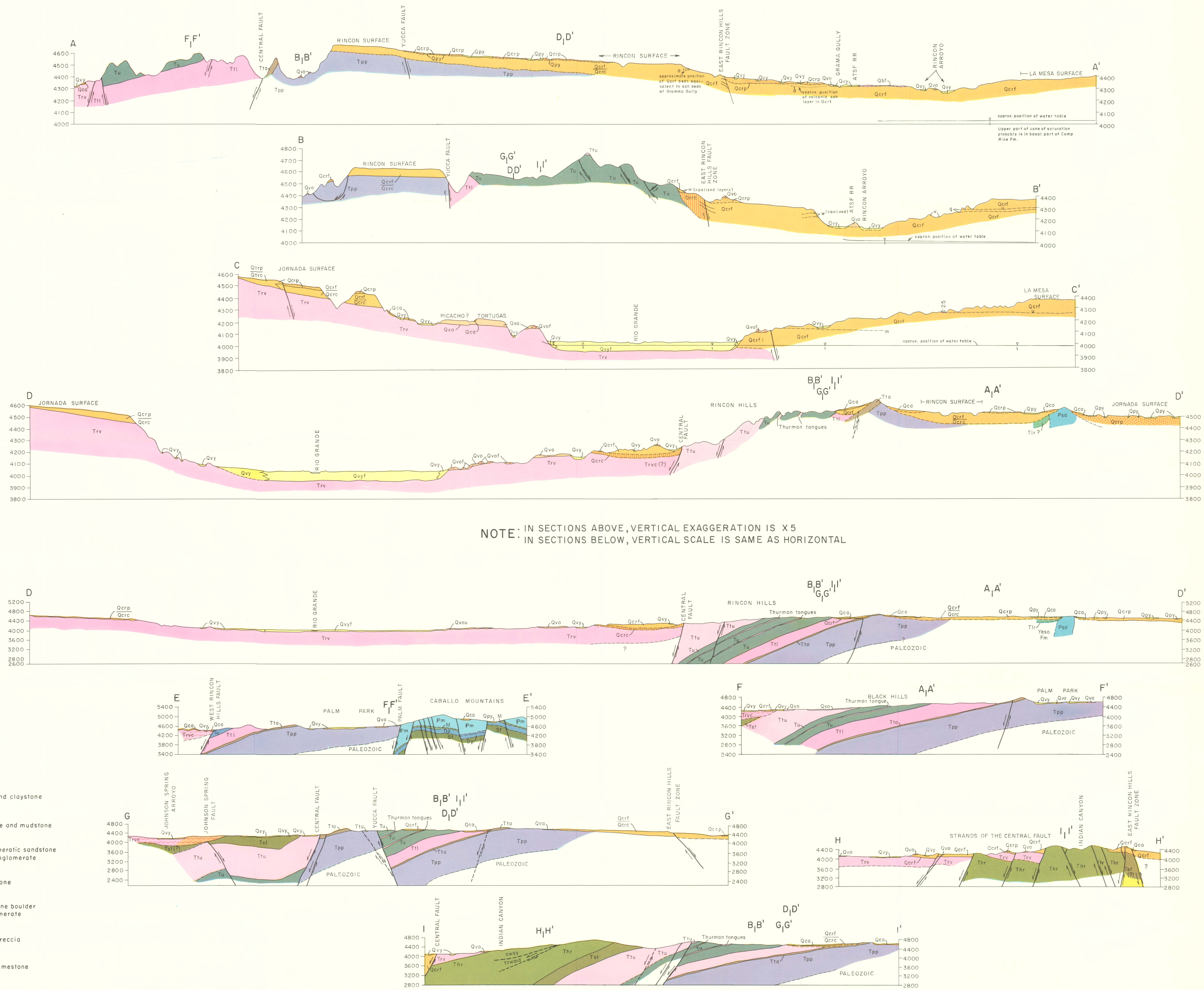
Base from the U.S. Geological Survey

Geology by William R. Seager and John W. Hawley

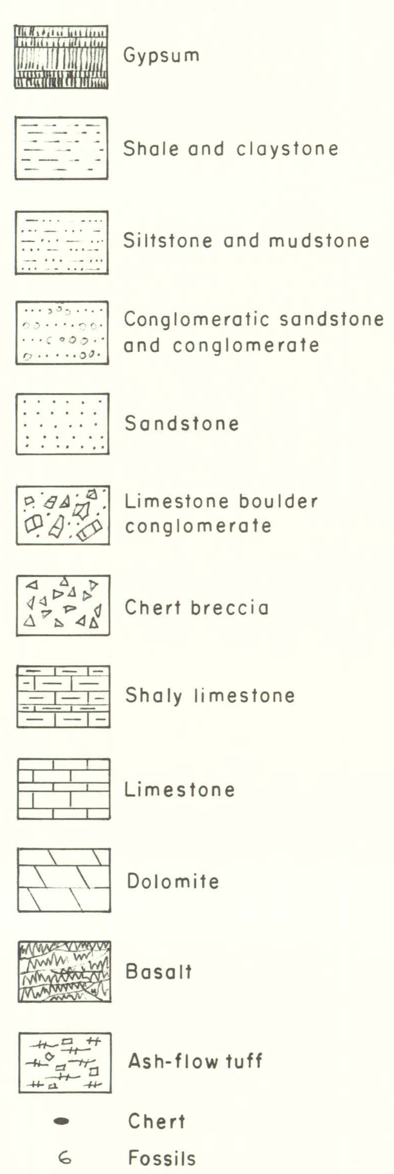
GEOLOGIC MAP OF RINCON QUADRANGLE, NEW MEXICO

by W.R. Seager and J.W. Hawley





NOTE: IN SECTIONS ABOVE, VERTICAL EXAGGERATION IS X5
IN SECTIONS BELOW, VERTICAL SCALE IS SAME AS HORIZONTAL



GEOLOGIC CROSS SECTIONS FOR RINCON QUADRANGLE, NEW MEXICO