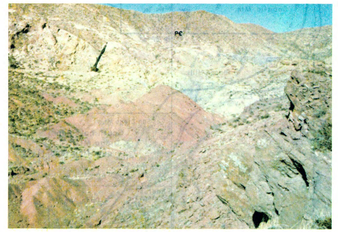
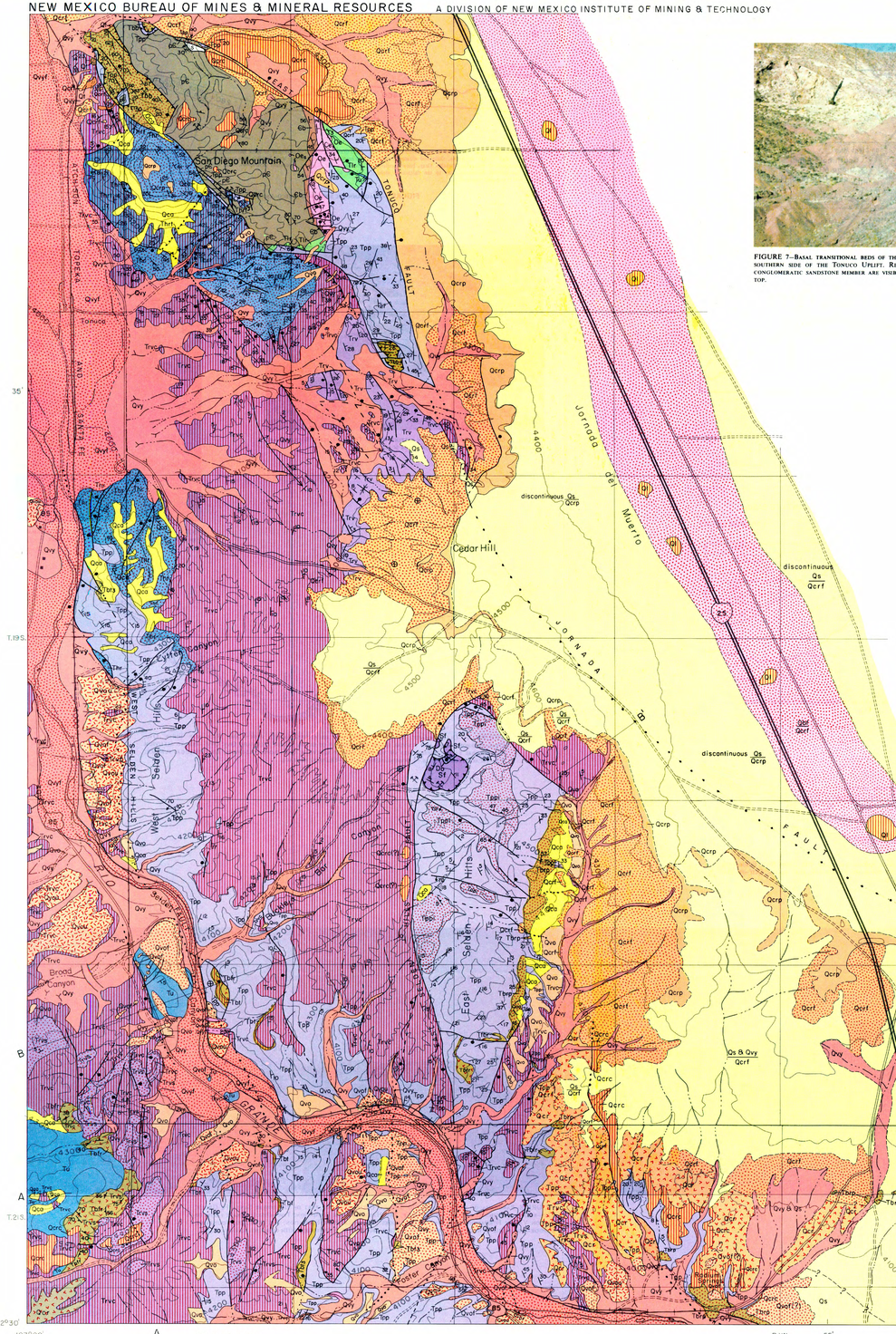


FIGURE 7–Basal transitional beds of the Lower Santa Fe Group exposed along the southern side of the Tonuco Uplift. Red fine-grained member and purplish-brown conglomeratic sandstone member are visible in foreground. Precambrian rocks (p€) at top.

FIGURE 9–Alluvial flat to playa facies of the Rincon Valley Formation (Trv) exposed south of the Tonuco Uplift. Fluvial facies of the Camp Rice Formation (Qcrf) caps the hill.

FIGURE 12–View southward over Selden Canyon showing Picacho surface (PS) and Tortugas surface (TS) developed on Santa Fe Strata. WSH, West Selden Hills; OM, Organ Mountains; RM, Robledo Mountains. Photo by John W. Hawley.


San Diego Mountain
Cedar Hill
Jornada del Muerto
Selden Canyon
West Selden Hills
East Selden Hills
Broad Canyon
Doña Ana Mountains
Rio Grande
Tonuco Fault
Jornada Fault
Topsen and Santa Fe Fault
Qcrp
Qcrf
Qvy
Qs
Tpp
Trvc
Tbp
Tu
Pa
Ph
Tmp
Tl
Qpy
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Qvo
Qvof
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Qcr
Qpy & Qs
Qs & Qvy
discontinuous Qs Qcrp
discontinuous Qs Qcrf
Qcrp & Qs Qcrf
Qcrf (?)
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TEXT ACCOMPANYING GEOLOGIC MAP 35

The San Diego Mountain 15-minute quadrangle is located about 15 miles north of Las Cruces in Doña Ana County, New Mexico (fig. 1). The northern half of the quadrangle is covered primarily by caliche and blow sand that form the surface of the Jornada del Muerto desert. A discussion of the Jornada del Muerto surface and its associated deposits was beyond the scope of this study, hence omitted from this report. Although large areas of the southern half of the quadrangle are also part of the Jornada del Muerto, entrenchment of the Rio Grande along the southwestern border has resulted in extensive exposures of older rocks ranging in age from Precambrian to Holocene. These rocks are significant to an understanding of the Tertiary structural and volcanic history of the region, and to the Pleistocene and Holocene evolution of the present landscape.

Previous workers in the quadrangle have been primarily concerned with ground water, soil-geomorphic studies, the Santa Fe Group, and Quaternary mollusican faunas. King and others (1971) described the ground-water conditions in the area, and the geology of the primary aquifer, the Santa Fe Group. Hawley and others (1969) studied the Santa Fe Group, subdividing it into several units. This work was continued by Seager and others (1971) in the San Diego Mountain area where formations were defined. Soil and geomorphic studies have been published by Ruhe (1962, 1967), Hawley (1965), Hawley and Kottlowski (1969), and Gile and others (1971). Metcalf (1967) presented details of late Quaternary valley-fill stratigraphy and associated mollusican fauna. Recent studies involving older rocks are by Kottlowski (1953), Hawley (1970), and Seager and others (1971).

REGIONAL TECTONIC SETTINGS

Regionally, the southern half of the San Diego Mountain quadrangle includes parts of 3 major areally overlapping Tertiary tectonic features (fig. 2). Patterns of Tertiary erosion and deposition were largely controlled by these structures. Erosion of the oldest feature, a Laramide uplift, produced early Tertiary fanglomerates and the striking unconformities at the base of the Tertiary section. The Oligocene Goodsight-Cedar Hills volcano-tectonic depression (Seager, 1973) affected distribution of Oligocene and early Miocene ash-flow tuffs, rhyolite intrusions, epiclastic sediments, and basaltic andesite flows. Throughout much of the Miocene, Pliocene, and Quaternary, fault-block uplifts and grabens of the Rio Grande rift controlled the pattern of bolson sedimentation. Significant among these grabens is an early Santa Fe basin in which the oldest known Santa Fe deposits in south-central New Mexico accumulated.

STRATIGRAPHY

Precambrian Rocks

Precambrian rocks are exposed only in the Tonuco uplift. Red microcline granite and pegmatite are the predominant rock types, although locally small pods of gneiss, schist and migmatite occur. Fluorite-barite veins of Miocene age are common in the granite.

Paleozoic Rock

About 125 ft of Bliss Sandstone overlies Precambrian granite on the eastern side of the Tonuco uplift. The formation consists of brown hematitic quartz sandstone and light-brown glauconitic shale and siltstone that locally contains a Late Cambrian trilobite fauna (Kottlowski and others, 1956; Flower, 1959). These are overlain conformably by about 300 ft of Lower Ordovician Sierrite Limestone (El Paso Group), much of which is silicified. Thin, crenulated siliceous streaks, flakes, and laminae impart a distinctive mottled appearance to the thin- to medium-bedded limestone. In the Tonuco uplift lower Tertiary fanglomerate overlies the El Paso and older rocks on an early Tertiary erosion surface.

South of the Tonuco uplift at the northern end of the East Selden Hills, part of the Fusselman Dolomite and Onate Formation are exposed in a small block. The rocks are sheared and silicified adjacent to the East Selden Hills fault, and also appear to be underlain along a sheared surface by Tertiary Palm Park strata. The Paleozoic rocks may constitute a slide block; clearly they are not rooted to older Paleozoic strata.

The Silurian Fusselman Dolomite comprises the bulk of the block. About 150 ft of the formation is exposed, the top and base being erosion and fault surfaces, respectively. Brown to light-gray cherty dolomite, sucrosic in places, and generally similar to the Fusselman in the Robledo Mountains to the south, is characteristic. The Onate Formation occurs in fault contact with the Fusselman, and consists of steeply dipping light-gray, buff, and yellow, thin-bedded siltstone and shale containing well-preserved Middle Devonian brachiopods (J. T. Dutro, Jr., letter 1974). No Percha Shale or younger rocks are present in the block.

Pennsylvanian strata and earliest Permian (Bursum) rocks are not exposed in the quadrangle, but the Wolfcampian Hueco Limestone and Abo Sandstone crop out extensively in the northern Doña Ana Mountains (fig. 3). About 400 ft of red Abo sandstone and siltstone interbedded with gray to buff, yellow or orange Hueco limestone overlie 1100 ft of dark-gray limestone, gray porcelanitic shale, black shale, light-gray, sandy limestone, and minor brown siliceous sandstone and siltstone, probably also part of the Hueco. The top and base of the section is not exposed in the San Diego Mountain quadrangle, but a mile or two south, rocks of possible Bursum age appear beneath the Hueco, and Palm Park strata overlie the Abo-Hueco sequence. Hueco strata in the northern Doña Ana Mountains appear to represent a basin facies. The porcelanitic rocks, black shale, and fine-grained siliceous sandstones are absent from a more typical shelf sequence of Hueco strata exposed in the Robledo Mountains.

Tertiary Rocks

Tertiary rocks include: 1) lower Tertiary Love Ranch Formation, 2) Eocene to Miocene volcanic and volcaniclastic rocks, 3) Miocene and Pliocene bolson deposits.

Love Ranch Formation

Within the San Diego Mountain quadrangle, the Love Ranch Formation is exposed only in the Tonuco uplift (significance discussed by Seager and others, 1971). The formation comprises about 200 ft of fanglomeratic strata derived from and overlying deformed Precambrian granite and Bliss and El Paso strata (fig. 4). A single 5-ft bed of microcrystalline limestone is present together with some finer grained red beds. In the Tonuco uplift the formation appears to be disconformable beneath the Palm Park Formation, but elsewhere in the region basal Tertiary conglomeratic strata similar to the Love Ranch – but containing andesitic debris – grades into the Palm Park (Kottlowski and others, 1956; Seager and others, 1975). Whether the disconformity at the top of the Love Ranch in the Tonuco uplift is local in extent and of no significance, or whether more than one basal Tertiary fanglomerate of different age occurs in the region is not clear. The Love Ranch underlies rocks dated 42 m. y. and is associated with Laramide structural features – both features are probably early Tertiary.

Volcanic and Volcaniclastic Rocks (Eocene to Miocene)

Overlying the Love Ranch Formation, Precambrian granite, or Paleozoic strata is a variable thickness of volcaniclastic and volcanic rocks and associated subvolcanic plutons. These rocks are subdivided from oldest to youngest into: Palm Park Formation (Kelley and Silver, 1952), Bell Top Formation (Kottlowski, 1953) and Doña Ana monzonite porphyry, and Uvas Basaltic Andesite (Kottlowski, 1953; Clemons and Seager, 1973).

The Palm Park Formation consists predominantly of andesitic epiclastic strata, mainly of laharic, fluvial, and overbank origin. At San Diego Mountain and in the East Selden Hills, small bodies of andesite porphyry appear to be semiconcordant sills. A hornblende-andesite porphyry flow is interbedded with laharic breccias in Lytten Canyon. Although the Palm Park is generally about 2000 ft thick, it thins markedly over topographic highs produced by Laramide deformation. Thus, in the Tonuco uplift, lower parts of the formation pinch out against Paleozoic strata adjacent to the Precambrian, and only a thinned upper part of the formation was deposited across the granite. Similar relations are observed elsewhere in the region where pre-Palm Park beds are exposed (Seager and others, 1975).

The most conspicuous part of the Palm Park Formation is the laharic breccia, thickest and best exposed in the fault-line escarpment of the West Selden Hills where several sheets and channelform lenses (each 50 to 100 ft thick) have weathered to impressive cliffs (fig. 5). Nonsorted, subangular boulders to 10 ft in diameter are embedded in a matrix of ash, crystals, pebbles, and cobbles. Equivalent facies exposed in the East Selden Hills and in areas to the west and south are finer grained laharic sheets and other epiclastic deposits. Although the source of lahars is unknown, thick andesite porphyry flows and plutons (?) exposed in the northern Doña Ana Mountains appear lithologically similar to many lahar clasts. These porphyrys may be the volcanic source of some laharic deposits. Dates of 51 m. y., 43 m. y. and 42 m. y. establish the Palm Park Formation as Eocene.

The Palm Park Formation formed the floor of the Goodsight-Cedar Hills depression west of the San Diego Mountain quadrangle, and constituted most of the eastern raised rim of the depression east of the Oligocene Cedar Hills vent zone (fig. 6). The East and West Selden Hills and the Selden Canyon area, formed largely of Palm Park beds, are block-faulted remnants of that rim.

Rock units of the Bell Top Formation are best developed west of the map area in the Cedar Hills and Sierra de las Uvas (Clemons and Seager, 1973; Seager and others, 1975). In this area, ash-flow tuff sheets and sedimentary units of the Bell Top were deposited in the Goodsight-Cedar Hills depression; flow-banded rhyolite domes (Tbfr) were intruded along the Oligocene Cedar Hills vent zone at the eastern margin (Seager, 1973). Potassium-Argon dates indicate this activity took place between 39 and 26 m.y. ago. East of the vent zone, over most of the San Diego Mountain quadrangle, the structurally high eastern raised rim of the depression precluded deposition of most Bell Top units. However, thin air-fall deposits and a stray ash-flow tuff (ash-flow tuff 3, Tbt_3) and rhyolite flow, which may have crossed the rim in low areas, are preserved as small remnants in a few places adjacent to the Rio Grande. At San Diego Mountain, about 700 ft of rhyolite pebble breccia in thin graded sheets was derived from erosion of rhyolite domes and forms part of the Bell Top. These breccias appear to be the distal ends of thin mudflows that crossed or were inset against the raised rim of the depression. Finally, small plugs, dikes, and sills of rhyolite porphyry (Tbrp) identical to those in the Robledo Mountains dated 35 m.y. by Kottlowski and others (1969), occur as scattered patches in the East Selden Hills and Radium Springs area.

Overlying Bell Top rock units in the Goodsight-Cedar Hills depression is the Uvas Basaltic Andesite – basaltic andesite flows and associated pyroclastic material up to 800 ft thick. A K-Ar date of 26 m.y. from a flow in the Sierra de las Uvas indicates an Oligocene-Miocene age (F. E. Kottlowski, letter, 1970). Like the Bell Top units, Uvas Basaltic Andesite is missing from the eastern raised rim of the depression. The outcrops of Uvas shown on the geologic map southwest of the Rio Grande are remnants of flows that crossed the Oligocene Cedar Hills vent zone in low areas between domes; and they are interpreted to have been deposited against fault-line scarps in the eastern rim. Small basaltic dikes in the Tonuco uplift may be Uvas or younger.

A thick, semiconcordant monzonite porphyry sill that intruded Hueco Limestone crops out in the northern Doña Ana Mountains. The sill forms the high peaks of Summerford Mountain and is associated with epidotization, marblization and hornfels in the Hueco. The tan- to gray-weathering porphyry consists primarily of orthoclase and plagioclase, with minor amounts of biotite and hornblende. The mafics are generally altered to epidote or limonite. Numerous tan rhyolite-trachyte dikes (Ti) cut the monzonite porphyry south of Summerford Mountain. A K-Ar date of 33 m.y. indicates the sill is the same age as part of the Bell Top Formation (F. E. Kottlowski, letter, 1972).

Bolson Deposits (Miocene)

Bolson deposits that accumulated in late Tertiary grabens of the Rio Grande rift are included in the lower Santa Fe Group (Kottlowski, 1953; Hawley and others, 1971). Three formations are recognized (older to younger): 1) unnamed transitional unit, 2) Hayner Ranch Formation, 3) Rincon Valley Formation. The first two comprise much of the fill of an early Santa Fe basin roughly located in the Rincon-Tonuco uplift area (fig. 2). The Rincon Valley Formation, thickest in the same basin, is more widespread, overlapping older bedrock to the north, west, and south (fig. 6).

The unnamed transitional unit (Tbtt, unit referred to as Tst in New Mexico Bureau of Mines & Mineral Resources, Bulletin 101) was originally excluded from the Santa Fe Group by Seager and others (1971), but later included (Seager and Hawley, 1973). In the Tonuco uplift, faulting obscures relationships between the transitional unit and underlying Bell Top breccias, but in the Rincon Hills the transitional strata gradationally overlie the Thurman Formation. Along the southern side of the Tonuco uplift the unit comprises 2 members: a lower, red micaceous siltstone, mudstone and sandstone member about 950 ft thick; and an upper purplish-brown sandstone, conglomerate, and conglomeratic sandstone about 700 ft thick (fig. 7). The strata appear to be piedmont-slope and basin-floor sediments that accumulated during the early stages of late Tertiary rifting in south-central New Mexico. The unit is probably early Miocene (Seager and Hawley, 1973).

Hayner Ranch Formation (fig. 8), about 1900 ft of brick-red sandstone, conglomeratic sandstone and conglomerate, lies conformably above the transitional unit in the Tonuco uplift. The formation was subdivided informally into 5 members (A,B,C,D,E) by Seager and others (1971). Inasmuch as more recent mapping has shown that the upper member (unit E) is a conglomeratic facies of the overlying Rincon Valley Formation, the unit has been removed from the Hayner Ranch in this report. Hayner Ranch strata, like the transitional beds beneath, are intertonguing piedmont-slope and basin-floor deposits that accumulated in a local, rapidly subsiding basin during early stages of rifting. The formation is Miocene in age.

In areas adjacent to the Tonuco uplift, the Rincon Valley Formation conformably overlies the Hayner Ranch Formation. Rincon Valley Formation comprises about 1350 ft of strata subdivided into: 1) an older, brown conglomeratic sandstone (piedmont-slope facies, Trvc) about 830 ft thick, and 2) a younger, pale-red gypsiferous shale and siltstone (basin-floor facies, Trv), about 520 ft thick. The upper gypsiferous facies appear to be playa to broad alluvial flat sediments that culminated to the filling of the basin containing the thick older Santa Fe rocks (fig. 9). To the south and west, however, the basin-floor facies is transformed by facies change into piedmont-slope conglomerates indistinguishable from the older Rincon Valley conglomerate facies. This undifferentiated piedmont-slope sequence (Trvc) is widespread, becoming coarser grained toward the Cedar Hills, and generally thinned to the south and east. Trvc overlaps the Hayner Ranch and transitional beds in the northern part of the West Selden Hills, and in the Selden Canyon area overlies several older Tertiary formations with angular unconformity. In general, the Rincon Valley overlies Palm Park strata on the eastern raised rim of Goodsight-Cedar Hills depression, but is above Uvas Basaltic Andesite or Bell Top flow-banded rhyolite from the Oligocene Cedar Hills vent zone westward (fig. 6).

One, and locally, two olivine basalt flows named Selden Basalt (Kottlowski, 1953), are interbedded in the Rincon Valley Formation in the Selden Canyon area. These have been dated by the K-Ar method at 9 m.y. (Gile and others, 1970). Using Newman's (1970) estimate of the Miocene-Pliocene boundary, the Rincon Valley Formation is probably entirely late Miocene in age, although the upper part of the formation may range through early Pliocene.

Pleistocene and Holocene Deposits

The youngest formation of the Santa Fe Group is the Camp Rice Formation of early to middle Pleistocene age. The formation marks the culmination of basin aggradation in south-central New Mexico prior to entrenchment of the present valley system. The base of the formation is marked by a widespread angular unconformity resulting in Camp Rice beds overlying rocks ranging in age from Precambrian to Miocene.

Two major facies of the Camp Rice Formation are recognized: 1) a basin-floor facies, which, although primarily composed of fluvial deposits of an ancestral Rio Grande system (Qcrf), includes laterally equivalent fine-grained alluvial flat and playa (?) sediments and minor piedmont toe-slope deposits (Qcrj); and 2) a piedmont-slope facies, chiefly consisting of alluvial fan gravel derived from local uplifts (Qcrc, Qcrp), but including fine-grained loamy sediments with multiple paleosols in a toe-slope position transitional to the basin-floor facies. These facies are summarized in fig. 10.

Most of the San Diego Mountain quadrangle lies in the central Jornada del Muerto Basin, and relatively distant from the major uplifts of the region. Hence the Camp Rice is represented in the quadrangle primarily by basin-floor facies. A thin, discontinuous basal fanglomerate (Qcrc) occurs locally. Above this is about 300 ft of fluvial sand, gravelly sand, sandstone, and conglomeratic sandstone containing the remains of Pleistocene horses, mastodons, and mammoths (Qcrf). Notable quantities of rounded pebbles of resistant rock types derived upstream from Hatch, and the distribution of the formation in and adjacent to the Rio Grande valley, suggest that the facies are deposits of an ancestral Rio Grande. The ancient river flowed southward as a widely shifting system through the San Diego Mountain quadrangle and adjacent areas to Lake Cabezra de Vaca in northern Chihuahua and western Trans Pecos Texas (Strain, 1966; Hawley, 1965; Reeves, 1969). Above the fluvial facies are up to 100 ft of brown loamy sediments containing multiple paleosols (Qcrp). These loamy sediments are associated with the Jornada I piedmont surface of middle Pleistocene age, which is graded to the La Mesa surface developed on Qcrf sediments in the central Jornada del Muerto basin (Ruhe, 1967; Gile and others, 1970; Hawley and Kottlowski, 1969). Toward the Doña Ana Mountains and other major uplifts of the region, the loamy (Qcrp) facies changes to partly indurated, gravelly piedmont-slope alluvium (also Qcrp) beneath the Jornada I surface (fig. 10).

Middle Pleistocene to Holocene deposits include: 1) valley alluvium associated with entrenchment of the present Rio Grande and its tributary arroyos; 2) piedmont-slope and basin-floor alluvium in areas not yet affected by Rio Grande drainage; and 3) wind-blown sand and loam.

The present Rio Grande valley and arroyo system is entrenched about 350 ft below the Jornada I or La Mesa surface. A stepped sequence of graded valley-border surfaces of both constructional and erosional origin is generally present in the San Diego Mountain quadrangle between the La Mesa surface and the river flood plain (figs. 11 and 12). These surfaces indicate that evolution of the Rio Grande valley was characterized by several episodes of major valley cutting, each followed by intervals of partial backfilling, perhaps corresponding to glacial and interglacial conditions in headwater regions farther north. Deposits associated with these surfaces are mapped in 2 groups: older and younger valley alluvium. Older valley alluvium comprises piedmont-slope gravels (Qvo), and fluvial facies (Qvof) associated with the Tortugas and Picacho geomorphic surfaces of middle to late Pleistocene age (Hawley, 1965; Ruhe, 1967; Hawley and Kottlowski, 1969). Younger valley alluvium is associated with surfaces graded to, or within a few feet of, the present river flood plain and ranges from late Pleistocene to Historic. Piedmont-slope facies, including arroyo, fan, and terrace alluvium are mapped as Qyv. Fluvial deposits beneath or adjacent to the present flood plain are designated Qyvf. Minor travertine deposits (Qt) and extensive wind-blown sand (Qs) are associated with the older and younger valley fill, respectively. Colluvium-alluvium of widely differing ages, mostly on valley sideslopes, are mapped as Qca. These map units are areas of time cementation in older alluvium. Thicknesses of units are generally 2 to 50 ft, and probably do not exceed 100 ft.

Landscape evolution along the northern and eastern sides of the Doña Ana Mountains was unaffected by the development of entrenched Rio Grande drainage. In these areas, late Quaternary piedmont-slope and basin-floor deposits overlap upper Camp Rice beds and older rock units. Older piedmont-slope deposits (Qpo) appear to correlate with the Jornada II morphostratigraphic unit of middle to late Pleistocene age (Gile and others, 1970). Younger piedmont-slope alluvium (Qpy) is predominantly Holocene (< 10,000 years), and correlated with the Organ and Isaack's Ranch morphostratigraphic units (Seager and Hawley, 1973). Playa lake deposits are mapped as Ql. Except for local accumulations of lime in older units, the alluvium is generally nonindurated, consisting of material eroded from the northern Doña Ana Mountains. Thickness of units is generally less than 10 ft. Much of the piedmont surface has a discontinuous cover of wind-blown sandy to loamy sediment, mapped as Qs.

STRUCTURE

Major tectonic features of the quadrangle outlined under Regional Tectonic Settings (shown in fig. 2) are: 1) Laramide structures of probably early Tertiary age; 2) Goodsight-Cedar Hills volcano-tectonic depression of Oligocene-Miocene age; and 3) late Tertiary-Holocene fault blocks.

Laramide structural features exposed in the late Tertiary Tonuco uplift were described by Seager and others (1971). Uplift along a north-trending axis in the Tonuco area prior to late Eocene time resulted in erosion of over 7000 ft of Paleozoic and Mesozoic strata. Precambrian rocks in the core of the structure were exposed. The fanglomeratic Love Ranch Formation, apparently comprising part of the erosional debris, was deposited across the core and limbs of the uplift. The uplift is inferred to be anticlinal, probably similar to the Laramide anticlines of the Rocky Mountains farther north. Remnants of a thrust, interpreted as a marginal thrust, and cascade folds are preserved along and within the eastern limb of the anticline in the Tonuco uplift. Eastward transport is indicated by both structures.

The eastern margin of the Goodsight-Cedar Hills volcano-tectonic depression is present in the San Diego Mountain quadrangle. The margin appears to be a 2- to 3-mile wide north-trending zone of block faulting and intrusive activity, roughly marked by the West Selden Hills fault and the flow-banded rhyolite intrusions of the Oligocene Cedar Hills vent zone (fig. 2). Judging from the remarkably dissimilar volcanic rocks on opposite sides of the West Selden Hills fault, movement along the fault may have contributed to elevation of the raised rim or subsidence of the depression in Oligocene time (fig. 6). The scarp apparently presented a barrier to movement of Bell Top ash flows and Uvas Basaltic Andesite lavas (fig. 6 and cross section *B–B'*). Several faults in the vicinity have small rhyolite intrusive masses along or adjacent to them. These and other faults may also have been active during the Oligocene. Late Tertiary movement along most of the faults is indicated by offset of the Rincon Valley Formation.

The late Tertiary fault pattern is shown on fig. 2 and the geologic map. Cross sections *A–A'* and *B–B'* illustrate the characteristic graben and horst structure. Cross sections of the Tonuco uplift are published (Seager and others, 1971). The major late Tertiary faults are the East and West Selden Hills faults, and the East and West Tonuco faults.

The former 2 faults border the East and West Selden Hills fault blocks, respectively. Maximum stratigraphic separation, measured on the base of the Rincon Valley Formation, is approximately 800 to 1000 ft for the western fault, and about 1500 ft for the eastern. The West Selden Hills fault passes into a west-dipping monocline just north of US-85 (NE¼NE¼ sec. 6, T.20 S., R.1 W.). Between the monocline and the East Selden Hills fault, broadly arched Palm Park beds, exposed along the Rio Grande southward, are broken into a series of small fault blocks and grabens, generally downdropped toward the crest of the arch (cross section *A–A'*).

The East and West Tonuco faults bound the Tonuco uplift, a cigar-shaped horst formed of lower to middle Tertiary, Paleozoic, and Precambrian rocks. Lower Santa Fe Group strata form downfaulted blocks along the southern and western margins of the horst. Along the south side, folded Santa Fe beds are above a low-angle fault crossing the steep West Tonuco fault. The low-angle fault is interpreted to be a slide fault, movement along which resulted in the displacement of the thick Santa Fe section from the horst onto the adjacent depressed block. Another low-angle fault, also interpreted to be a slide surface, occurs at the northwestern corner of the uplift. Steeply dipping to overturned Bell Top breccias overlie sheared Palm Park beds or Precambrian granite along a gently westward-dipping fault surface. Drag features exposed in a window indicate the Bell Top strata in the upper plate moved northwest, away from the axis of the horst. Gravity sliding and major displacement along the West Tonuco fault both involve the upper part of the Rincon Valley Formation, indicating that important uplift of the Tonuco horst and gravitation adjustments probably took place in middle to late Pliocene time.

Following this uplift and tectonic denudation of lower Santa Fe and older strata, Camp Rice fluvial sandstone and fanglomerate overlapped and buried much of the Tonuco uplift. Middle to late Pleistocene movement along the East Tonuco fault is indicated by about 100 ft of offset of the Camp Rice beds. Older periods of more substantial displacement along other faults of the region occurred at various times during the Miocene and Pliocene. Evidence of this displacement is: 1) major offset of older formations of the Santa Fe Group, and 2) coarse fanglomerate wedges and angular unconformities within the Santa Fe Group (Seager and others, 1971; Seager and Hawley, 1973).

ACKNOWLEDGEMENTS

The distribution and subdivision of Quaternary units on the Jornada del Muerto shown on the geologic map was provided by John W. Hawley and Leland H. Gile from their unpublished mapping within the Desert Soil-Geomorphology Project, sponsored and staffed by the Soil Survey Investigations, U. S. Soil Conservation Service. Relationships among Quaternary units shown in figs. 10 and 11 and depicted in the Rio Grande valley areas on the geologic map are based mostly on the models developed by R. V. Ruhe, A. L. Metcalf, F. E. Kottlowski, and J. W. Hawley. Acknowledgement is made to R. E. Clemons for this section examination of rocks in the San Diego Mountain area, and to F. E. Kottlowski for encouraging this study and making available K-Ar dates. The New Mexico Bureau of Mines & Mineral Resources provided financial support for the project. I am especially grateful to John Hawley for reviewing the map and text, and for many hours of discussion of Quaternary units and landscape evolution of the map area.

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Note: Figures 1, 3-6, 8, 10, 11 are to right.
Figures 2, 7, 9, 12 are on front side of map.

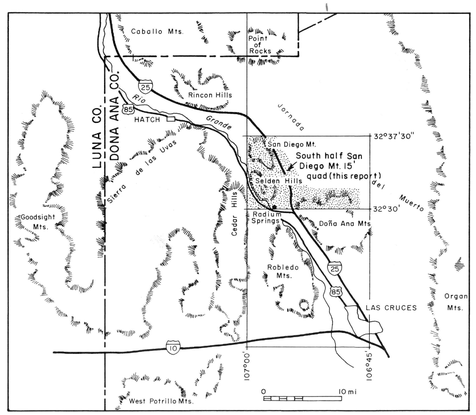


FIGURE 1—Location and index map.

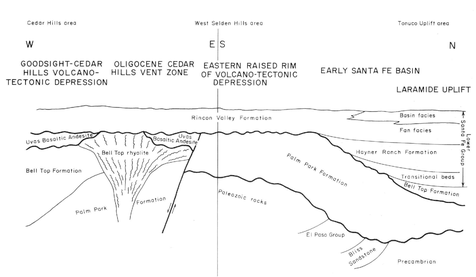


FIGURE 6—Diagrammatic section illustrating relations among paleotectonic elements and rock units.

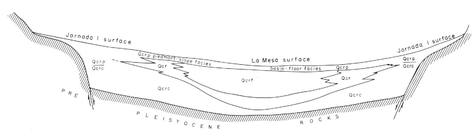


FIGURE 10—Diagrammatic section illustrating relations among facies of the Camp Rice Formation. Qcrp—piedmont-slope to basin-floor facies. Qcr—piedmont toe-slope to alluvial flat facies; Qcrf—fluvial facies (ancestral Rio Grande deposits); Qcrc—fanglomerate.

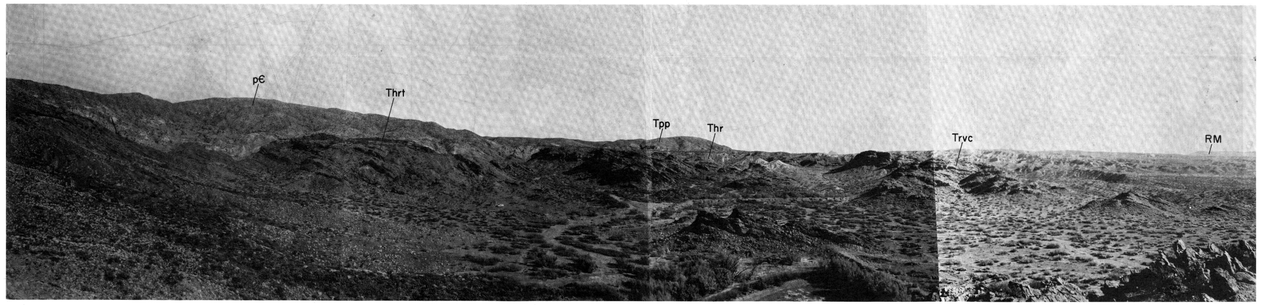


FIGURE 8—Panorama of southern edge of Tonuco Uplift showing part of the lower Santa Fe Group. Thrt—basal transitional beds of the Santa Fe; Thr—Hayner Ranch Formation; Trvc—conglomerate facies of Rincon Valley Formation; pЄ—Precambrian rocks; Tpp—Palm Park Formation; RM—Robledo Mountains. Topographic relief of hogbacks in middle distance is about 200 ft. View looks south on right, to east on left.

Photo by Charles B. Hunt

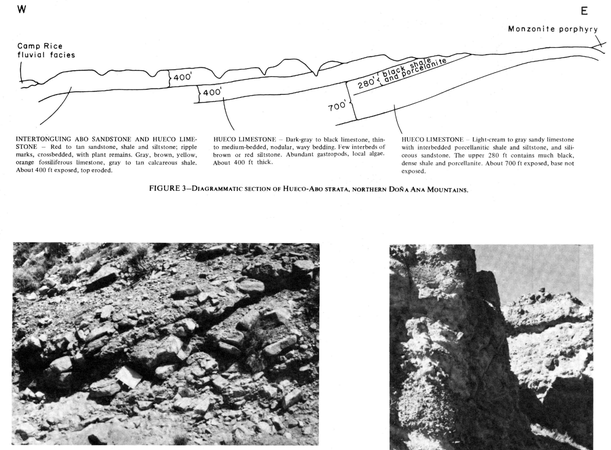
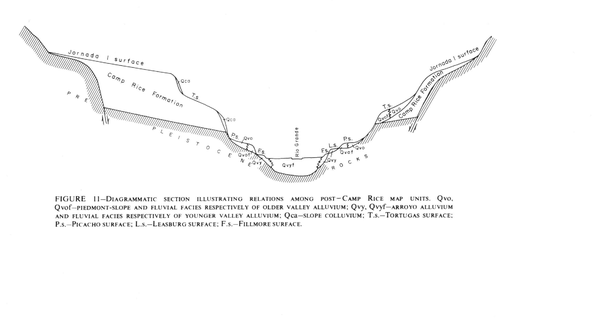


FIGURE 3—Diagrammatic section of Hueco-Abo strata, northern Doña Ana Mountains.

FIGURE 4—Love Ranch Formation on eastern side of Tonuco Uplift. Boulders are Sierrite Limestone slabs. Note mapboard for scale.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