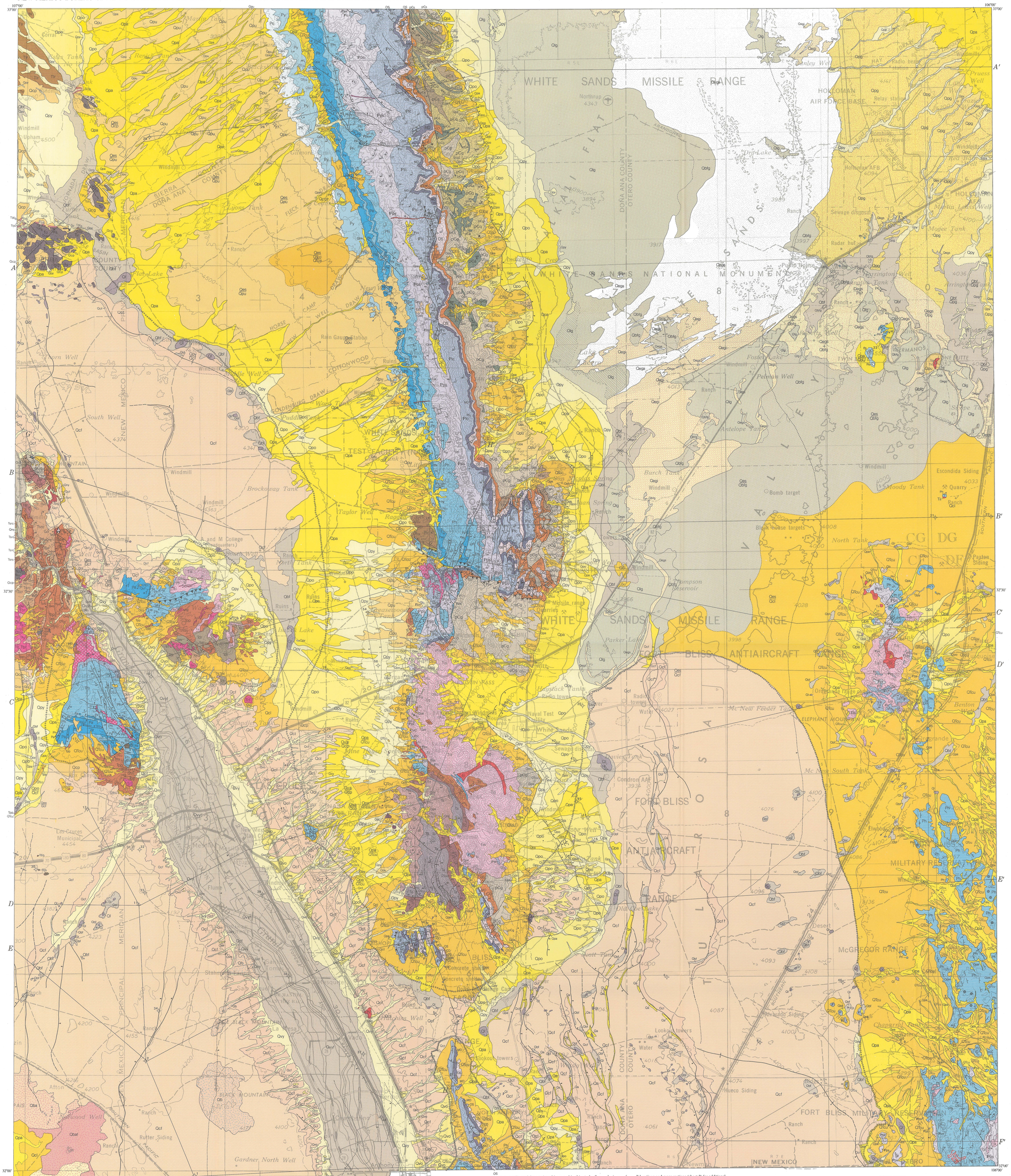


Base adapted from U.S. Geological Survey 1° x 2° Las Cruces 1:250,000 quadrangle, 1971 revision.

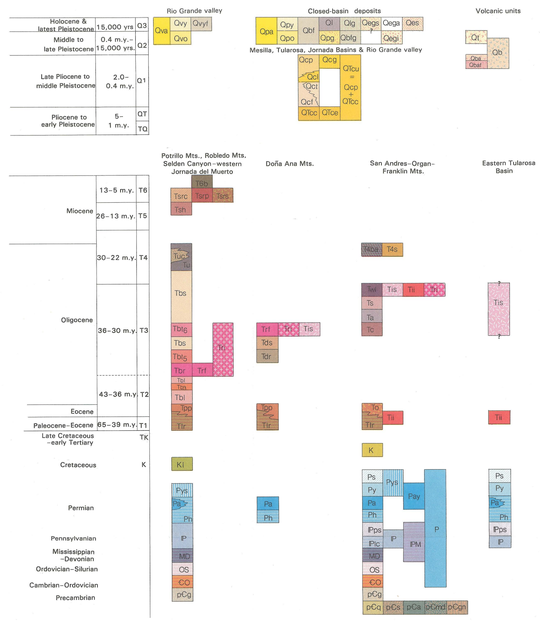
Geology of east half of Las Cruces and northeast El Paso 1° x 2° sheets (scale 1:125,000), New Mexico

by William R. Seager, John W. Hawley, Frank E. Kottlowski, and Shari A. Kelley

Scale 1:125,000

1987

CORRELATION OF ROCK UNITS



DESCRIPTION OF ROCK UNITS

DEPOSITS ASSOCIATED WITH LATEST ENTRENCHMENT AND BACKFILLING OF RIO GRANDE VALLEY—*Qvy and Qvyf (descriptions of individual units listed below)*

Qvy ARROYO CHANNEL, TERRACE, AND FAN DEPOSITS—*Mostly sand with pebble to boulder gravel zones and some loam to clay; noninduraded; up to 10 m thick*

Qvyf RIO GRANDE FLOODPLAIN AND CHANNEL DEPOSITS—*Mostly clay to sand with basal gravelly zones; noninduraded; up to 30 m thick (Cole and others, 1997)*

DEPOSITS ASSOCIATED WITH YOUNGER BASIN-FLOOR SURFACES AND PIEDMONT SLOPES GRADED TO THOSE SURFACES—*Qpy, Qbf, Ql, Qlg, Qes, Qegs, Qegi, Qeqi (descriptions of individual units listed below)*

Qpy YOUNGER PIEDMONT-SLOPE DEPOSITS—*Unconsolidated sand, gravel, and loamy sediments of disingressives that crisis and are least below or bury older piedmont slopes, and of fans constructed on distal piedmont slopes at lower end of such disingressives; up to 10 ft thick*

Qbf BASIN-FLOOR SEDIMENTS—*Mostly loam, silt, or clay, locally with thin gypsiferous beds; playas in eastern Tularosa Basin are commonly gypsiferous; up to 3 ft thick*

Ql DEPOSITS OF SMALL, NON-ALKALINE PLAYA LAKES AND DEPRESSIONS—*Mostly clay and silt; up to 15 ft thick*

Qlg GYPSIFEROUS LAKE DEPOSITS IN THE TULAROSA BASIN—*In chubbs large ancestral Lake Otero with highest shoreline near 3,960 ft and several younger, lower lake stands; mostly gypsiferous silt, sand, and lesser pebbly sand and green clay, and gypsiferous silt, locally covered by thin, loamy to silty, eolian deposits of alluvium; at least 35 ft thick*

Qegs EOLIAN DEPOSITS ASSOCIATED WITH TULAROSA BASIN LAKES—*Mostly inactive, ridge-like dunes of yellowish to tan, gypsiferous quartzose silt and fine quartzose sand with gypsic layers; located on the lee (east) side of lake (Qlg) beds; many have 1–2 ft of pedogenic gypsite (gypcrete) capping the deposits; up to 30 ft thick*

Qegi ACTIVE GYPSUM DUNES—*White dunes of pure gypsum sand located east of and derived from modern playa of ancestral Lake Lucero; up to 80 ft thick*

Qeqi INACTIVE GYPSUM DUNES—*Dunes of gypsite with well-developed gypcrete crusts; may be sandy or silty (quartz) locally, grading into Qegs; up to 30 ft thick*

Qes EOLIAN QUARTZOSE SAND—*Dunes and irregular hummocks of quartz sand, especially extensive on eastern piedmont slopes of San Andres Mountains; on the La Mesa surface southwest of Las Cruces; west of San Diego Mountain; and in Playas Valley; commonly the sand is derived largely from Camp Rice Formation (QTcf); up to 30 ft thick*

Qvo OLDER RIVER, ARROYO, AND FAN ALLUVIUM AND EROSION-SURFACE VENEERS—*Associated with graded surfaces formed during at least two major episodes of incision and partial backfilling of the Rio Grande and other major arroyos; commonly 2–3 terraces are present; deposits are calcareous and show accumulation in upper five feet; generally carbonate horizons are commonly indurated; river deposits of sand and rounded gravel interfingure with fan alluvium coming out in lefty and Mills adjacent to the Rio Grande; up to 100 ft thick*

Qpo OLDER PIEDMONT-SLOPE DEPOSITS—*Fan and terrace deposits and erosion-surface veneers on piedmont slopes graded to closed-basin floors and playas; deposits are calcareous and show accumulation in upper five feet; gravel, grading downslope to gravelly loam, with thin horizons (surficial and buried) of soft carbonate and clay accumulation; gravelly carbonate horizons are commonly indurated and form thin pedogenic calcretes; at least two generations of fans are present at most places along the San Andres–Organ–Franklin Mountains front; up to 30 ft thick*

UNDIFFERENTIATED *Qvy and Qvo*

Qya UNDIFFERENTIATED *Qpy and Qbf*

Qa UNDIFFERENTIATED ALLUVIUM AT BASE OF LOW FAULT AND EROSIONAL SCARPS ON FLOORS OF TULAROSA AND MESILLA BASINS—*Correlative with Qpy*

Qdg OLDER GYPSIFEROUS BASIN-FLOOR AND DISTAL PIEDMONT SLOPE DEPOSITS—*Primarily distal piedmont deposits in east-central Tularosa Basin; mostly gypsiferous red silty silt, tan, eolian gypsum sand, yellow, limonite quartzose sand, tan, clayey siltstone (playas), of moderately well indurated; and gypsic; unit is capped irreversibly by 1–2 ft of gypsite of Gile and Grossman (1979) on the Jornada del Muerto; but probable late Pleistocene, younger than 0.4 m.y.; up to 20 ft thick*

Qblg OLDER GYPSIFEROUS BASIN-FLOOR DEPOSITS AND LAKE BEDS—*Mostly red and green gypsiferous clay and silt interbedded with gypsic, upper 1–3 ft is gypsite of probable pedogenic origin; unit crops out as high as 5,300 ft and underlies much of the central Tularosa Basin floor of the Jornada Mountain; grades to Qlg; about 4,000 ft age of exposed beds is uncertain, but some may be as young as 0.4 m.y.; exposed thickness 0–4 m.*

Qt AIR-FALL TUFF AND BRECCIA—*Associated with Pleistocene Kilbourne Hole, Hunt House, and Crater Romero eruptions of crystal-rich, Quaternary-basaltic andesitic ranges with many lacrolian beds of coarse-grained lahartic breccia, all derived from volcanic rocks of intermediate composition; calcareous, lithic, and pumiceous lapilli are common in the eastern Jornada del Muerto; Pleistocene fragments also comprise a significant part of the deposit; large blocks of basalt or other lithic debris form occasional veg structures in the tuff; up to 100 ft thick*

Qb OLIVINE BASALT—*Mostly, if not entirely, alkali-olivine basalt; forms cinder cones and flow features; dates (K-Ar): 0.183 ±0.05 m.y.; 1.31±0.06 m.y.; 0.93±0.03 m.y.; 0.48±0.02 m.y.; 0.535±0.1 m.y.; 0.181±0.1 m.y.; 0.18±0.1 m.y.; 0.09±0.1 m.y.; 0.04±0.1 m.y.; 0.04±0.1 m.y.; 0.18±0.1 m.y.; 0.181±0.05 m.y.; 0.07±0.05 m.y. (Seager and others, 1984; Hoffer, 1976; 1977; Loeble and Smith, 1979)*

Qba ADEN BASALT—*Alkali-olivine basalt flows associated with Aden volcano (located 4 mi west of Afton, west of 106°W longitude); flows overlie La Mesa surface; radiometric date: 0.933±0.06 m.y. (Seager and others, 1984)*

Qbaf AFTON BASALT—*Alkali-olivine basalt flows and cones; overlie La Mesa surface and associated soil carbonate horizons in Qd or Qcf; radiometric dates: 0.83±0.08 m.y.; 0.74±0.35 m.y.; 0.183±0.084 m.y.; 0.5±0.1 m.y. (Seager and others, 1984; Hoffer, 1976; Hawley and Kottlowski, 1969)*

UNDIFFERENTIATED *Qpu and Qbo*

Qfcu CAMP RICE FORMATION, *Qcp and* QTcc, UNDIVIDED

Qcf CAMP RICE FORMATION, SEDIMENTS ASSOCIATED WITH LA MESA SURFACE—*Basin-floor sediments, the contractional top of which is the La Mesa surface (known on geologic map with horizontal lines); sand dunes (Qes) covering Qcf were mapped locally; ash lenses near the base of the unit are approximately 2.0 m.y. old (Olinek, 1985); near the top, approximately 0.8 m.y. old (Seager and others, 1984); radiometric dates are 0.8 ±0.1 m.y. in south-central New Mexico (Seager and Mickelson, 1978); interpreted to be 700 ft thick in subsurface of east-central Mesilla Basin (Wilson and others, 1981)*

Qct CAMP RICE FORMATION, TRANSITIONAL FACIES—*Light-gray, tan, and brown sandstone, mudstone, and conglomerate mudstone that represent distal piedmont slopes, alluvial fans, and eolian environments transitional between fluvial plains (Qcf) and piedmont slopes (QTcc, Qcp, or QTcu)*

Qcg CAMP RICE FORMATION, GYPSUM—*Yellow to gray gypsite capped by 1–2 ft of pedogenic gypsite (gypcrete); gypsite occurs in irregular patches in basin-floor areas in the Jornada Del Muerto of Rio Grande rift; the gypsum is exposed on slopes and in carcons of bedrock tilts east of Chicken Well where the gypsum apparently partly buried fault-rolls, extending up carncons as much as 200 ft higher than the general level of Camp Rice piedmont slopes; up to 25 ft thick*

Qfce CAMP RICE FORMATION, EOLIAN SAND—*Mostly light-gray, friable, quartz sand and silt, moderately to weakly calcareous; thin tongues of gravelly piedmont alluvium; probably intertongues with* QTcc; *occurs only in small areas along the western margin of the San Andres Mountains; at least 100 ft thick*

Qfcc CAMP RICE FORMATION, FANGLOMERATE FACIES—*Calcite-cemented, reddish-brown to tan fanglomerate and conglomerate underlying* Qcp, Qct, *or* Qcf; *locally intertongues with* Qcf; *locally contains basalt flows dated 2.1–1.0 m.y. (Seager and others, 1984); as thick as 500 ft where the formation filled late Pliocene valleys cut into uplifts, probably much thicker in subsurface below range-bounded faults*

Qbs BASALT FLOWS AND PLUGS—*Black to gray, alkali-olivine basalt in small plugs and flows; flows have vesicular tops and bottoms; commonly have basal gravelly accumulations; 1.07±0.05 m.y. (Seager and others, 1984)*

SANTA FE GROUP—Tsrs, Tsrc, Tsrp, Tsh *(descriptions of individual units listed below)*

Tsrs SELDEN BASALT—*Black to dark-gray, alkali-olivine basalt; carving phenocrysts of olivine and plagioclase; flows, plugs, and cinder cones in Selden Canyon, each less than 30 ft thick; flows are interbedded in Rincon Valley Formation; radiometric dates: 9.3 m.y.; 8.6±0.3 m.y. (Gile and others, 1978; Seager and others, 1984)*

Tsrc RINCON VALLEY FORMATION, CONGLOMERATIC FACIES—*Red-brown, poorly sorted, calcareous, lithic conglomerate, sandstone, and siltstone; distal mudstone that conformably overlies Hayner Ranch Formation in early rift basins but elsewhere overlies older Tertiary rock units unconformably; formation is broken into several small fault blocks in the Selden Canyon area but once formed a huge eastward-tapering fan derived from the Cedar Hills and Sierra de Las Uvas; as much as 1,000 ft thick in the Cedar Hills (Seager and others, 1975; Seager and others, 1984) and as much as 1,500 ft in the Hueco Mountains; to 1,000 ft or more thick (Seager, 1975)*

Tsrp RINCON VALLEY FORMATION, PLAYA FACIES—*Pale-red siltstone, claystone, and mudstone of playa facies, that accumulated on alluvial fans and playas near the center of early rift basins; grades laterally to* Tsrc; *up to 2,000 ft thick (Seager and others, 1984)*

Tsh HAYNER RANCH FORMATION—*Brown, purplish-brown, and red fanglomerate, conglomerate, sandstone, siltstone, and pink to lightgray mudstone with thin, fresh-water limestone tongues; mostly derived from local volcanic rocks; locally silicified, with veins of barite, fluorite, and galena; as much as 1,000 ft thick in early rift basins (Seager and others, 1975; Seager, 1979)*

Tuc UVAS BASALTIC ANDESITE, COYOTE CANYON MEMBER—*At San Diego Mountain, the unit consists of numerous charred shaped, gnarled beds up to 3 ft thick separated by red siltstone beds up to 10 ft thick; at other localities also crops each gnarled breccia bed; elsewhere in the region, the unit is predominantly brown fanglomerate and conglomeratic sandstone derived from flow-banded rhyolite domes in the Cedar Hills vent zone; approximately 700 ft thick at San Diego Mountain (Seager, 1979)*

Tlb UVAS BASALTIC ANDESITE—*Thin, black to medium-gray, vesicular basalto-andesite flows in Selden Canyon; a few hundred ft thick; radiometric ages: 35.8±1.8 m.y., 28.1±1.4 m.y., 27.4±1.2 m.y. (Clemons and Seager, 1973; Clemons, 1979a)*

Tlbx INTERMEDIATE-COMPOSITION PLUTONIC ROCKS—*Map unit includes two distinct groups of rocks: 1) dark-gray to greenish-gray, slightly porphyritic, alkalic diorite and monzodiorite; K-Ar dates from Cox Canyon stated at 31.6±1.4 m.y. (Seager and Clemons, 1975); and 2) a group of gray, reddish-gray, and reddish-brown, vesicular basalt flows, at least 500 ft thick, forming Black Mountain in the southeast foothills of Organ Mountains; rocks with approximately 50% SiO_2 and 8–10% K_2O in the Organ Mountains are commonly trachytic in texture, but the high potassium content is a result of alteration in unknown; the flows unconformably overlie middle Tertiary tuffs and are brecciated with Santa Fe-type fanglomerate (Tfrb)*

Tfrb FANGLOMERATE—*Reddish-brown, boulder to cobble fanglomerate interbedded with and underlying* Tlbx *in the southeast Organ Mountains; well-cemented, volcanic clasts; at least 100 ft thick (Seager, 1981)*

Tis SILICIC PLUTONIC ROCKS (OLIGOCENE AND EOCENE)—*Quartz-monzonite porphyry, granite, quartz syenite, and granite of the Organ batholith; monzonite-porphyry dikes, small stocks, and a laccolith of the Doña Ana Mountains; granite porphyry dikes in the Franklin Mountains; rhyolite porphyry dikes, aplitic dikes and associated stocks (?) or laccoliths (?) in the Hueco Mountains; the Organ and Doña Ana intrusives (32.8 m.y. and 35.7 m.y., respectively; Seager, 1981; Loring and Loring, 1980; Seager and others, 1978) are associated with thick caldera-fill, ash-flow tuffs; the Organ intrusives also are related to a caldera, but no caldera-fill rocks are known; the Franklin Mountains (Sawtooth or Organ Mountains of Lindgren, 1905) are related to intermediate in the Dragoncito district*

Tfrt FLOW-BANDED RHYOLITE—*Pink to tan, crystal poor, flow-banded, calc-alkaline rhyolite domes and flows of the Cedar Hills vent zone; rhyolites intrude the tuffs of the Bell Top and are unconformably overlain by younger Bell Top tuffs (Tbs)*

Tbl LOWER AIR-FALL AND EPICLASTIC BEDS, AND BASAL BASALTIC FLOWS—*Ascending order includes: 1) basalt; flows as much as 150 ft thick; 2) rhyolitic air-fall tuffs and brecciaic and volcaniclastic mudstone and sandstone; as much as 1,000 ft thick in the Cedar Hills vent zone; 3) rhyolitic air-fall tuff, breccia, and epiclastics; to 3 mi beds related to Cedar Hills vent; as much as 800 ft thick in adjacent vents; 4) rhyolitic ash-flow tuff; up to 1,200 ft and underlies much of the central Tularosa Basin floor of the Jornada Mountain; grades to* Qbg *above 4,000 ft; age of exposed beds is uncertain, but some may be as young as 0.4 m.y.; exposed thickness 0–4 m.*

Tbs PALM PARK FORMATION—*Mostly purple, red, and gray, fine- to medium-grained epiclastic zones with many lacrolian beds of coarse-grained lahartic breccia, all derived from volcanic rocks of intermediate composition; calcareous, lithic, and pumiceous lapilli are common in the eastern Jornada del Muerto; Pleistocene fragments also comprise a significant part of the deposit; large blocks of basalt or other lithic debris form occasional veg structures in the tuff; up to 100 ft thick*

Tbs OLIVINE BASALT—*Mostly, if not entirely, alkali-olivine basalt; forms cinder cones and flow features; radiometric dates (K-Ar): 0.183±0.05 m.y.; 1.31±0.06 m.y.; 0.93±0.03 m.y.; 0.48±0.02 m.y.; 0.535±0.1 m.y.; 0.181±0.1 m.y.; 0.18±0.1 m.y.; 0.09±0.1 m.y.; 0.04±0.1 m.y.; 0.04±0.1 m.y.; 0.18±0.1 m.y.; 0.181±0.05 m.y.; 0.07±0.05 m.y. (Seager and others, 1984; Hoffer, 1976; 1977; Loeble and Smith, 1979)*

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Tbs UVAS BASALTIC ANDESITE—*Thin, black to medium-gray, vesicular basalto-andesite flows in Selden Canyon; a few hundred ft thick; radiometric ages: 35.8±1.8 m.y., 28.1±1.4 m.y., 27.4±1.2 m.y. (Clemons and Seager, 1973; Clemons, 1979a)*

Tbs INTERMEDIATE-COMPOSITION INTRUSIVES AND FLOWS—*Map unit includes two distinct groups of rocks: 1) dark-gray to greenish-gray, slightly porphyritic, alkalic diorite and monzodiorite; K-Ar dates from Cox Canyon stated at 31.6±1.4 m.y. (Seager and Clemons, 1975); and 2) a group of gray, reddish-gray, and reddish-brown, vesicular basalt flows, at least 500 ft thick, forming Black Mountain in the southeast foothills of Organ Mountains; rocks with approximately 50% SiO_2 and 8–10% K_2O in the Organ Mountains are commonly trachytic in texture, but the high potassium content is a result of alteration is unknown; the flows unconformably overlie middle Tertiary tuffs and are brecciated with Santa Fe-type fanglomerate (Tfrb)*

Tis SILICIC PLUTONIC ROCKS (OLIGOCENE AND EOCENE)—*Quartz-monzonite porphyry, granite, quartz syenite, and granite of the Organ batholith; monzonite-porphyry dikes, small stocks, and a laccolith of the Doña Ana Mountains; granite porphyry dikes in the Franklin Mountains; rhyolite porphyry dikes, aplitic dikes and associated stocks (?) or laccoliths (?) in the Hueco Mountains; the Organ and Doña Ana intrusives (32.8 m.y. and 35.7 m.y., respectively; Seager, 1981; Loring and Loring, 1980; Seager and others, 1978) are associated with thick caldera-fill, ash-flow tuffs; the Organ intrusives also are related to a caldera, but no caldera-fill rocks are known; the Franklin Mountains (Sawtooth or Organ Mountains of Lindgren, 1905) are related to intermediate in the Dragoncito district*

Tis INTERMEDIATE-COMPOSITION PLUTONIC ROCKS (OLIGOCENE AND EOCENE)—*Medium- to dark-gray, equigranular monzodiorite stock in the Cedar Hills; K-Ar dates from Cox Canyon stated at 31.6±1.4 m.y. (Seager and Clemons, 1975); and 27.4±1.2 m.y. (Seager and others, 1975) and andesite porphyry to diorite of Cristo Rey plateau and Vado Hills (47.1±2.2 m.y. by analogy with Carrizo Andesite; Hoffer, 1976)*

Tbs NON-FOLIATED RHYOLITE INTRUSIVES—*Nonporphyritic to slightly porphyritic, alkaloxic dikes, sills, and small plugs in the Robledo Mountains; Selden Canyon area and northwest Organ Mountains and dendritical, yellow-brown, vesicle intrusive rhyolite and breccia in the western Doña Ana Mountains; 36 m.y. (Seager and Clemons, 1975)*

VOLCANIC ROCKS OF DOÑA ANA CAULDRON—Tvt, Tds, Tdr *(descriptions of individual units listed below)*

Tvt FLOW-BANDED RHYOLITE—*Pink, gray, cream, platy to massive, flow-banded rhyolite dikes and rocks of rhyolite domes in the Doña Ana Mountains and of Picacho Mountain*

Tds YOUNGER FILL OF DOÑA ANA CAULDRON—*Light-colored, tuffaceous, rhyolitic sandstone, mudstone, and pebble conglomerate, as well as air-fall tuff and breccia; the rhyolitic rocks are mostly epiclastic rocks, collectively as much as 1,400 ft (Seager and others, 1984); vitreic masses of intrusive rhyolite and breccia (Tvt) are locally included in Tds*

Tdr DOÑA ANA RHYOLITE—*Cauldron-facies ash-flow tuff in Doña Ana cauldron; reddish-brown, brown, or medium-gray; the tuff is a compacted welding unit, crystal poor at the base becoming crystal rich at the top and is moderately to densely welded, pumiceous, and, locally, lithic rich; approximately 500 ft of epiclastic and air-fall tuff, sandstone, and breccia occur at the base; as much as 2,000 ft thick (Seager and others, 1975; Seager, 1979)*

VOLCANIC ROCKS OF ORGAN CAULDRON—Twt, Tts, Tx *(descriptions of individual units listed below)*

Twt WEST-SIDE LAVAS—*Approximately 1,000 ft (Seager, 1981) of porphyritic dacite, rhyolite, and rhyolite flows overlying Soledad Rhyolite along the western slopes of the Organ Mountains; generally dark brown to medium gray with a few interbeds of conglomeratic sandstone; 33.7±0.7 m.y. (Seager, 1981)*

SOLEDAD RHYOLITE—Tts, Tx *(descriptions of individual units listed below)*

Tts TUFF OF SQUAW MOUNTAIN—*Dark reddish-brown to medium-gray, densely welded, pumiceous ash-flow tuff as much as 1,100 ft thick in the Organ caulderon (Seager, 1981); compound cooling unit; compositionally zoned from aphyric rhyolite (72% SiO_2) at the base to sanidine-rich quartz latite (68% SiO_2) at the top*

Tx TUFF OF ACHENBACK PARK—*Dark-gray to dark reddish-brown, densely welded, pumiceous ash-flow tuff as much as 2,100 ft thick in the Organ caulderon (Seager, 1981); compound cooling unit; compositionally zoned from aphyric rhyolite (76% SiO_2) at the base to sanidine-rich rhyolite (70% SiO_2) at the top*

Tx TUFF OF COX RANCH AND CUEVA TUFF—*Tuff of Cox Ranch is dense, dark-gray, densely welded, crystal poor, quartz latitic ash-flow tuff; compositionally zoned from approximately 70% to rhyolite at 2,300 ft in the Organ caulderon; one (locally two) single cooling units; tuff of Cox Ranch gradationally overlies Cueva Tuff, which is a sequence of light-colored (yellow, pink, gray) rhyolitic ash-flow tuffs, most of which are aphyric, lithic rich, and high in silica (78%); the Cueva Tuff is composed of several (at least three in the Organ caulderon) cooling units are present; two crystal-rich, sanidine-cooling units near center of sequence may be stray tuff sheets unrelated to the Organ caulderon, but most of the sequence, as thick as 1,500 ft, represents surface-erupted ash-flow tuffs associated with the Organ caulderon; 32.0±1.4 m.y. (Seager, 1981)*

BELL TOP FORMATION—Tbs, Tbg, Tbb, Tbt, Tbl, Tbi, Tb_p *(descriptions of individual units listed below)*

Tbs SEDIMENTARY ROCKS AND TUFF—*White, tan, and gray tuffaceous sandstone, mudstone, and conglomeratic sandstone interbedded between* Tb_p *and* Tb_g *and between* Tb_g *and* Tb_t; *as much as 1,000 ft thick in Palm of Rocks hills*

Tbg ASH-FLOW TUFF B—*Densely welded, grayish-red, crystal-rich, ash-flow tuff; simple cooling unit; less than 50 ft thick in Palm of Rocks Hills; 36.5±1.4 m.y. (Clemons, 1979b)*

Tbb ASH-FLOW TUFF B—*Porous to densely welded, grayish-pink, crystal-rich, ash-flow tuff with abundant white pumice fragments; simple cooling unit; less than 50 ft thick in Palm of Rocks Hills; 36.1±1.3 m.y. (Clemons, 1979b)*

Tbr FLOW-BANDED RHYOLITE—*Pink to tan, crystal poor, flow-banded, calc-alkaline rhyolite domes and flows of the Cedar Hills vent zone; rhyolites intrude the tuffs of the Bell Top and are unconformably overlain by younger Bell Top tuffs (Tbs)*

Tbl LOWER AIR-FALL AND EPICLASTIC BEDS, AND BASAL BASALTIC FLOWS—*Ascending order includes: 1) basalt; flows as much as 150 ft thick; 2) rhyolitic air-fall tuffs and breccia and volcaniclastic mudstone and sandstone; as much as 1,000 ft thick in the Cedar Hills vent zone; 3) rhyolitic air-fall tuff, breccia, and epiclastics; to 3 mi beds related to Cedar Hills vent; as much as 800 ft thick in adjacent vents; 4) rhyolitic ash-flow tuff; up to 1,200 ft and underlies much of the central Tularosa Basin floor of the Jornada Mountain; grades to* Qbg *above 4,000 ft; age of exposed beds is uncertain, but some may be as young as 0.4 m.y.; exposed thickness 0–4 m.*

Tbi TUFF 3—*Pink, tan, orange, gray, cream, or brown; ash-flow tuff; simple cooling unit; underlies to pass, but may be as much as 300 ft thick (Seager and Clemons, 1975); 20.2±1.2, 20.4±1.3, 21.0±1.0 m.y. (Clemons, 1979b)*

Tb_p PALM PARK FORMATION—*Mostly purple, red, and gray, fine- to medium-grained epiclastic zones with many lacrolian beds of coarse-grained lahartic breccia, all derived from volcanic rocks of intermediate composition; calcareous, lithic, and pumiceous lapilli are common in the eastern Jornada del Muerto; Pleistocene fragments also comprise a significant part of the deposit; large blocks of basalt or other lithic debris form occasional veg structures in the tuff; up to 100 ft thick*

OREJON ANDESITE—*Intermediate-composition, porphyritic flows, lahartic breccia, and other volcaniclastic rocks in the Organ Mountains; generally dark gray, greenish gray, or purple gray; compositions seldom distinctive; approximately 2,000 ft thick (Seager, 1981); correlative with Palm Park Formation*

LOVE RANCH FORMATION—*Pebble to boulder conglomerate, red mudstone, and sandstone derived from Paleozoic rocks and Sierra(?) Precambrian; as much as 1,000 ft thick in the Organ Mountains; generally coarse, poorly sorted, and poorly bedded; commonly contains a few thin, lenticular, pink, fine-grained sandstone; approximately 200 ft thick in the Dona Ana Mountains; 1,000 ft in the Doña Ana Mountains; 1,000 ft in the Organ Mountains; 1,000 ft in the Hueco Mountains; 1,000 ft in the Sierra Cristo Rey; and 1,000 ft in the Franklin Mountains (Seager and others, in preparation); S Cobalders Formation—Brown-weathering, dolomitic siltstone and nodular, gray, fossiliferous, shaly limestone; 6.80 ft thick in Organ-southern San Andres Mountains (Seager, 1981); Devonian rocks—U Percha Shale—Black, gray, and purplish-gray, fissile shale with yellow-weathering, fine-grained, medium-bedded limestone locally at base, and thin, nodular limestone and siltstone interbedded throughout; Percha Shale is as much as 100 ft thick in the Franklin Mountains (Seager and others, 1986); 5–140 ft thick (Kottlowski and others, 1956; Bachman and Myers, 1969; Seager, 1981); D Canutillo Formation—Fossiliferous siltstone and cherty black limestone; present only at Bishop Cap and northern Franklin Mountains; 44–97 ft thick (Harbour, 1972; Seager, 1981)*

OS MONTOYA GROUP AND FUSSELMAN DOLOMITE—*Fusselman Dolomite (Silurian)—Massive, dark-gray, cherty dolomite in northern part of range; in southern part of range, the Fusselman is a light-gray, medium-bedded unit thins regularly northward because of post-Fusselman erosion; Fusselman is 948 ft thick in northern Franklin Mountains (Harbour, 1972); 210 ft thick at Bishop Cap (Seager, 1981); 110 ft thick in southern San Andres Mountains (Seager, 1981); 81 ft thick at Hondoño Canyon (Kottlowski and others, 1956); Montoya Group (Ordovician)—Upper part is light-gray, medium-bedded Montoya Group (Ordovician)—Basal, tan, coarse-grained Cable Canyon Sandstone overlain by massive, dark-gray Upham Dolomite, followed upward by thin, platy, dark-gray, silty dolomite and limestone of the Aleman Formation; Montoya is 1,000 ft thick; Upham is medium-bedded Cutter Dolomite; Aleman is approximately 300 ft thick in northern Franklin Mountains (Harbour, 1972); 470 ft thick at Bishop Cap (Seager, 1981); 340–400 ft thick in the southern San Andres Mountains as far north as Hondoño Canyon (Kottlowski and others, 1956); Upham is as much as 300 ft thick in the southern San Andres Mountains (Seager and others, in preparation); Aleman is 70 ft thick in Robledo Mountains (Seager and others, in preparation)*

Co BLISS SANDSTONE AND EL PASO GROUP—*El Paso Group (Ordovician)—Thin-bedded, siliceous, smoky orange- to brown-weathering limestone in lower third; thick- to medium-bedded gray dolomite or limestone in upper two-thirds; unit thins northward because of pre-Montoya erosion; El Paso Group is 1,240 ft thick in northern Franklin Mountains (Harbour, 1972); at least 810 ft thick at Bishop Cap (Seager, 1981); 390–430 ft thick in southern San Andres Mountains (Seager and others, in preparation); the Abo is Early Permian (Wolfcampian), and the Yeso is middle Permian (Leonardian) in age*

HUECO FORMATION—*Algal limestone, grainstone-rudstone-boundstone limestone, fusulinid limestone, chert-pebble conglomerate, sandy limestone, and red, brown, and green shale; commonly cyclic; as much as 1,000 ft in Organ Mountains, sandstone, pseudoolitic black shale, and oncrinoidal limestone; light to dark gray, cream, yellow, orange; Wolfcampian (Early Permian) age; 1,300 ft thick in the Robledo Mountains (including Cutter's tongue of Abo Formation 320 ft thick in the upper part one), at the base, approximately 200 ft of Abo Formation; 1,000 ft in the Hueco Mountains (including 200 ft of Abo Formation); as much as 2,200 ft thick in the Doña Ana Mountains (Seager and others, 1978); 2,400 ft thick in the southern San Andres Mountains, thinning northward to 320 ft thick at Hondoño Canyon (Kottlowski and others, 1956; Bachman and Myers, 1969; Seager, 1981); 1,300 ft thick in the central Organ Mountains (Seager, 1981); 1,000 ft thick in the Franklin Mountains (Harbour, 1972); at least 2,300 ft thick in the Franklin Mountains (Harbour, 1972); and 1,600 ft thick in the Hueco Mountains, including approximately 100 ft of basal Powwow Conglomerate Member (Hardie, 1990)*

Pp PANTHER SEEP FORMATION—*Brown to gray shale, sandstone, siltstone, and limestone; contains distinctive phosphatic shale and phosphatic limestone, deposited in the Delaware Basin; grades downdlard into Middle Pennsylvanian beds and upward into Hueco Formation; approximately 1,400 ft thick near Hondoño Canyon, 2,500 ft thick in the Ash Canyon–San Andres Canyon area (Kottlowski and others, 1956); approximately 2,000 ft thick in the southern San Andres Mountains (Seager and others, in preparation); 1,500 ft thick in the Franklin Mountains (Harbour, 1972); approximately 1,200 ft thick in the Franklin Mountains (Harbour, 1972); and at least 1,300 ft thick in the northern Hueco Mountains (Hardie, 1990)*

Pfc LEAD CAMP LIMESTONE—*Massive, thick- to medium-bedded, fossiliferous, cherty, gray limestone and dolomite cyclically interbedded with shale; contains distinctive fusulinid and coral fauna; Wolfcampian (Early Permian) age; mostly Early to Middle Pennsylvanian in age; formation becomes very dolomitic, shaly, and gypsiferous at top where it weathers orange, yellow, or brown; as much as 1,000 ft in Organ Mountains; 1,000 ft in Franklin Mountains; 1,000 ft in Hueco Mountains; 1,200 ft thick in central San Andres Mountains near Hondoño Canyon (Kottlowski and others, 1956); 800 ft thick near Dunsmuir on Otero County line (Seager and others, 1986); approximately 200–400 ft thick in northern Organ–southern San Andres Mountains, thinning to 34 ft thick at Bishop Cap (Seager, 1981); at least 100 ft thick in the Robledo Mountains (Seager and others, in preparation); S Caballero Formation—Brown-weathering, dolomitic siltstone and nodular, gray, fossiliferous, shaly limestone; 6.80 ft thick in Organ-southern San Andres Mountains (Seager, 1981); Devonian rocks—U Percha Shale—Black, gray, and purplish-gray, fissile shale with yellow-weathering, fine-grained, medium-bedded limestone locally at base, and thin, nodular limestone and siltstone interbedded throughout; Percha Shale is as much as 100 ft thick in the Franklin Mountains (Seager and others, 1986); 5–140 ft thick (Kottlowski and others, 1956; Bachman and Myers, 1969; Seager, 1981); D Canutillo Formation—Fossiliferous siltstone and cherty black limestone; present only at Bishop Cap and northern Franklin Mountains; 44–97 ft thick (Harbour, 1972; Seager, 1981)*

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