

Hydrogeologic Framework of the Mesilla Basin Region of New Mexico, Texas, and Chihuahua (Mexico)— Advances in Conceptual and Digital-Model Development

Appendix F

Selected Photographs and Satellite Images of Representative Landscapes and Hydrogeologic Features in the South-Central New Mexico Border Region

John W. Hawley



View of the SE end of Rincon Valley and head of Selden Canyon from the rim of VAO-capped Ash Mine Mesa. San Diego Mtn., Tonuco Uplift, and the NW Selden Hills are on the northern skyline (NM WRRI photo, 2000).

October 2025 • NM WRRI Report No. 363, Appendix F

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APPENDIX F¹

SELECTED PHOTOGRAPHS AND SATELLITE IMAGES OF REPRESENTATIVE LANDSCAPES AND HYDROGEOLOGIC FEATURES IN THE SOUTH-CENTRAL NEW MEXICO BORDER REGION

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¹APPENDIX F *in* Hawley, J.W., Swanson, B.H., Walker, J.S., Glaze, S.H., and Ortega Klett, C.T., 2025, Hydrogeologic Framework of the Mesilla Basin Region of New Mexico, Texas, and Chihuahua (Mexico)—Advances in Conceptual and Digital Model Development: NM Water Resources Research Institute, NMSU, Technical Completion Report No. 363, 359 p., 8 Appendices.

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F1. Index Maps and Diagrams (Plates F1-1 to F1-10) and Tables (Tbls. F1-1 to F1-6); with Names and Acronyms of Hydrogeologic Subdivisions and Fault Zones.

- Pl. F1-1 (p. 3; no. 23).** Index map of the Mesilla Basin region (MBR) showing locations of the Study Area (**Fig. 1-3**, red outline), major landscape features in the northern Mexican Highland section of the B&R province, and basins of the southern RG-rift province (**Fig. 1-1**). Blue shading shows the approximate extent of the areas inundated by pluvial-Lakes Palomas and Otero at their respective Late Pleistocene high stands in the Zona Hidrogeológica de Conejos Médanos/El Barreal basin complex, and the Tularosa Basin. Swanson Geoscience, LLC compilation on a 2017 Google Earth® image-base. EPdN=El Paso del Norte.
- Pl. F1-2 (p. 4; no. 24).** U.S. Bureau of Reclamation Map showing locations of major surface-water management structures of the Rio Grande Project between the San Marcial (removed 1964) and Fort Quitman Gaging Stations. EBID indicates Elephant Butte Irrigation District operations (courtesy of Rhea Graham; *cf.* USBOR 2011).
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- Pl. F1-4 (F1-4a and 1-4b; p. 6 and 7; nos. 26 and 27).** Index maps to major geohydrologic features of the Study Area (**Fig. 1-3**). The approximate pre-development (~1976) potentiometric-surface altitude (amsl) is shown on **Pl. F1-4a** with 20- and 100-ft contours, and on **Pl. F1-4b** with 5-, 10-, and 30-m contours. Major surface-watershed divides are shown by solid and dashed thick blue lines. The dashed blue line with arrows in the map's SW corner marks the approximate boundary between EPdN- and Los Muertos Basin-directed GW flow.
- Pl. F1-5. (p. 8; no. 28)** Index map for major hydrogeologic subdivisions of the Study Area (**Fig. F1-5**). The Mesilla GW Basin (MeB) is in blue shades, and the Mesilla Valley of the Rio Grande is in dark blue. El Parabién and Southern Jornada GW Basins (EPB and SJB) are in pink and light green, respectively. SCyn-Selden Canyon and EPdN-El Paso del Norte. Solid and dashed black lines are boundaries of interbasin-uplift and intrabasin subdivisions. Acronyms and names of hydrogeologic-subdivision categories, including fault zones (lines with bar and ball symbols), are defined in **Tbls. F1-1 and F1-2** (Rpt. **Tbls. 1-4 and 1-5**). USGS DEM base.
- Table F1-1 (p. 9 and 10; no. 29).** Names and Acronyms of Hydrogeologic Subdivisions shown on Maps, Cross-Sections, and the Well-Information Spreadsheet (**PLS. 1 to 8, TBLs. 1 to 3, and Fig. 1-8 and Tbl. 1-5**)
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- Pl. F1-6 (p. 12; no. 33).** Pliocene and Early Pleistocene geomorphic setting of the ARG distributive fluvial system (DFS-red lines) that terminated in the Lake Cabeza de Vaca (LCdV) basin complex of Strain (1966, 1971). Schematic depiction of ARG distributary channel-belt in the southeastern B&R province (adapted from Hawley 1975a, Fig. 2). Explanations of the symbols that show the general positions of primary Distributive Fluvial System (DFS)-apex and channel-belt segments of ancestral rivers with fluvial-deltaic termini in the LCdV basin complex on **Table F1-3**. The Rios Casas Grandes (violet), Santa Maria and Carmen (pink and orange), and the Mimbres River (yellow) remain as the major surface and subsurface flow fluvial contributors to ephemeral lake-plain remnants of Late Quaternary Paleo-Lake Palomas: Lagunas Guzman, Santa Maria and Patos, and El Barreal-Salinas de Unión. Only parts of the Mesilla Basin and Hueco Bolson have surface/subsurface connection with Rio Grande at present (*cf.* **Pls. F1-1 and F1-4**; Hawley 1975a, Gile et al. 1981, Connell et al. 2005, Castiglia and Fawcett 2006, Weissmann et al. 2011, Davidson et al. 2013, and Nichols 2015). 2018 Google Earth® image base.
- Table F1-3 (p. 13; no. 34).** Explanation of **Plate F1-3** alpha-numeric symbols for Pliocene and early Pleistocene Distributive Fluvial Systems (DFSs) of ancestral-river systems with fluvial-deltaic termini in the Paleo-Lake Cabeza de Vaca complex (LCdV) and Bolson de los Muertos (BdlM).
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- P. F1-8 (p. 15; no. 36).** Idealized triangular diagram of dominant textural classes in lithofacies assemblages (LFAs) 1 to 10; and primary LFA composition of SFG Hydrostratigraphic Units (HSUs) - USF/MSF/LSF. *See Plate F1-7 and Tables F1-4 to F1-6*.
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Table F1-6 (p. 17; no. 38). Summary of major sedimentary properties that influence groundwater-flow and aquifer-production potential of Lithofacies Assemblages (LFAs) a to c in post-SFG RG-valley and basin fills. Modified from Hawley and Kernodle (2000). *See Plates F1-8, and Table F1-3.*

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F2. Plates F2-1 to F2-9. Space-Platform Images and Photographs, and High-Altitude Aerial Photographs: Apollo (6 and 9), Landsat-ERTS and 5TM, and Google Earth®.

Pl. F2-1 (no. 42). Apollo 6 mission, multispectral 502 series, stereoscopic space photo (frame VI-1447); 4/5/1968 (0756 solar time); ~102 naut. miles amsl. The photo centers over White Sands Missile Range (WSMR) Hq., with the El Paso/Cd. Juárez metroarea at photo south-edge center. The Tularosa Basin/Hueco Bolson and Southern Jornada/Mesilla Basin areas are, respectively, east and west of the central San Andres-Organ-Franklin Mtn. chain. The western Sacramento Mtns., Otero Mesa, and Hueco Mtns. and Diablo Plateau are at the photo's east edge. Its west edges include parts of the southern Caballo Mtns., Sierra de las Uvas, Aden (basaltic) volcanic field, and East Potrillo Mtns. *See Morrison 1969, TBL 1.*

Pl. F2-2 (no. 43). Apollo 9 mission, multispectral SO-65 series, stereoscopic space photo (frame AS-22-3460); 3/9/1969 (1936 GMT); 103 naut. miles amsl. Cropped-photo centers over the El Paso/Cd. Juárez metroarea; with southern Organ Mountains and Fillmore Pass at north center, and the Médanos de Samalayuca (dune field) at its south center. The photo's respective west and east edges are in the west-central MeB, and the eastern edge of the northern Hueco Bolson. *See Morrison 1969, TBL 1.*

Pl. F2-3 (no. 44). Apollo 9 mission, multispectral SO-65 series, stereoscopic space photo (frame AS-22-3757); 3/9/1969 (1936 GMT); 103 naut. miles amsl. Photo centers approximately over Columbus, NM / Puerto Palomas, Chihuahua; with Deming at center of north edge. Fluvial-deltaic plain of the lower Rio Casas Grandes and Laguna Guzman are in its south-central part. Ascensión, Chihuahua is located in the Rio Casas Grandes Valley at the SW corner of the photo. Its west-central and east-central edges are respectively near the Cedar Mtns. and Carrizalillo Hills, and Kilbourne and Hunts Holes in the western Mesilla GW Basin (MeB). *See Morrison 1969, TBL 1, FIG. 2.*

Pl. F2-4 (no. 45-46). Google Earth® image-base index map of the binational/tristate region covered by parts of 1969 Apollo 9 mission space photos (F2-2 and F2-3; 2013 NM WRRRI compilation). Major landscape features include: (1) the Florida and Tres Hermanas Mtns. in the image's NW (Luna County) part; (2) the West Potrillo (basaltic volcanic field) and the East Potrillo Mtns., southern Mesilla GW Basin; (3) the southern Mesilla Valley, Franklin Mtns, and western edge of the Hueco Bolson in its NE part; (4) Sierras Juárez, Sapello, Presidio and Samalayuca, the

Médanos de Samalayuca in its SE part; (5) El Barreal area of Bolsón de los Muerto in its south-central part; and (6) the lower Rio Casas Grande fluvial-deltaic plain and Laguna Guzman its southwestern part.

- Pl. F2-5 (no. 47).** Landsat-5 color-IR Image (*circa* 2005) of the binational/tristate Mesilla Basin region, with shaded overlay of the Mesilla (center) and northern El Parabién (SW) GW Basins. SE Sierra de las Uvas and western Tularosa Basin in respective NW and NE corner of the image. The southernmost Jornada Basin and Organ Mtns. are located E of Las Cruces; and the respective Franklin Mtn. and Sierra Juárez-western Hueco Bolson area are N and S of El Paso. The West Potrillo volcanic field is in the image's central-western part; and the NE edge of the Bolson de los Muertos floor that was inundated pluvial-Lake Palomas is in the SW corner of the image (*cf.* **Pl. F1-5**). Line A-A' shows the approximate position of Hydrogeologic Cross-Section I-I' (Rpt. **PL. 5i**).
- Pl. F2-6 (UTEP compilation; no. 48).** Landsat-5TM gray-scale image that is centered on El Parabién Basin of Jiménez and Keller (2000). Blue line (misabeled "SW Terraces") shows general position of ARG distributary channel in the Mendez-Vergel Inflow Corridor (MVIC) the between Sierras Juárez (NE) and Sapello (SW). The approximate northeastern high-shoreline of pluvial-Lake Palomas is also mislabeled "Camel Mountain Scarp Fault."
- Pl. F2-7 (no. 49).** Landsat-5 color-IR Image (*circa* 2005) of the binational/tristate SW Hueco Bolson area that includes much of Ciudad Juárez and eastern El Paso in its northern part (mostly gray tones). The eastern Sierra de Juárez is at image's western edge; and the lower end of El Paso del Norte (EPDN) is in its NW corner. The floor of the upper El Paso/Juárez Valley of the Rio Grande/Bravo (gray line) includes large areas of irrigated cropland (red); and remnants of early- to mid-Pleistocene basin floors that are underlain by Upper SFG-ARG deposits are the dominant landform south of the river valley. The dashed black line shows the approximate position of the eastern Sierra Juárez fault zone (SJfz); and line SW—NE is near Hydrogeologic Section GD' in Hawley and others (2009).
- Pl. F2-8 (no. 50).** Landsat-5 TM color-IR image of the Southern Jornada (E), and northern Mesilla (W) GW Basin (MeB) area (*circa* 2010). The floor of the northern Mesilla Valley (MeV) of the Rio Grande (blue-gray) is dominated by irrigated cropland and pecan orchards (red and reddish brown); and gray to reddish-gray tones mark the Las Cruces-Mesilla-NMSU metroarea at its eastern edge. The southern San Andres and Organ Mtns. (peak alt. 9,012 ft/2,747 m) are at the upper (E) edge of the image; and the southern Doña Ana and Robledo Mts. border the northern MeV in its NW. The Isaacks Lake and Talavera Subbasins of the Southern Jornada GW Basin are located E of the MeV. In the northern West Mesa area of the MeB, two levels on the Early Pleistocene La Mesa geomorphic surface are separated by the SW-trending East Robledo fault zone (tan strip to S of Las Cruces Airport runways). Rift- structural offset of the two levels is here about 300 ft (90 m) (*See* **Pl. F2-7**).
- Pl. F2-9 (no. 51).** Landsat-ERTS Image of the White Sands (E) and Alkali Flat (W) area of the Central Tularosa Basin, and the southern San Andres Mtns., NM. (2002 Landsat imagery compilation by John C. Dohrenwend®). Isaacks Lake Subbasin of the Southern Jornada GW Basin and the Jarilla Mountains in the images respective SW and SE corners. The WSMR Hq. area on the NE Organ Mtn. piedmont is at the south-central edge of the image (*cf.* **Pl. F2-7**).

F3. Plates F3-1 to F3-5 Series. Aerial Photographs of Major Landscape, Cultural, and Hydrogeologic Features in the Southern Rio Grande Rift Region.

Plates F3-1a to F3-1j. USGS-NAQUA Project—Rio Grande Valley and Canyon Overflight Series (June 4, 1991): Elephant Butte Reservoir to the Lower Mesilla Valley. *See* Plate 1-3 RG-Project Map.

- Pl. F3-1a (NM BMMR; no. 54).** View to southwest from south end of Elephant Butte (EB) Reservoir toward northern Palomas Basin and southern Black Range (peak alt. 10,011 ft/3,051 m). Elephant Butte (EB) “Island” and Dam are in the foreground; and the Caballo Mountains are on the southern skyline (Seager and Mack 2003). The short canyon reach of the Rio Grande between the dam and the City of Truth or Consequences (T or C) is cut in Upper Cretaceous sedimentary rocks. *See* **Pls. F3-1b**.
- Pl. F3-1b (NM BMMR; no. 55).** View up Percha Creek Valley in the Palomas Basin from Caballo Dam and Caballo Reservoir on the Rio Grande (spillway crest 4,172 ft/1,272 m). *See* **Pls. F5-3a and 3b**. The southern Black Range is on the western skyline, with Emory Pass (alt. 8,128 ft/2,477 m) in the gap south of Hillsboro Peak (alt. 10,011 ft/3,051 m). *See* Wilson and others (1981), Seager and others (1982 and 1984), Hawley and Kennedy (2004), and Koning and others (2015).
- Pl. F3-1c (NM BMMR; no. 56).** View of lower Selden Canyon and Upper Mesilla Valley (MeV) of the Rio Grande. Masson Farm Geothermal Greenhouses at Radium Springs (Witcher and Mack 2018) in the foreground north of historic Fort Selden (1864-1894) and the Rio Grande Project Leasburg Dam (**Pl. F1-3**). The Robledo Mountains are at photo-center, with the Cedar-Corralitos Upland Basin (CCUB) to the west of the Robledos (Seager et al. 1987 and 2008). The Franklin and East Potrillo Mtns. (and Mt. Riley) are on the respective southeastern and southwestern horizons (**Pls. F5-2g to 2j**, and **Pls. F3-3a and F6-1f**).
- Pl. F3-1d (NM BMMR; no. 57).** View of the East-Central Robledo Mtns. and East Robledo Fault Zone (ERfz) from the Leasburg Inflow Corridor (LBic) Area of the Upper Mesilla Valley (MeV); with Upper SFG Basin-Fill Exposed in Piedmont Area between Rio Grande and ERfz (Seager et al. 2008).
- Pl. F3-1e (NM BMMR; no. 58).** View of Picacho “Peak” and the ERfz from above the Picacho (Village) area of the Mesilla Valley. The Rough and Ready Hills, and southern Cedar Hills on are on skyline west of the Aden-Robledo Uplift (ARU) and the Corralitos Ranch Subbasin (CRSB) of the Cedar-Corralitos Upland Basin (Seager et al. 1987, Seager et al. 2008).
- Pl. F3-1f (NM BMMR; no. 5; no. 59).** View along Interstate Hwy. 10 from above its bridge over the Rio Grande about 1 mi (1.6 km) west of the village of Fairacres in the Upper Mesilla Valley; the Mesilla Basin-West Mesa area, Cedar-Corralitos Upland Basin, and the Rough and Ready Hills are on the northwestern skyline. The East Robledo Fault Zone (ERfz) forms the western structural boundary of the Fairacres Subbasin (FASB) of the MeB.
- Pl. F3-1g (NM BMMR; no. 60).** Rio Grande Project-Mesilla Diversion Dam near Stahmann Farm Pecan Orchard (**Pl. F1-4**). Viewpoint above boundary between the MeB Fairacres and Mesquite Subbasins (FASB-MSB). Western border of the Mesilla Valley and potential site for managed aquifer recharge (MAR) in background.
- Pl. F3-1h (NM BMMR; no. 61).** View to SW of the Stahmann Farms pecan orchard on the west-central Mesilla Valley floor, with the East Potrillo Mtns. on the western skyline. Basalt flows

from the Santo Tomas, San Miguel, and Little Black Mountain volcanic centers partly cap Mesilla-Valley border and Mesilla Basin-West Mesa surfaces (Hoffer 1971, Seager et 1987, Williams 1999, Dunbar 2005). *See* **Pl. F3-2d**.

Pl. F3-1i (NM BMMR; no. 62). The Ancestral Rio Grande (ARG) fluvial-deltaic facies of the Camp Rice Fm (HSU-USF2) is exposed on western MeV rim NW of Sunland Park. Early-stage Santa Teresa Industrial Park (STIP) development is located in the southern MeB-West Mesa area; and the western Sierra Juárez and Sierra Sapello Uplift in Mexico are on the southern skyline (Córdoba 1969b, Drewes and Dyer 1993).

Pl. F3-1j (NM BMMR; no. 63). Anapra and Sunland Park area of the Lower Mesilla Valley at the head of El Paso del Norte (EPdN). Cerro del Cristo Rey in left center and Sierra Juárez on the southern skyline in Chihuahua, Mexico (Lovejoy 1976a, Lucas et al. 1998).

Plates F3-2a to F3-2j Series. Mesilla Valley Area, and Contiguous RG-Rift Basins and Mountain Uplifts (Slides 36-45).

Pl. F3-2a (USDA-SCS; 7/12/1963; no. 65). View to SW toward Mesilla Basin from Isaacks Lake Subbasin (ILSB) of the Southern Jornada GW Basin (SJB). Isaacks Lake Playa after near-maximum level following 7/8-9/1963 rain-storm event (Gile et al. 1981). *See* **Pl. F3-2b**.

Pl. F3-2b (USDA-SCS; 9/1969; no. 66). View across the Southern Jornada GW Basin (SJB) from the eastern edge of the Mesilla Valley floor, with the San Agustín and Organ Mountains in the background. The SJB-Isaacks Lake and Talavera Subbasin (TVSB) boundary is shown with a dashed blue line, which also marks the approximate location of the drainage divide between the Jornada and Mesilla Basin surface-watersheds and GW-flow systems. *See* **Pls. F3-2a and F3-2c**.

Pl. F3-2c (USDA-SCS; 6/1970; no. 67). View across from eastern edge of the Mesilla Valley and Tortugas Mountain Uplift (TMU) and the SJB-Talavera Subbasin (TVSB); with the central Organ Mountains and Southern Tularosa Basin in the background. *See* **Pls. F4-2b, F5-3f, and F6-1g**.

Pl. F3-2d (USDA-SCS; 10/1968; no. 68). The Late Pleistocene Santo Tomas basalt flow caps Camp Rice Fm (HSU-USF2) and Rio Grande-terrace deposits in the MeV-border area west of the Stahmann Farm pecan orchard (Hoffer 1971, Seager et al. 1987, Dunbar 2005). The canalized reach of the Rio Grande is immediately downstream from Mesilla Dam (**Pls. F1-4 and F3-1g**). *See* Baker (1943) and Glover (2018).

Pl. F3-2e (USDA-SCS; 9/15/1968; no. 69). View from the south end of the Southern Jornada Basin and the Organ Mountains to the Southern San Andres Mtns., with the Tularosa Basin-White Sands area in the background (Seager et al. 1987). *See* **Pls. F3-2b and F5-3f**.

F3-2f (USDA-SCS; 9/15/1968; no. 70). View to the northeast from Bishop Cap Uplift and the Organ Mountains to the Southern San Andres Mtns., with the Tularosa Basin-White Sands area in the background (Seager 1981). *See* **Pls. F7-4e**.

Pl. F3-2g (USDA-SCS; 9/15/1968; no. 71). West-tilted Franklin Mountain fault-block complex between the Mesilla Basin and NW Hueco Bolson RG-rift structural depressions (Collins and Raney 2000). *See* **Pls. F3-2i, and F4-1j and 4-1k**.

Pl. F3-2h (USDA-SCS; 9/15/1968; no. 72). Anthony Gap pass between the northern and southern Franklin Mountains, and the northwestern Hueco Bolson and southeastern Mesilla Basins of the

Rio Grande rift. *See* **Pl. F7-2b** for photo of (~0.77 Ma) Bishop Ash fall exposure in El Paso Natural Gas pipeline excavation (Kelley and Matheny 1983).

Pl. F3-2i (NM BMMR; 8/21/1984; no. 73). Transmountain (TM) Hwy at SE base of North Franklin Mountain (7,192 ft/2,192 m) ascending towards Smuggler's Gap Pass (5,250 ft/1,600 m). The Mesilla Basin is on the western skyline The East Franklin fault zone (EFfz) in the foreground forms the structural boundary between the Franklin Mountains and Hueco Bolson (Lovejoy and Hawley 1978, Collins and Raney 2000, Collins et al. 2015). *See* **Pls. F3-2g and F3-2j.**

Pl. F3-2j (USDA-SCS; 3/4/1971; no. 74). View to the northwest of the Central Franklin Mountains from the northeastern part of El Paso in the far-western Hueco Bolson. Organ Mountains on northern skyline are located north of Fillmore Pass and east of the central Mesilla Basin. The East Franklin fault zone (EFfz) is at the base of the mountains in the foreground. *See* **Pls. F3-2g and F3-2i.**

Plates F3-3a to F3-3c Series. August 21, 1984, USGS Overflight of the Rio Grande/Bravo Valley and Canyon Area between the Southeastern End of the Hueco Bolson and the Northwestern Presidio Bolson.

Pl. F3-3a (NM BMMR; no. 76). Upper Fort Hancock and basal Camp Rice Fms of the Upper SFG are well exposed in badlands of the SE Hueco Bolson area near McNary and the Madden Arroyo section of the SP (UP) RR (Albritton and Smith 1965, Strain 1966, Gustavson 1991a). *See* **Pl. F7-2a.**

Pl. F3-3b (NM BMMR; no. 77). Rio Grande/Bravo Canyon across complexly folded and faulted Lower Cretaceous sedimentary rocks on the southern Quitman–northern Cieneguilla uplift SE of Indian Hot Springs. The photo site is above the Sierra Cieneguilla. The Red Light Bolson is in the northeastern background, with Sierra Blanca on the northern skyline (Albritton and Smith 1965, Akerston 1970, Reaser and Underwood 1980, Underwood 1980, Reaser 1982, Henry and Price 1985). *See* **Pl. F4-1m to 1o.**

Pl. F3-3c (NM BMMR; no. 78). View to the southwest of the Rio Grande/Bravo canyon in SE-dipping Lower Cretaceous sedimentary rocks of the Indio-Sierra Pilares uplift. The photo site is above the Indio Mountains and the upper end of Presidio Bolson (Groat 1972, Reaser and Underwood 1980, Underwood 1980, Henry and Price 1985).

Plates F3-4a to F3-4e Series. USGS-NAQUA Project—June 4, 1991, Rio Grande Basin Overflight: Late-Pleistocene Volcanic Features in the Southwestern Mesilla Basin Area.

Pl. F3-4a (NM BMMR; no. 80). Late Pleistocene Hunts Hole hydromagmatic volcanic center (maar) in the Kilbourne-Noria Subbasin of the Mesilla GW Basin (MeB), with the East Potrillo Mountains are on the southwestern skyline (DeHon 1965, Dunbar 2005).

Pl. F3-4b (NM BMMR; no. 81). Late Pleistocene Kilbourne Hole hydromagmatic volcanic center in the Kilbourne-Noria Subbasin of the MeB, with Sierra de Las Uvas, and the Robledo and Organ Mountains on the northeastern skyline (DeHon 1965, Gile 1987a, Seager 1987, Williams 1999, Dunbar 2005). *See* **Pls. F7-3a to 3d.**

Pl. F3-4c (NM BMMR; no. 82). Late Pleistocene Aden Crater and Aden volcanic field (~19 ka) in the Aden Sector of the Aden-Robledo Uplift on the northwestern border the MeB (Seager 1995, Dunbar 2005 [Tbl. 2], DeHon and Earl 2018). The Robledo, Doña Ana, San Andres and Organ Mountains are on the northeastern skyline. *See* **Pls. F2-3, F3-4d and 4e, and F7-3e.**

Pl. F3-4d (NM BMMR; no. 83). Aden Crater and western Aden volcanic field, with Sierra de Las Uvas, Sleeping Lady Hills, Cedar-Corralitos Upland Basin, and the Robledo Mtns. on the northern skyline. *See Pls. F2-3, F3-4c and 4e, and F7-3e.*

Pl. F3-4e (NM BMMR; no. 84). Aden Crater (~19 ka) in foreground, with West Aden Hills and Aden Hills Uplifts on the northwestern Skyline. *See Pls. F2-3, and F3-4c and 4d.*

Plates F3-5a and F3-5b. Fall 2019 Border-Wall Series. Courtesy of PBS-New Mexico in Focus—Our Land: New Mexico’s Environmental Past, Present and Future.

Pl. F3-5a (no. 86). Border Wall and Northern Rim of Potrillo Maar in Foreground (Reeves and DeHon 1965, Seager et al. 1984, Hoffer 2001a, Dunbar 2005). View to ESE across the southern MeB fluvial-deltaic plain of the Ancestral Rio Grande (ARG). The Franklin Mountains, and Sierras Juárez and Sapello are on the eastern Skyline. *See Pl. F7-2f.*

Pl. F3-5b (no. 87). Early impact of Border Wall construction where it crosses a typical Chihuahuan Desert (*Mesquite* scrub) landscape in the Malpais GW Basin at the southwestern edge of Doña Ana County (Seager 1995). *See Pls. F2-3 and F2-4.*

F4. Plates F4-1 to F4-3 Series. Land-Surface Photographs of Major Geomorphic, Cultural, and Hydrogeologic Features in the Lower Rincon Valley, Mesilla Basin, and Hueco Bolson Region.

Plates F4-1a to F4-1m. Representative Geomorphic, Cultural, and Hydrogeologic Features in the Valleys and Canyons of the Rio Grande/Bravo Fluvial System Between the Lower Rincon Valley, NM and El Paso del Norte.

Pl. F4-1a (USDA-SCS; June 1963; no. 90). View of San Diego Mountain of the Tonuco Uplift from the eastern rim of the lower Rincon Valley and western edge of the Southern Jornada GW Basin (Seager et al. 1971, 2023). The Robledo Mtns. are on the southwestern skyline. Jeep is on La Mesa Surface petrocalcic soil that caps Upper SFG-ARG basin fill deposits (HSU-USF2).

Pl. F4-1b (R.T. Hanson-USGS; 9/15/2004; no. 91). Hayner Farms chili field and pecan orchard in lower Rincon Valley of the Rio Grande. San Diego Mtn. of the Tonuco Uplift is on the eastern skyline. It is capped by Lower SFG conglomerates of the type Hayner Ranch Fm (HSU-LSF, LSF 8; Seager et al. 1971, 2023). The Historic El Camino Real, San Diego paraje is located at the edge of the Rincon Valley near the northern base of San Diego Mtn. (Moorhead 1954, p. 170).

Pl. F4-1c (NM BMMR; 5/1989; no. 92). Bean field on lower Rincon Valley floor is bordered on the SW by bluffs with exposures of light reddish-brown beds of the Middle SFG-Rincon Valley Fm (HSU-MSF1 and 2) that are capped by Upper SFG-Camp Rice Fm (ARG and piedmont facies—HSU-USF). *See Seager and others (1975).*

Pl. F4-1d (NM WRRI, 4/2/2007; no. 93). Bank-full Rio Grande at the lower end of the Rincon Valley and head of Selden Canyon. San Diego Mtn., Tonuco Uplift, and the northern Selden Hills are on the northern skyline (Seager et al. 2021,2023). *See Pl. F4-1b.*

Pl. F4-1e (NM WRRI, 5/26/2000; no. 94). View of the lower (SE) end of Rincon Valley and head of Selden Canyon from the rim of VAO-capped Ash Mine Mesa (**Pl. F4-1d**). San Diego Mtn. and the NW Selden Hills are on the northern skyline (Seager 1975b, Seager et al. 1987 and 2021). *See Pls. F4-1b, 1d and 1f.*

Pl. F4-1f (USDA-SCS; 1972; no. 95). Southeast face of Ash Mine Mesa at mouth of Broad Canyon and western edge of Selden Canyon (Seager et al. 1975, Fig. 10). Older valley-border fan alluvium (VAO) caps 0.64 Ma Lava Creek Ash and high-level RG-terrace deposits that are unconformably underlain by the Middle SFG Rincon Valley Fm. (HSU-MSF1 [LFA 5]). *See Pls. F4-1e, F4-1g, F5-2e and F7-2d.*

Pl. F4-1g (NM WRRI; 5/26/2000; no. 96). View of the upper end of Selden Canyon of the Rio Grande from the eastern edge of Ash Mine Mesa. Older Broad Canyon fan gravel (VAO, LFA 6) caps reworked bed of 0.64 Ma Lava Creek B Ash in foreground. San Diego Mtn. and northern Selden Hills are on the northeastern skyline. *See Pls. F4-1e and F4-1f.*

Pl. F4-1h (NM WRRI; 5/21/2007; no. 97). View to NE across the upper Mesilla Valley and the MeB Leasburg Inflow Corridor (LBic). Middle- to late-Quaternary valley-border deposits flanking the Robledo Mtns. are in the foreground, with the Doña Ana Mtns. on the skyline. *See Pl. F4-1i.*

Pl. F4-1i (NM WRRI, 5/21/2007; no. 98). View of the Rio Grande channel and floodplain in the upper Mesilla Valley in the area of **Pl. F4-1h**. Middle- to late- Quaternary valley-border deposits flanking the Robledo Mtns. are on the northern skyline.

Pl. F4-1j (HAWLEY GEOMATTERS, 7/27/10; no. 99). View to north across the Mesilla Valley from Smuggler's Gap in the Franklin Mountains. The Transmountain Hwy. is in the foreground, with the Robledo Mtns are on the northwestern skyline (Lovejoy and Hawley 1978, Collins and Raney 2000). *See Pls. F3-2h and F3-2j.*

Pl. F4-1k (HAWLEY GEOMATTERS, 7/27/10; no. 100). View to the west across the southern Mesilla Basin from Smuggler's Gap in the Franklin Mtns., with the southern Mesilla Valley in the foreground. The Santa Teresa Industrial Park at the eastern edge of the MeB West Mesa is in the background; and the East Potrillo Mountains, and the Mt. Cox and Riley twin peaks are on the skyline (Seager and Mack 1994, Seager 1995). *See Pls. F3-1i, F3-3a and F3-4a.*

Pl. F4-1l (HAWLEY GEOMATTERS, 7/27/10; no. 101). View to south from Smuggler's Gap across the MeB-Sunland Park Outflow Corridor (SPoc) and Anapra-Oasis Bench (AOBN) of the Mesilla Valley. Cerro del Cristo Rey is in the background; and Sierra Juárez is on the skyline (Lovejoy 1976a, Drewes and Dyer 1993, Lucas et al. 1998 and 2010). *See Pls. F3-1j and F4-1m.*

Pl. F4-1m (HAWLEY GEOMATTERS, 7/27/10; no. 102). The Rio Grande at Courchesne Bridge and Gaging Station at the lower end of the Mesilla Valley and the head of El Paso del Norte. Cerro del Cristo Rey is on the SW skyline. Hydrologist James Hogan is at lower left. *See Pls. F1-4 and F3-1l.*

Plates F4-2a to F4-2g. Representative Geomorphic, Cultural, and Hydrogeologic Features in the Valleys and Canyons of the Rio Grande/Bravo Fluvial System Between the Southeastern Hueco Bolson and Indian Hot Springs.

Pl. F4-2a (NM WRRI; 5/18/2003; no. 104). The Rio Grande/Bravo at low stage near southeastern end of the Hueco Bolson and below the Fort Quitman Gaging Station (*See Pl. F1-4*). Hydrologist Barry Hibbs sampling water-salinity levels in foreground, with the Quitman Mountains on the southeastern skyline (Albritton and Smith 1965, Henry and Price 1984, Eastoe et al. 2008).

Pl. F4-2b (NM WRRI; 5/18/2003; no. 105). The Rio Grande/Bravo at low stage between Fort Quitman Gaging Station and Indian Hot Springs. Hydrologists Chris Eastoe and Barry Hibbs are on the US-bank of the “Rio Pequeño,” with the Quitman Mountains in the northeast background.

PL. F4-2c (NM WRRI; 5/18/2003; no. 106). Chris Eastoe sampling one of the spring pools at Indian Hot Spring, Texas; with the southern Quitman Mountains on the northeastern skyline (Henry 1979, Reaser and Underwood 1980, Eastoe et al. 2008). *See Pls. F3-3b, and F4-2e to F4-1g.*

Pl. F4-2d (NM WRRI; 5/18/2003; no. 107). Entering Eastern Chihuahua across the International Rio Grande/Bravo “Footbridge” at Indian Hot Springs. *See Pl. F4-2e.*

Pl. F4-2e (NM WRRI; 5/18/2003; no. 108). View eastward from the “US-Abutment” of the International Rio Grande/Bravo “Footbridge” at Indian Hot Springs, with southern end of Quitman Mountains in the background (Reaser and Underwood 1980). *See Pls. F4-2c and F4-2f.*

Pl. F4-2f (NM WRRI; 5/18/2003; no. 109). Texas Historical Commission “Buffalo Soldiers” Monument at Indian Hot Springs, with southern end of Quitman Mtns. on the northern skyline (Reaser and Underwood 1980). *See Pls. F4-2c and F4-2e.*

Pl. F4-2g (NM WRRI; 5/18/2003; no. 110). Texas Historical Commission Monument to the “Buffalo Soldiers” of the U.S. Army 10th Cavalry at Indian Hot Springs “Three-Flags” site. *See Pls. F4-3e and F4-3f.*

Pls. F4-3a and 3b. Representative Quaternary Geomorphic and Hydrogeologic Features on Piedmont Slopes of the Southern Jornada GW Basin (SJB).

Pl. F4-3a (USDA-SCS; 6/1963; no. 112). Fillmore Arroyo channel on piedmont slope in the Talavera Subbasin of the SJB. Photo site about 3 mi (5 km) east of Tortugas Mtn. USDA-SCS Soil Scientist Leland (Lee) Gile in foreground, with Organ Mtns. on eastern skyline (peak alt.: 9,012 ft/2,747 m). *See Pl. F6-1a.*

Pl. F4-3b (USDA-SCS; 8/1963; no. 113). Afternoon arroyo flash flood on upper piedmont slope at E edge of Isaacks Lake Subbasin in Southern Jornada Basin. About 3 mi (5 km) NNW of the village of Organ, with Doña Ana Mountain on the western skyline (Seager et al. 1976, Seager and Mack 2018). *See Pl. F3-2a.*

F5. Plates F5-1 to F5-5 Series. Land-Surface Photographs of Representative Hydrostratigraphic Units (HSUs) and Lithofacies Assemblages (LFAs) in Santa Fe Group (SFG) Basin-Fill Deposits.

Plates F5-1a and F5-1b. Representative Exposures of the Lower SFG-Hayner Ranch Formation (HSU-LSF, LFAs 7 and 8) in the Eastern Rincon Valley Area.

Pl. F5-1a (NM BMMR; 5/23/1988; no. 116). View to south across the East Tonuco Corridor (ETNC) between the lower Rincon Valley and Southern Jornada Basins. Steeply dipping conglomeratic sandstones of the “Type” Hayner Ranch Fm (HSU-LSF, LFAs 7 and 8) are in the foreground; and the Robledo Mountains and northern Selden Hills are on the skyline (Seager et al. 1971, Seager 1975b, Seager et al. 2023). *See Pl. F5-2c.*

PL. F5-1b (USDA-SCS; 4/1965; no. 117). Johnson Springs Arroyo exposure of south-dipping conglomerate beds near base of the Hayner Ranch Fm (HSU-LSF, LFA 8). The photo site is

about 3 mi (4.8 km) NE of Hatch at the southwestern edge of the Rincon Hills (Seager and Hawley 1973).

Plates F5-2a to F5-2f. Representative Exposures of Middle SFG Hydrostratigraphic Unit (HSU-MSF) and its Lithofacies Assemblages (LFAs) in the Southern Palomas Basin and Northern Selden Canyon Areas.

Pl. F5-2a (USDA-SCS; Spring 1969; no. 119). Gypsiferous Rincon Valley Fm mudstone beds (MSF2, LFA 10) exposed in north wall of Arroyo Cuervo in the southeastern Palomas Basin, about 10 mi (16 km) NW of Hatch (Seager et al. 1982, Jochems 2017). Note minor compaction-deformation features and offset of gypsite bed.

Pl. F5-2b (NM BMMR; 4/8/1981; no. 120). I-25 roadcut exposure of W-dipping gypsiferous mudstone beds, with small-scale fault offsets, in “type-area” of the Rincon Valley Fm (HSU-MSF2, LFA 10). Photo site is between I-25 MPs-36 and 37, with the Rincon Hills on the northeastern skyline. *See* Seager and Hawley (1973).

Pl. F5-2c (USDA-SCS; Summer 1968; no. 121). Exposures of interbedded sandstone and mudstone of the Rincon Valley Fm (HSU-MSF 2, LFAs 3 and 9) in the East Tonuco Corridor (ETNC) between the lower Rincon Valley and Southern Jornada Basins. The Tonuco Uplift is on the northern skyline. *See* Seager and others (1971).

Pl. F5-2d (USDA-SCS; 4/1965; no. 122). Tongue of Selden Basalt (~9.5 Ma) in conglomeratic-mudstone of the Middle SFG-Rincon Valley Fm (MSF1, LFA 7) exposed in northwestern wall of lower Broad Canyon (Seager et al. 1975, 2021). Photo site is about 0.5 mi (0.8 km) southwest of northern Selden Canyon.

Pl. F5-2e (USDA-SCS; 1972; no. 123). View from upper Selden Canyon rim, with San Diego Mtn., Tonuco Mtns. Uplift, and the northern Selden Hills on the northeastern skyline. Middle SFG-Hayner Ranch Fm pebbly mudstone (MSF1, LFA 5) is exposed on the eastern slope of Ash Mine Mesa (*See* **Pls. F4-1c and F5-2f**; Seager et al. 1975, Fig. 10).

Pl. F5-2f (USDA-SCS; Spring 1972; no. 124). University of Colorado sediment and paleo-mag sampling of Middle SFG-Rincon Valley Fm at Ash Mine Mesa site (**Pl. F5-1e**; *see* **Pls. F4-1d, F5-2b and F7-2d**; Reynolds and Larsen 1972, Seager et al. 1975, Gile et al. 1995).

Plates F5-3a to F5-3i. Representative Exposures of the Upper SFG Palomas and Camp Rice Fms in the Palomas- and Mesilla-Basin Areas (HSU USF).

Pl. F5-3a (NM WRRI; 3/10/2016; no. 126). Upper SFG-Palomas Fm piedmont facies (USF1, LFA 5) exposed in the south wall of Percha Creek Valley about 6 mi (10 km) west of Caballo Dam. General southern Palomas Basin setting in **Pl. F3-2b**; and details of outcrop behind geologist Dan Koning in **Pl. F5-3b** (Koning et al. 2015; no. 127).

Pl. F5-3b (NM WRRI; 3/10/2016). Percha Creek recharging the Palomas Fm-piedmont facies aquifer (USF1, LFA 5). Southern Palomas Basin about 6 mi (10 km) west of Caballo Dam. *See* **Pl. F5-3a**.

Pl. F5-3c (USDA-SCS; Spring 1968; no. 128). View across the upper Mesilla Valley (MeV) from the western edge of the East Robledo fault zone (ERfz) to the Experimental Range Subbasin of the SJB (**Pls. F3-1d and F5-3e**). Intertonguing piedmont and ARG facies are exposed in the lower part of the Camp Rice Fm (Seager et al. 2008).

Pl. F5-3d (USDA-SCS; Spring 1968; no. 129). About 300 ft (90 m) of Upper SFG Camp Rice Fm (HSU-USF) exposed on hanging wall of ERfz at the base of the northern Robledo Mtns (site location on **Pl. F5-3c**). Partly indurated fan-piedmont deposits (USF1, LFAs 5 and 6) conformably overlie pebbly-sand ARG channel facies (USF2/ LFA 2). *See* Seager and others (2008).

Pl. F5-3e (USDA-SCS; April 1965; no. 130). Basal Upper SFG-Camp Rice Fm (USF2/USF1) exposed at the head of Faulkner Canyon Arroyo in the NE Corralitos Ranch Subbasin of the Cedar-Corralitos Upland Basin. Rock hammer is at contact between USF2 (ARG) facies sandstone, and Robledo Mtn.-source USF1 fanglomerate (LFA 8). *See* Seager and others (2008).

Pl. F5-3f (USDA-SCS; 12/1965; no. 131). Exposure of Upper SFG Camp Rice Fm-ARG channel facies (USF2, LFA 2) at the Inman Sand & Gravel Pit site on the eastern Mesilla Valley border north of Tortugas Mountain (Gile et al. 1981). *See* **Pls. F3-2c** and **F5-3g**.

Pl. F5-3g (USDA-SCS; 12/1965; no. 132). Upper pallet of the Early Pleistocene mastodont *Cuvieronius* collected from the Inman Sand & Gravel Pit site shown in **Pl. F5-3f** (Lucas et al. 1999).

Pl. F5-3h 5/22/2007; no. 133). Upper SFG Camp Rice Fm-ARG channel facies (USF2, LFA 1) exposed on western Mesilla Valley rim about 200 ft (60 m) SSE of the NMSU Lower La Mesa trench site (**Pl. F7-1e**). The southern Organ Mtns., Bishop Cap, and Fillmore Pass, are on the southeastern Skyline (Gile et al. 1995, p. 30-32).

Pl. F5-3i (USDA-SCS; 10/1971; no. 134). Upper SFG Camp Rice Fm piedmont-alluvial facies (USF1, LFA 6) exposed in fan-head trench in the western Soledad Canyon section of the central Organ Mountains (Gile et al. 1981 [p. 204-207]; Seager 1981). *See* **Pl. F3-2c** for photo-site location.

Plates F5-4a and F5-4b. Exposures of Basin-Floor Lithofacies Assemblages LFA-3 and LFA-10 in Camp Rice and Fort Hancock Fm (HSU-USF2) in the Hueco Bolson Area.

Pl. F5-4a (UACJ- Granados Olivas; 1/14/2003; no. 136). SW Hueco Bolson mesa-rim exposure of sandy Upper SFG-Camp Rice Fm of mixed fluvial and eolian origin (USF2, LFA 3). John Hawley and John Kennedy at Pan-American Hwy. site, about 10 km south of the Cd. Juárez Airport (Hawley et al. 2009, Pl. 2g). *See* **Pl. F7-1f** for “mesa-caprock” petrocalcic-soil detail, and **Pl. F2-7** for photo-site location.

Pl. F5-4b (NM BMMR; 3/26/1994; no. 137). Gypsiferous lacustrine facies of the Fort Hancock Fm (USF2, LFA 3/10) exposed in the south wall of lower Nealy Canyon (Gustavson 1991a, Fig. 14). The white layer near the exposure’s base is an undated, altered volcanic ash-fall bed of probable early- to mid- Pliocene age (Gustavson 1991a, Fig. 14). The photo site is about 1 mi (1.6 km) east of the Rio Grande/Bravo, and about 4 mi (6.4 km) SSE of the Fort Quitman Gaging Station (**Pl. F1-4**).

Plates F5-5a and F5-5b. Exposures of Upper SFG Hydrostratigraphic Units (USF2) and Basin-Floor Lithofacies Assemblages (LFAs) in the Northern Bolsón de Los Muertos Area.

Pl. F5-5a (NM WRRI; 6/5/2009; no. 139). Gravel-pit exposure of ancestral Rio Casas Grandes channel deposits (USF2, LFA 1) capped by petrocalcic soil. Fine-grained beds at base of pit are possibly deposits of paleo-Lake Cabeza de Vaca (*See* **Pl. F1-3 [c1]**). Photo site but 100 m northeast of the Federal Hwy. 2 - Palomas Hwy. junction at Los Trios [aka El Entronque] (*see* **Pls. F2-3** and **F2-4**).

Pl. F5-5b (NM WRRI; 6/5/2009; no. 140). Ancestral Rio Mimbres fluvial-deltaic deposits (USF2, LFAs 2 and 3) exposed in the rim of El Barreal ephemeral (playa)-lake plain at the northeastern edge of Bolsón de Los Muertos (*aka* “Camel Mountain escarpment.” Córdoba et al. 1969 [p. 6-7], Hawley 1969b [FIG. 2], Morrison 1969 [FIG. 3], Reeves 1969 [FIG. 1], **APPENDIX D1-Note 3**). El Barreal is the largest remnant of pluvial-Lake Palomas (**Pls. F1-1 and F1-2**, Reeves 1969, Hawley et al. 2000 [Pl. 1], Castiglia and Fawcett 2006). The photo site is at the south edge of Mexico Federal Highway 2, and about 5 mi (8 km) WNW of Rancho La Laguna (*see* **Pl. F2-4**).

F6. Plates F6-1 to F6-3 Series. Land-Surface Photographs of Representative Hydrostratigraphic Units (HSUs) and Lithofacies Assemblages (LFAs) in Post-Santa Fe Group Basin- and Valley-Fill Deposits.

Plates F6-1a to F6-1f. Post-SFG Hydrostratigraphic Units and Lithofacies Assemblages in the Southern Jornada Basin.

Pl. F6-1a (USDA-SCS; 6/1963; no. 143). Exposure of Middle Pleistocene arroyo-channel gravel (HSU-VAO, LFA 6) in north bank of Fillmore Arroyo. The deposit is capped with a thin stage-IV petrocalcic soil. The photo site is about 1-mi (1.6 km) SE of Tortugas Mountain in the SJB-Talavera Subbasin (Gile et al. 1995, p. 91-93, FIG. 10). *See* **Pls. F3-2c and F4-3a** for site location.

Pl. F6-1b (NM WRRI; 5/23/2012; no. 144). NMSU Soil-pit exposure of Middle Pleistocene fan-piedmont gravel (HSU-PAO, LFA 6). The deposit is capped with a thin, stage-IV petrocalcic soil. The photo site about 0.5 mi (0.8 km) from the base of the northeastern Doña Ana Mountains in the SJB-Isaacks Ranch Subbasin.

Pl. F6-1c (NM BMMR; 8/1982; no. 145). Initial NMSU Soil-Moisture Research Project excavation in piedmont-slope alluvial deposits (Wierenga et al. 1990, 1991). Hydrostratigraphic Units PA/USF1 (LFA 5), with multiple buried soils, are exposed in the trench (depth about 33-ft/10-m). The photo site is in the SJB-Isaacks Ranch Subbasin; and the Mount Summerford (NE Doña Ana Mtns.) sediment-source area is in the background (Seager and Mack 2018). *See* **Pl. F6-1d** for trench detail.

Pl. F6-1d (NMSU; 1983; no. 146). Nearly completed NMSU soil-moisture research excavation in piedmont-slope deposits derived from the northeastern Doña Ana Mountains- Mount Summerford area (Wierenga et al. 1990, 1991). Hydrostratigraphic Units PA (upper) and USF1 (lower), with multiple buried soils, are exposed trench, with John Hawley and NMSU soil scientist Leroy Daugherty standing at its northern face. *See* **Pl. F6-1c** for geomorphic-setting detail.

Pl. F6-1e (NM WRRI; 5/24/2007; no. 147). Floor of Isaacks Lake playa, with the San Agustín and northern Organ Mountains on the eastern skyline (**Pls. F2-8, F3-2a and F4-3b**). *See* **Pl. F5-6f** for more-detailed view of Vertisol exposed in USDA-NRCS trench in foreground.

Pl. F6-1f (NM WRRI; 5/24/2007; no. 148). Detail of **Pl. F6-1e** trench exposure of Vertisol in Isaacks Lake playa, with 1.8-m (71-in) tape for scale. The soil structure reflects high shrink-swell properties of the clay-rich (>60% <2 μ) playa-lake sediment (Gile et al. 1981, p. 170-174, FIG. 70).

Plates F6-2a to F6-2f. Representative Exposures of Late Quaternary Hydrostratigraphic Units and Lithofacies Assemblages in the Inner Mesilla Valley.

Pl. F6-2a (USDA-SCS; 3/1971; no. 150). Historic RG-channel deposits exposed in Burn Lake (I-10) borrow-pit. *See Pl. F2-8* for site location, and **Pls. F6-2b to 2d** for lower pit details.

Pl. F6-2b (USDA-SCS; 3/1971; no. 151). SCS-Soil Scientist Leland H. (Lee) Gile (~6-ft, 2-in) photographing lower part of the Burn Lake borrow-pit exposure of Rio Grande channel deposits (HSU-RA, LFA a2; *See Pls. F6-2a, 2c and 2d*). The photo site is about 1.5-mi (2.5-km) north of La Mesilla at the northeast edge of the I-10 right-of-way (*See Pl. F2-8*).

Pl. F6-2c (USDA-SCS; 3/1971; no. 152). Fragment of *cottonwood* log in the HSU-RA channel deposit (LFA a2) exposed in the Burn Lake borrow pit near photo-site **Pl. F6-2b**. The ¹⁴C age of the sampled wood is ≤ 200 yrs. *See Pl. F1-7* for information on basic LFA a and b relationships.

Pl. F6-2d (USDA-SCS; 3/1971; no. 153). Historic RG channel-deposit (HSU-RA/ LFA a2) detail in cross-bedded, pebbly-sand exposed in the Burn Lake borrow pit near photo-site **Pl. F6-2b**. *See Pl. F1-7* for information on basic LFA a and b relationships.

Pl. F6-2e (NM WRRI; 4/1996; no. 154). Late Quaternary (mostly Holocene) Fillmore Arroyo-channel fill (HSU-VAY, LFA b) exposed in excavation at southeast edge of the NMSU Campus. The northern Organ Mountains are on the northeastern skyline. *See Pl. F6-2f* for exposure detail, and **Pl. F3-2c** for site-location information. Soil-geomorphic relationship in the general area is described by Gile and others (1981, p. 93-98).

Pl. F6-2f (NM BMMR; 4/1996; no. 155). Detail of Fillmore Arroyo-channel fill (HSU-VAY, LFA b) at the **Pl. F5-7e** photo site. Rock hammer in near the contact of Late Quaternary arroyo alluvium on the Upper SFG-Camp Rice Fm (USF2). *See Pl. F1-7* for information on basic LFA a and b relationships.

F7. Plates F7-1 to F7-4 Series. Land-Surface Photographs of Quaternary-Age Petrocalcic Soils, Volcanic-Ash Beds, Volcanic-Eruptive Features, and Fault Zones.

Plates F7-1a to F7-1g. Petrocalcic Soils and Associated Soil-Geomorphic Features.

Pl. F7-1a (NMSU; 5/23/2007; no. 158). View to the NW across SJB-Experimental Range Subbasin and Early Pleistocene fluvial plain of the ARG (La Mesa geomorphic surface). Soil scientist Lee Gile in USDA-ARS soil-test pit that exposes a stage-V petrocalcic horizon. *See Pl. F7-1b* for exposure details.

Pl. F7-1b (NM WRRI; 5/24/2000; no. 159). Degraded, stage-V petrocalcic soil exposed in 12-ft (3.7-m) deep USDA-ARS test-pit (**Pl. F7-1a**). The soil caps Upper SFG Camp Rice Fm ARG (USF2) deposits that include Jemez Mtn.-derived clasts of 1.61 Ma. Guaje Pumice (Mack et al. 1996, Goff and Gardner 2004, Dunbar 2005 [Tbl. 2], Mack 2018 [FIG. 3.18]). USDA-NRCS Soil Scientist, Carolyn Olsen is at lower right.

Pl. F7-1c (NM BMMR; 10/1981; no. 160). Stage V petrocalcic soil capping Upper SFG-ARG deposits on Upper La Mesa Surface west of the East Robledo fault zone (ERfz). The Organ Mountains are on the skyline east of the Mesilla Valley (MeV) and the south end of the Southern Jornada Basin (SJB). Retired SCS Soil Scientist, Lee Gile stands in drainage trench at east edge of the Las Cruces Airport (Gile et al. 1981, p. 118-124; Machette 1985; Gile et al. 1995, p. 16; Mack et al. 1993). *See Pl. F2-8* for site-location and **Pl. F6-2f** for exposure details.

Pl. F7-1d (NM WRRI; 5/17/2007; no. 161). Mid-Pleistocene solution-pipe in stage-V petrocalcic soil exposed in the south face of the airport-drainage trench shown in **Pl. F7-2c**.

Pl. F7-1e (NMSU; 7/18/1988; no. 162). View to the west from a 1988 NMSU calcic-soil research trench at northeastern edge of the Lower La Mesa surface, with the East Robledo fault zone (ERfz) and Upper La Mesa surface on the western horizon (Monger et al. 1991, Gile et al. 1995 [p. 30-32. FIG. 17]). John Hawley stands below a stage-IV petrocalcic soil (**Pl. F7-1e**) that overlies the Camp Rice Fm ARG facies (USF2, LFA 2). *See* **Pls. F5-3h** and **F7-1f**.

Pl. F7-1f (NM WRRI; 5/22/2007; no. 163). Two-meter (~80-in) exposure of the Stage-IV petrocalcic soil in the upper part of 1988 NMSU calcic-soil research trench shown in **Pl. F7-1e**.

Pl. F7-1g (UACJ-Granados Olivas; 1/14/2003; no. 164). John Hawley at exposure of stage-III/IV petrocalcic soil that caps Camp Rice Fm deposits of mixed fluvial and eolian origin shown in **Pl. F5-4a**. *See* **Pl. F2-7** for southwestern Hueco Bolson site location.

Plates F7-2a to F7-2d. Pleistocene Volcanic Ash-Fall Deposits that are Interbedded with or Cap Upper Santa Fe Gp-Camp Rice Fm Basin Fill.

Pl. F7-2a (USDA-SCS; 3/1975; no. 166). UTEP Biostratigrapher, W.S. (Bill) Strain at exposure of a 2.1 Ma Ash-fall bed in SP[UP]RR-cut. Madden Arroyo site in the southeastern Hueco Bolson near McNary (**Pl. F3-3a**). The bed is in the basal part of the Camp Rice Fm near its erosional contact with the Fort Hancock Fm; and the ash fall is a product of the Yellowstone volcanic center-Huckleberry Ridge eruption (Izett and Wilcox 1982, Sarna-Wojcicki and Davis 1991).

Pl. F7-2b (USDA-SCS; 10/1969; no. 167). Bishop Ash-fall bed (~0.77 Ma) exposed in El Paso Natural-Gas pipeline cut W of Anthony Gap in the northern Franklin Mountains (Kelley and Matheny 1983). The ash fall is a product of the Long Valley (CA) caldera eruption (Izett et al. 1988, Sarna-Wojcicki and Davis 1991); and it caps an eolian-sand unit in the Camp Rice Fm piedmont facies (USF1/ LFA 5 & 6). *See* **Pl. F3-2h** for site location.

Pl. F7-2c (USDA-SCS; 9/1969; no. 168). Lee Gile points to base of Bishop Ash-fall bed (~0.77 Ma) exposed in Rincon Arroyo W of Grama Siding on the BNSFRR (~6 mi/10 km NNE of Rincon, NM (Seager and Hawley 1973 [Fig. 6], Kortemeier 1982, Izett et al. 1988). The bed is conformable on Upper SFG-Camp Rice Fm piedmont facies (USF1-LFA 5); and it is unconformably overlain older piedmont-slope alluvium (HSU-PAO) with a southeastern Caballo Mountains source.

Pl. F7-2d (USDA-SCS; 1972; no. 169). Lava Creek Ash-fall bed (~0.64 Ma) exposed in eastern face of Ash Mine Mesa in the upper Selden Canyon of the Rio Grande (**Pl. F4-1d**). The bed conformably overlies the highest (300-ft/90-m) RG-terrace gravel at this locality (Hawley et al. 1969b, p. 75-76, Seager et al. 1975, Fig. 10). The ash fall is a product of the Yellowstone volcanic center-Lava Creek eruption (Izett and Wilcox 1982, Sarna-Wojcicki. and Davis 1991); and the terrace gravel records the initial stage of river-valley incision following SFG deposition (Gile et al. 1995, p. 36; Connell et al. 2005).

Plates F7-3a to F7-3f. Pleistocene Basalt Flows and Associated Eruptive Material that Overlie Santa Fe Gp (SFG) Basin Fill in the Western Mesilla Basin Area.

Pl. F7-3a (USDA-SCS; 3/1965; no. 171). Eastern rim of Kilbourne Hole maar, with exposures of a Mid-Pleistocene basalt flow, and capping Late-Pleistocene vent-material and tuff-ring deposits, all of which disconformably overlie Camp Rice Fm-ARG fluvial-deltaic facies (USF2; Gile 1987a, Seager 1987, Seager et al. 1987). *See* **Pls. F3-3b**, and **F7-3b** to **3d**.

- Pl. F7-3b (USDA-SCS; 3/1965; no. 172).** Eastern rim of Kilbourne Hole (**Pl. F7-3a** detail). Tuff-ring deposits partly cover a Mid- Pleistocene basalt flow that caps Camp Rice Fm-ARG fluvial-deltaic facies (USF2, LFA 3). *See Pls. F7-3c and 3d.*
- Pl. F7-3c (USDA-SCS; 3/1965; no. 173).** Kilbourne Hole SE rim detail-1 (with 7-ft/2-m tape). Basalt flow with Late Pleistocene tuff-ring cover partly buries Camp Rice Fm fluvial deltaic facies (USF2-LFA 3). *See Pl. F7-3d.*
- Pl. F7-3d (USDA-SCS; June 1969; no. 174).** Kilbourne Hole SE rim detail-2 (with 6-ft, 2-in man). Late Pleistocene base-surge tuff-ring facies and Mid-Pleistocene basalt-flow tongue are unconformable on AGR fluvial-deltaic facies of the Camp Rice Fm (USF2-LFA 3), which has a La Mesa surface, stage- III calcic soil cap (Gile 1987a, Seager et al. 1987).
- Pl. F7-3e (Chester Callahan; 11/15/2012; no. 175).** Collapse feature in basalt-flow of the Aden volcanic field (Dunbar 2005, DeHon and Earl 2018). *See Pl. F3-3c.*
- Pl. F7-3f (PBS-Our Land: New Mexico's Environmental Past, Present and Future; Fall 2019; no. 176).** Northern rim of Potrillo Maar at Border Wall crossing (*See Pl. F3-4a*). Late Pleistocene base-surge tuff deposits disconformably overlie Camp Rice Fm-ARG fluvial-deltaic facies (USF2-LFA 3), with capping La Mesa Surface petrocalcic soil (white layer). *See Reeves and DeHon 1965, Seager and others 1984, Hoffer 2001a, Dunbar 2005.*

Plates F7-4a to F7-4e. Quaternary Faults and Fault Scarps.

- Pl. F7-4a (USDA-SCS; Spring 1968; no. 178).** Canyon-wall exposure of the East Robledo fault zone (ERfz) at the base of the Robledo Mountain Uplift (RMU) and the western edge of the northern Mesilla GW Basin (Seager et al. 2008). The youngest fault displacements involve Middle Pleistocene basin fill. *See Pls. F3-1d and F5-3d.*
- Pl. F7-4b (NM BMMR; 4/1981; no. 179).** East Potrillo fz (EPfz) at base of East Potrillo Mountains Uplift (EPMU) and the southwestern edge of the southern Mesilla GW Basin (MeB). Youngest fault displacement involves Middle Pleistocene basin fill (Seager and Mack 1994). *See Pls. F3-1d and F5-3d.*
- Pl. F7-4c (USDA-SCS; April 1968; no. 180).** Exposure of Camp Rice Fm-ARG facies (USF2/ LFA 2) in foot-wall block of the Jornada fz (Jfz) at the western edge of the SJB-Experimental Range Subbasin and the eastern edge of the East Tonuco Corridor (ETNC, **Pl. F1-6**, and **TbIs. F1-3** and **F1-4**). The stacked sequence of buried soils in Jfz hanging-wall colluvium documents the episodic nature of Early Pleistocene basin-boundary fault displacement (Seager et al. 1971, p. 31-33, Morgan et al. 2017, Seager et al. 2021 and 2023).
- Pl. F7-4d (NM BMMR; 8/1987; no. 181).** 90-ft (27.4-m) Late Quaternary scarp of the Cox Ranch strand of the Organ Mountains fault zone (OMfz) at the Tularosa Basin's southwestern structural boundary (Seager 1981; Machette 1987; Beehner 1990; Gile 1986, 1991 and 1994b). The northern Organ Mountains and San Agustín Pass are on the western skyline *See Pl. F7-4e* for fault-zone trench detail.
- Pl. F7-4e (NM BMMR; 8/1987; no. 182).** Cox Ranch strand of the OMfz exposed in trench about 0.5 mi (0.8 km) southeast of the **Pl. F7-4d** photo site, and at the western edge of the WSMR HQ area of the Tularosa Basin. At least 32 ft (10 m) of Holocene fault displacement has occurred at this locality, with as much as 10 ft (3 m) taking place in the past 2,000 years.

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Topic/Subtopic Categories, with Alphanumeric Cross-Reference Codes (Appendix B)

A. Bibliographies, Dictionaries, Glossaries, Biographies, Reviews, and News Items

- A1. Bibliographies, Dictionaries, and Glossaries
- A2. Biographies and Reviews
- A3. News Items

B. Time: Geologic, Prehistoric, and Historic

- B1. Geologic and Prehistoric Time
- B2. Prehistoric Perspective: US Southwest and Northern Mexico
- B3. Historic Perspective: US Southwest and Northern Mexico

C. Environmental, Physiographic, and Geologic Setting

- C1. Climatic, Hydrographic, Ecologic, and Paleoenvironmental Setting
- C2. Geologic and Geomorphic Setting
 - C2a. Geologic and Geomorphic Setting: Pre-1990
 - C2b. Geologic and Geomorphic Setting: Post-1989
- C3. Soil-Geomorphic Relationships and Soil Surveys
- C4. Geophysical/Geochemical Data and Interpretations

D. Basic Hydrogeologic Concepts

- D1. Conceptual Models, Definitions, and Regional Overviews
- D2. Groundwater-Flow Systems, Including Recharge

E. GIS/Remote Sensing and GW-Resource Management/Planning

- E1. GIS/Remote Sensing
- E2. Resource Management/Planning
 - E2a. Desalination
 - E2b. Recharge and Recovery
 - E2c. Groundwater-Quality Projection and Waste Management
- E3. Legal and Environmental Issues and Constraints

F. Transboundary Regional Hydrogeology and Geohydrology

- F1. Binational
- F2. USA
- F3. México

G. Early Documents on Mesilla Basin Regional Aquifer Systems (1858-1970)

- G1. 1858 to 1935
- G2. 1935 to 1970

H. Contemporary Documents on Mesilla Basin Regional Aquifer Systems

- H1. Hydrogeology
- H2. Hydrochemistry
- H3. Flow Models

I. Paleohydrology: Ancestral Fluvial and Pluvial Lake Systems

- I1. Regional Overviews
- I2. Transboundary Region Paleohydrologic Systems
- I3. Evolution of the Rio Grande Fluvial System

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PART F1. Index Maps and Diagrams (Plates F1-1 to F1-10) and Tables (Tbls. F1-1 to F1-6); with Names and Acronyms of Hydrogeologic Subdivisions and Fault Zones

PLATE and TABLE Numbers

- Pl. F1-1. (p. 3)** Index map of the Mesilla Basin region (MBR) showing locations of the Study Area (**Fig. 1-3**, red outline), major landscape features in the northern Mexican Highland section of the B&R province, and basins of the southern RG-rift province (**Fig. 1-1**). Blue shading shows the approximate extent of the areas inundated by pluvial-Lakes Palomas and Otero at their respective Late Pleistocene high stands in the Zona Hidrogeológica de Conejos Médanos/El Barreal basin complex, and the Tularosa Basin. Swanson Geoscience, LLC compilation on a 2017 Google Earth® image-base. EPdN=El Paso del Norte.
- Pl. F1-2. (p. 4)** U.S. Bureau of Reclamation Map showing locations of major surface-water management structures of the Rio Grande Project between the San Marcial (removed 1964) and Fort Quitman Gaging Stations. EBID indicates Elephant Butte Irrigation District operations (courtesy of Rhea Graham; *cf.* USBOR 2011).
- Pl. F1-3. (Rpt. PL. 1A; p. 4 [p. 5 in APNDX F-Part 1])** Study Area index map showing locations of the Mesilla, Southern Jornada, and El Parabién groundwater (GW) basins (MeB, SJB and EPB; outlined in green, orange, and red, respectively). Also shown are the locations of hydrogeologic cross-section A-A' to S-S' (Report **PLATES 5a to 5s**), major terrain features (incl. the Mesilla Valley, Selden Canyon and El Paso del Norte of the Rio Grande), and the Las Cruces and El Paso/Ciudad Juárez metropolitan centers. USGS DEM base, with UTM-NAD83 SI-system and latitude/longitude coordinates.
- Pl. F1-4. (F1-4a and 1-4b; p. 6 and 7)** Index maps to major geohydrologic features of the Study Area (**Fig. 1-3**). The approximate pre-development (~1976) potentiometric-surface altitude (amsl) is shown on **Pl. F1-4a** with 20- and 100-ft contours, and on **Pl. F1-4b** with 5-, 10-, and 30-m contours. Major surface-watershed divides are shown by solid and dashed thick blue lines. The dashed blue line with arrows in the map's SW corner marks the approximate boundary between EPdN- and Los Muertos Basin-directed GW flow.
- Pl. F1-5. (Rpt. PL. 1B; p. 24 [p. 8 in APNDX F-Part 1])** Index map for major hydrogeologic subdivisions of the Study Area (**Fig. F1-5**). The Mesilla GW Basin (MeB) is in blue shades, and the Mesilla Valley of the Rio Grande is in dark blue. El Parabién and Southern Jornada GW Basins (EPB and SJB) are in pink and light green, respectively. SCyn-Selden Canyon and EPdN-El Paso del Norte. Solid and dashed black lines are boundaries of interbasin-uplift and intrabasin subdivisions. Acronyms and names of hydrogeologic-subdivision categories, including fault zones (lines with bar and ball symbols), are defined in **Tbls. F1-1 and F1-2** (Rpt. **Tbls. 1-4 and 1-5**). USGS DEM base.
- Table F1-1. (p. 9 and 10)** Names and Acronyms of Hydrogeologic Subdivisions shown on Maps, Cross-Sections, and the Well-Information Spreadsheet (**PLS. 1 to 8, TBLS. 1 to 3, and Fig. 1-8 and Tbl. 1-5**)
- Table F1-2. (p. 11)** Names, and Acronyms for Basin- and Subbasin-Boundary Fault Zones (**Pl. F1-5**).
- Pl. F1-6. (p. 12)** Pliocene and Early Pleistocene geomorphic setting of the ARG distributive fluvial system (DFS-red lines) that terminated in the Lake Cabeza de Vaca (LCdV) basin complex of Strain (1966, 1971). Schematic depiction of ARG distributary channel-belt in the southeastern B&R province (adapted from Hawley 1975, Fig. 2). Explanations of the symbols that show the general positions of primary Distributive Fluvial System (DFS)-apex and channel-belt-segments of ancestral rivers with fluvial-deltaic termini in the LCdV basin complex on **Table F1-3**. The Rios Casas

Grandes (violet), Santa Maria and Carmen (pink and orange), and the Mimbres River (yellow) remain as the major surface and subsurface flow fluvial contributors to ephemeral lake-plain remnants of Late Quaternary Paleo-Lake Palomas: Lagunas Guzman, Santa Maria and Patos, and El Barreal-Salinas de Unión. Only parts of the Mesilla Basin and Hueco Bolson have surface/subsurface connection with Rio Grande at present (*cf.* **Pls. F1-2** and **F1-3**; Hawley 1975, Gile et al. 1981, Connell et al. 2005, Castiglia and Fawcett 2006, Weissmann et al. 2011, Davidson et al. 2013, and Nichols 2015). 2018 Google Earth® image base.

Table F1-3. (p. 13) Explanation of **Plate F1-6** alpha-numeric symbols for Pliocene and early Pleistocene Distributive Fluvial Systems (DFSs) of ancestral-river systems with fluvial-deltaic termini in the Paleo-Lake Cabeza de Vaca complex (LCdV) and Bolson de los Muertos (BdlM).

Pl. F1-7. (p. 14) Schematic distribution patterns of major lithofacies assemblages (LFAs) in intermontane-basin and river-valley fills of the RG-rift province. Modified from Hawley and others (1995, Fig. 6) and Hawley and Kernodle (2000). *See* **Plate 1-8** and **Tables F1-4** to **F1-6**.

Pl. F1-8. (p. 15) Idealized triangular diagram of dominant textural classes in lithofacies assemblages (LFAs) 1 to 10; and primary LFA composition of SFG Hydrostratigraphic Units (HSUs) - USF/MSF/LSF. *See* **Plate F1-7** and **Tables F1-4** to **F1-6**.

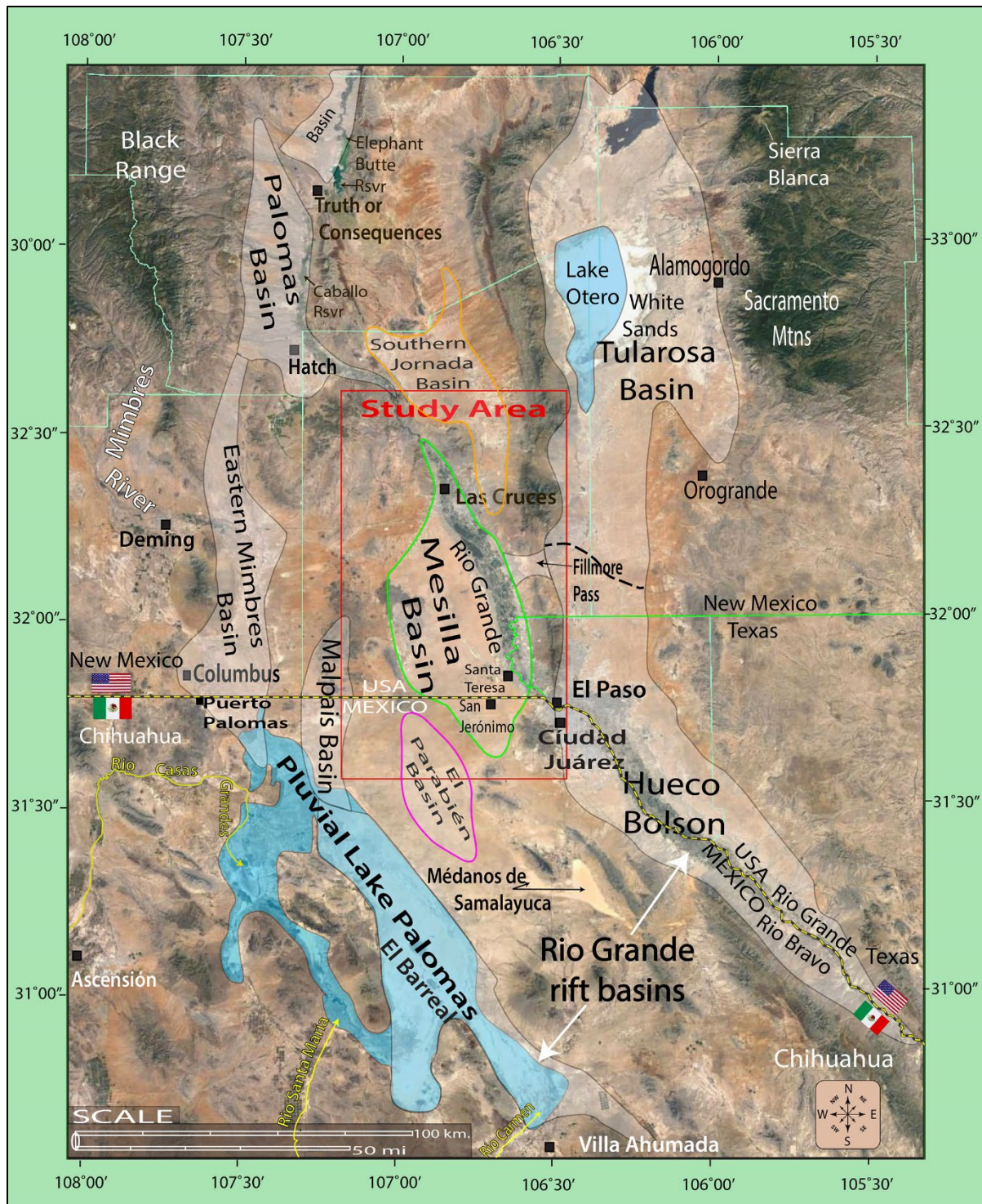
Table F1-4. (p. 16) Summary of depositional setting and dominant textures of major lithofacies assemblages (LFAs) in Santa Fe Group basin fill (1-10) and Rio Grande Valley fill (a-c) in the intermontane basins of the Rio Grande rift tectonic province. Modified from Hawley and Kernodle (2000). *See* **Plates F1-7** and **8**, and **Tables F1-5** and **F1-6**.

Table F1-5. (p. 17) Summary of major sedimentary properties that influence groundwater-flow and aquifer-production potential of Lithofacies Assemblages (LFAs) 1 to 10 in Santa Fe Group basin fill. Modified from Haase and Lozinsky (1992). *See* **Plates F1-7** and **8**, and **Table F1-4**.

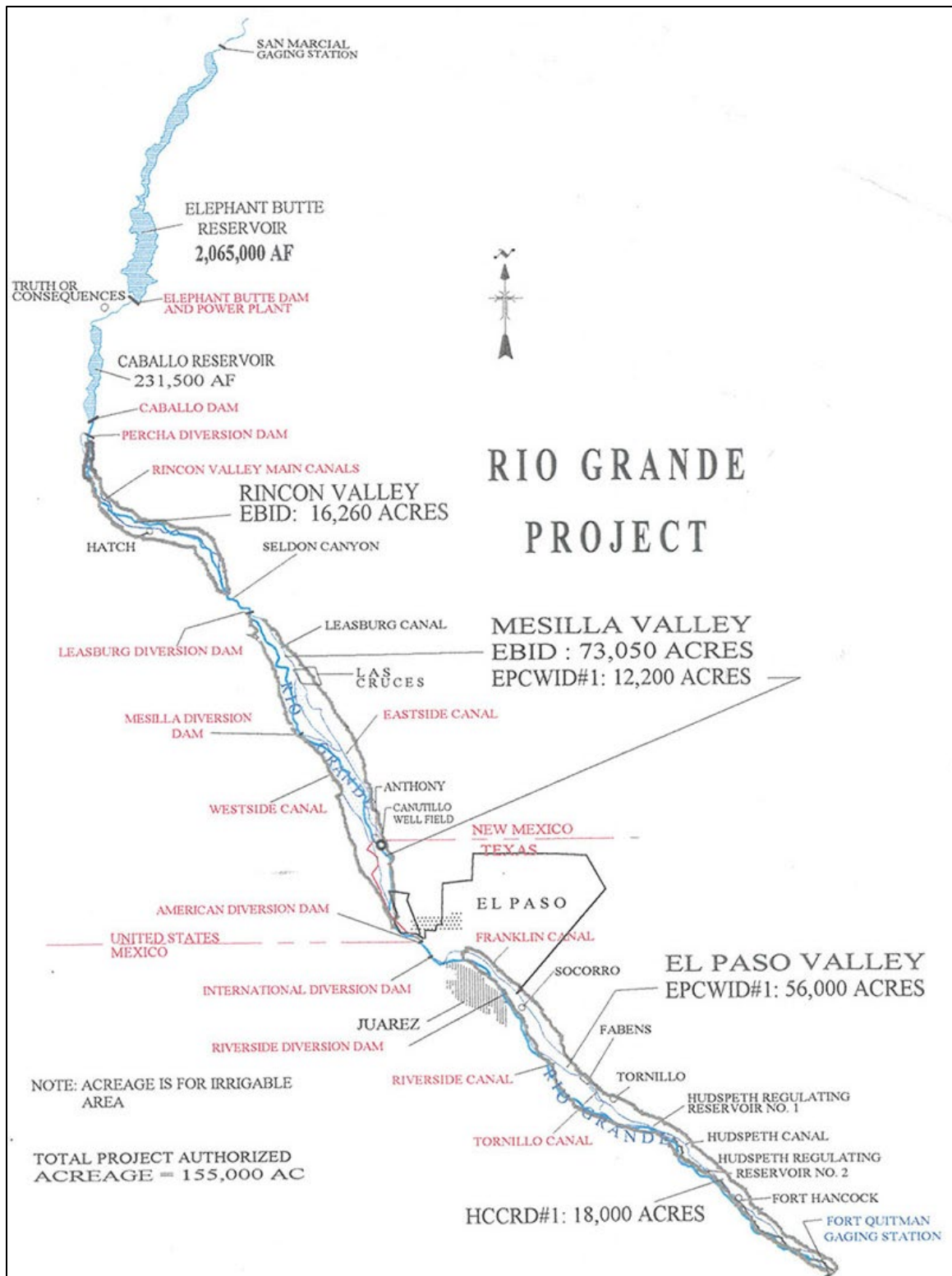
Table F1-6. (p. 17) Summary of major sedimentary properties that influence groundwater-flow and aquifer-production potential of Lithofacies Assemblages (LFAs) a to c in post-SFG RG-valley and basin fills. Modified from Hawley and Kernodle (2000). *See* **Plates F1-7** and **8**, and **Table F1-4**.

Pl. F1-9. (Modified from Hawley et al. 2009, Fig. 6; p. 18) Correlation diagram of major Time-Rock classes, and lithostratigraphic and hydrostratigraphic units of Cenozoic Age in the southern RG-rift region of New Mexico, Texas, and Chihuahua. Bedrock units: Qb—Quaternary basalt, Tb—Tertiary mafic volcanics, and Tv—older Tertiary intermediate and silicic volcanics, and associated plutonic-igneous and sedimentary rocks. *See* **Pls. F1-7** and **F-8**, **TbIs. F1-4** to **F1-6**.

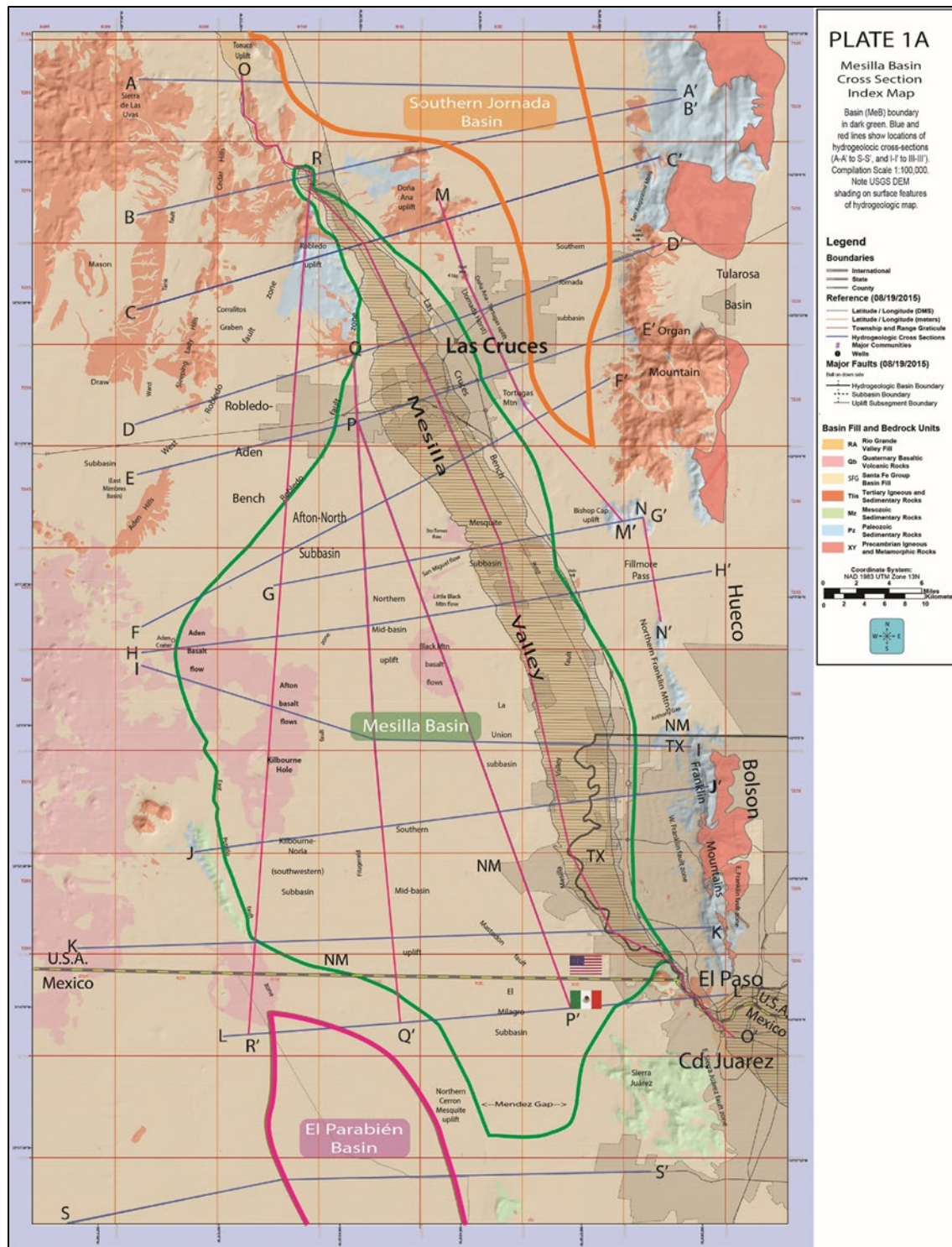
Pl. F1-10. (p. 19) Definitions of Divisions of Geologic Time used in this Report.



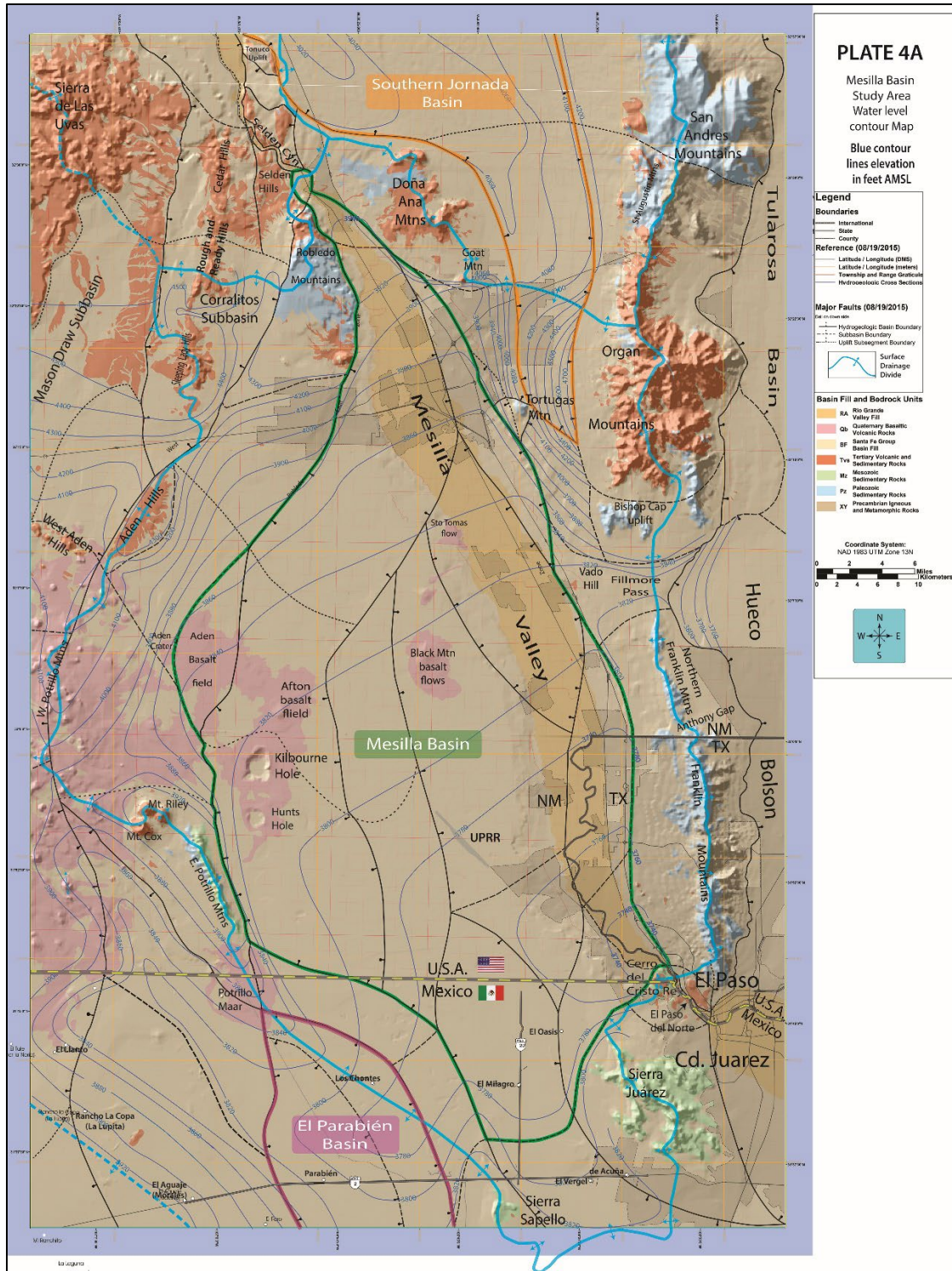
Pl. F1-1. Index map of the Mesilla Basin region (MBR) showing locations of the Study Area (**Fig. 1-3**, red outline), major landscape features in the northern Mexican Highland section of the B&R province, and basins of the southern RG-rift province (**Fig. 1-1**). Blue shading shows the approximate extent of the areas inundated by pluvial-Lakes Palomas and Otero at their respective Late Pleistocene high stands in the Zona Hidrogeológica de Conejos Médanos/El Barreal basin complex, and the Tularosa Basin. Swanson Geoscience, LLC compilation on a 2017 Google Earth® image-base. EPdN=El Paso del Norte.



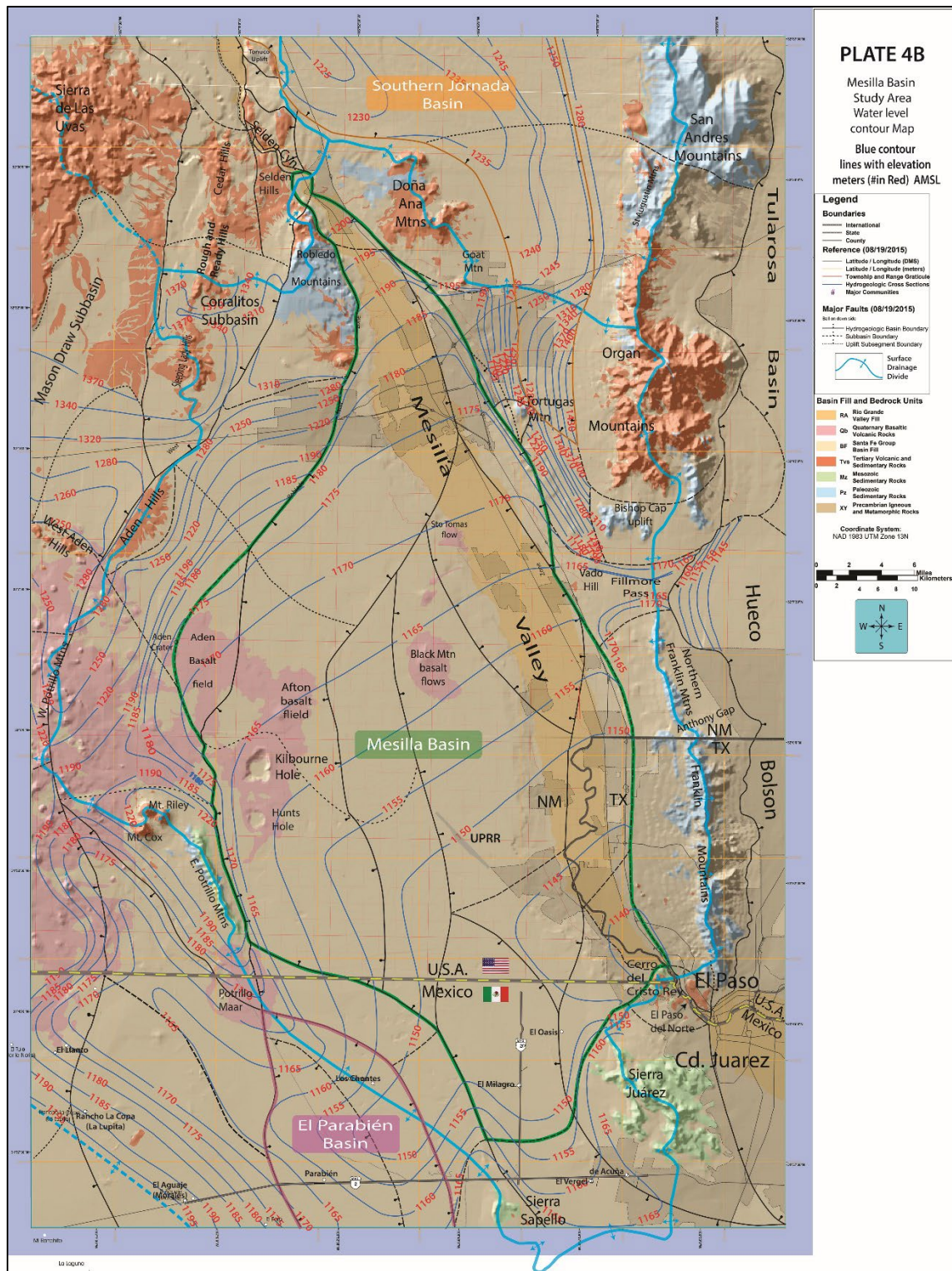
Pl. F1-2. U.S. Bureau of Reclamation Map showing locations of major surface-water management structures of the Rio Grande Project between the San Marcial (removed 1964) and Fort Quitman Gaging Stations. EBID indicates Elephant Butte Irrigation District operations (courtesy of Rhea Graham; cf. USBOR 2011).



PL F1-3. (Rpt. PL. 1A) Study Area index map showing locations of the Mesilla, Southern Jornada, and El Parabién groundwater (GW) basins (MeB, SJB and EPB; outlined in green, orange, and red, respectively). Also shown are the locations of hydrogeologic cross-section A-A' to S-S' (Report PLATES 5a to 5s), major terrain features (incl. the Mesilla Valley, Selden Canyon and El Paso del Norte of the Rio Grande), and the Las Cruces and El Paso/Ciudad Juárez metropolitan centers. USGS DEM base, with UTM-NAD83 SI-system and latitude/longitude coordinates.



Pl. F1-4a. Index map to major geohydrologic features of the NM WRI Study Area (**Fig. 1-3**). The approximate pre-development (~1976) potentiometric-surface altitude (amsl) is shown on **Pl. F1-4a** with 20- and 100-ft contours, and on **Pl. F1-4b** with 5-, 10-, and 30-m contours. Major surface-watershed divides are shown by solid and dashed thick blue lines. The dashed blue line with arrows in the map's SW corner marks the approximate boundary between EPdN- and Los Muertos Basin-directed GW flow.



Pl. F1-4b. Index map to major geohydrologic features of the NM WRI Study Area (**Fig. 1-3**). The approximate pre-development (~1976) potentiometric-surface altitude (amsl) is shown on **Pl. F1-4a** with 20- and 100-ft contours, and on **Pl. F1-4b** with 5-, 10-, and 30-m contours. Major surface-watershed divides are shown by solid and dashed thick blue lines. The dashed blue line with arrows in the map's SW corner marks the approximate boundary between EPdN- and Los Muertos Basin-directed GW flow.

Table F1-1. Names and Acronyms of Hydrogeologic Subdivisions shown on Maps, Cross-Sections, and the Well-Information Spreadsheet (**PLS. 1 to 8, TBLs. 1 to 3, and Fig. 1-8 and Tbl. 1-5**)

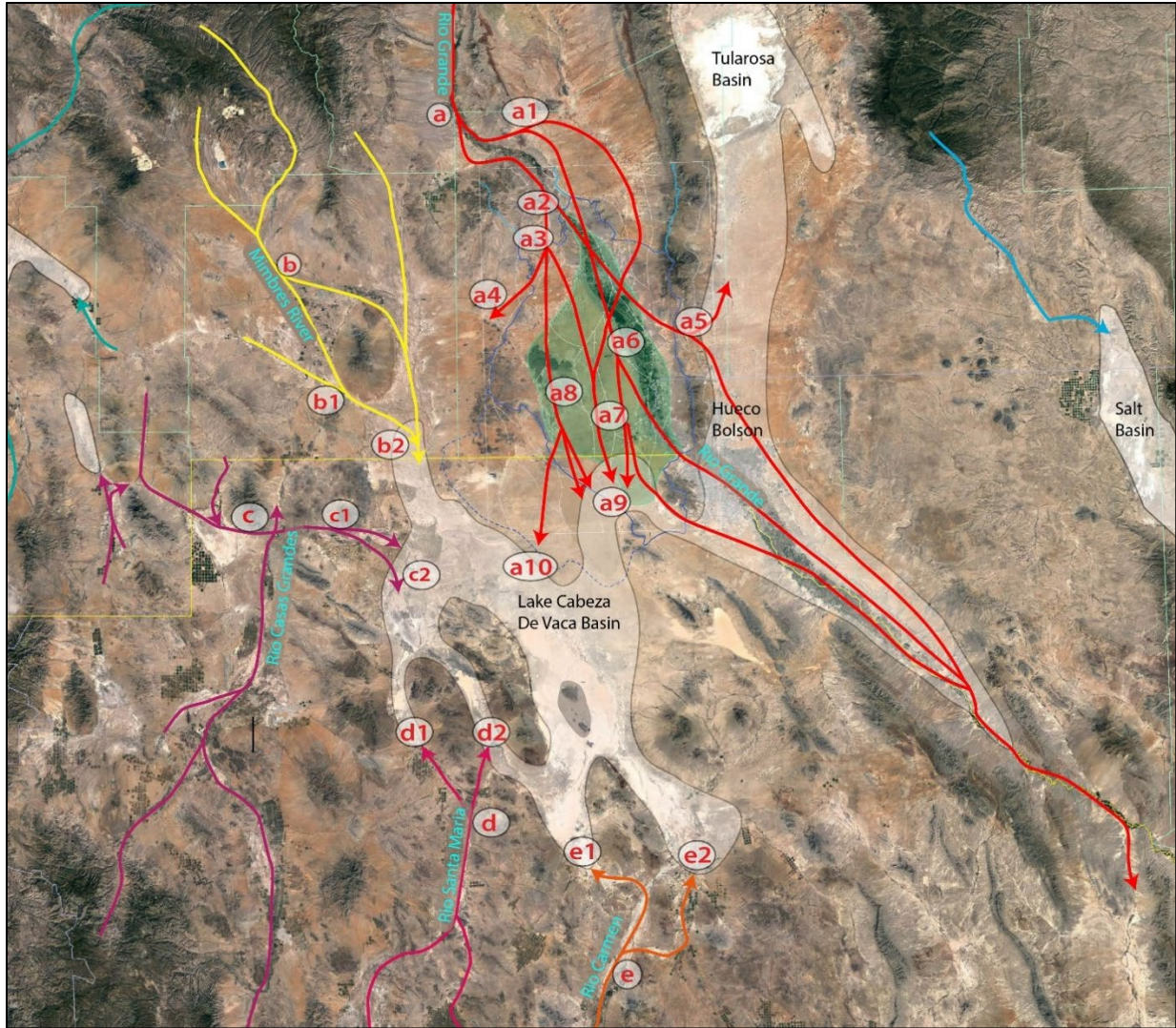
<u>ACRONYM</u>	<u>RIO GRANDE (RG) VALLEY AND CANYONS (NARROWS)</u>	
EPdN	El Paso del Norte (Cyn)	
MeV	Mesilla Valley	
SCyn	Selden Canyon (Cyn)	
EPJV	El Paso-Juárez Valley	
<u>ACRONYM</u>	<u>MESILLA GW BASIN (MeB)</u>	<u>SUBDIVISION (2,419: area in km²)</u>
MeB-ACBn	Mesilla Basin	Anthony-Canutillo Bench (138)
MeB-AfSB	Mesilla Basin	Afton Subbasin (180)
MeB-AOBn	Mesilla Basin	Anapra-Oasis Bench (72.7)
MeB-BMSB	Mesilla Basin	Black Mountain Subbasin (353)
MeB-EABn	Mesilla Basin	East Aden Bench (70.7)
MeB-EMSB	Mesilla Basin	El Milagro Subbasin (203)
MeB-FASB	Mesilla Basin	Fairacres Subbasin (382)
MeB-KNSB	Mesilla Basin	Kilbourne-Noria Subbasin (278)
MeB-LBic	Mesilla Basin	Leasburg Inflow Corridor (25.4)
MeB-LCBn	Mesilla Basin	Las Cruces Bench (97.5)
MeB-MSB	Mesilla Basin	Mesquite Subbasin (228)
MeB-NMbH	Mesilla Basin	North Mid-Basin High (143)
MeB-SMbH	Mesilla Basin	South Mid-Basin High (121)
MeB-STBn	Mesilla Basin	Santa Teresa High (89.5)
MeB-SPoc	Mesilla Basin	Sunland Park Outflow Corridor (33.4)
<u>ACRONYM</u>	<u>OTHER GW BASINS (B)</u>	<u>SUBDIVISION</u>
EPB	El Parabién Basin (N-part—Drains to MeB)	
EPB-EESB	El Parabién Basin	El Espejo Subbasin (157)
EPB-LCSB	El Parabién Basin	Los Chontes Subbasin (126)
HB	Hueco Bolson (W-edge—Receives inflow from MeB through EPdN)	
HB-NWSB	Hueco Bolson	Northwestern Subbasin
HB-NWSB	Hueco Bolson	Southwestern Subbasin
MbB	Mimbres Basin (No-flow boundary with MeB; surface and subsurface flow to Los Muertos Basin (LMB—Bolsón de los Muertos)	
MbB-WPBn	Mimbres Basin	West Potrillo Bench
MpB	Malpais GW Basin (E-edge—connects with BTC, MbB, and LMB)	
MpB-GLSB	Malpais Basin	Guzmans Lookout Subbasin (SB)
MpB-LLBn	Malpais Basin	La Laguna Bench (Bn)
RVB	Rincon Valley GW Basin (Drains to MeB through SCyn)	
RVB-BASB	Rincon Valley Basin	Bignell Arroyo Subbasin (47.2)
RVB-TNoc	Rincon Valley Basin	Tonuco Outflow Corridor (5)
SJB	Southern Jornada GW Basin (495-Drains to MeB and RVB)	
SJB-ERSB	Southern Jornada Basin	Experimental Range Subbasin (264)
SJB-ILSB	Southern Jornada Basin	Isaacks Lake Subbasin (164)
SJB-TvSB	Southern Jornada Basin	Talavera Subbasin (68.2)
SWTB	Southwestern Tularosa Basin	
<u>ACRONYM</u>	<u>UPLAND GW BASIN</u>	<u>SUBDIVISION</u>
CCUB	Cedar-Corralitos Upland Basin (UB)	
CCUB-CHSB	Cedar-Corralitos	Cedar Hills Subbasin (96.2)
CCUB-CRSB	Cedar-Corralitos	Corralitos Ranch Subbasin (205)

Table F1-1. (concluded) Names and abbreviations of Hydrogeologic Subdivisions

<u>ACRONYM</u>	<u>INTERBASIN HIGH (IBH)</u>	<u>SUBDIVISION</u>
PSH	Potrillo-Sapello High (163)	
PSH-LJS		La Joya Sector (93.5)
PSH-CMIC		Chontes-Milagro Inflow Corridor (69.5) (EPB-LCSB to MeB-EMSB)
<u>ACRONYM</u>	<u>INTERBASIN UPLIFT (U)</u>	<u>SUBDIVISION</u>
AHU	Aden Hills Uplift	
ARU	Aden-Robledo Uplift	
ARU-AdS	Aden-Robledo Uplift	Aden Sector (S)
ARU-SR _{ic}	Aden-Robledo Uplift	South Robledo Inflow Corridor (145)
BCU	Bishop Cap Uplift	
BHU	Black Hills Uplift	
CAHU	Campus-Andesite Hills Uplift	
CCRU	Cerro del Cristo Rey Uplift	
CMU	Camel Mountain Uplift	
DAMU	Doña Ana Mountains Uplift	
EAU	El Aguaje Uplift (310)	
EPU	East Potrillo Uplift	
EPU-BT _{ic}	East Potrillo Uplift	Brock Tank Inflow Corridor (227)
EPU-PR _S	East Potrillo Uplift	Potrillo-Mt. Riley Sector (S)
FMU	Franklin Mountains Uplift	
OMU	Organ Mountains Uplift	
RMU	Robledo Mountains Uplift	
SAMU	San Andres Mountains Uplift	
SHU	Selden Hills Uplift	
SJU	Sierra Juárez Uplift	
SSU	Sierra Sapello Uplift (41)	
TMU	Tonuco Mountain Uplift	
TtU	Tortugas Uplift	
TtMU	Tortugas Uplift	Tortugas Mountain Uplift (U)
TtU-NT _{ic}	Tortugas Uplift	North Tortugas Inflow Corridor (63.5)
TtU-ST _{ic}	Tortugas Uplift	South Tortugas Inflow Corridor (59.2)
UGU	Uvas-Goodsight Uplift	
UGU-SLU	Uvas-Goodsight Uplift	Sierra de las Uvas (U)
UGU-MDS	Uvas-Goodsight Uplift	Mason Draw Sector (S)
UGU-ML _{ic}	Uvas-Goodsight Uplift	Muzzle Lake Inflow Corridor (to Mimbres Basin-MbB)
WAU	West Alden Uplift	
<u>ACRONYM</u>	<u>MAJOR INTERBASIN GROUNDWATER-FLOW CORRIDORS</u>	
BTC	Border Tank Corridor (214)	
	(Malpais Basin to El Parabién Basin underflow)	
ETNC	East Tonuco Corridor (13.5)	
	(Jornada Basin to Rincon Valley Basin underflow)	
FPC	Fillmore Pass Corridor (73.7)	
	(Mesilla Basin-Hueco Bolson—potential inter-basin underflow)	
MVIC	Méndez-Vergel Inflow Corridor (115)	
	(possible Hueco Bolson to Mesilla Basin underflow)	

Table F1-2. Names, and Acronyms for Basin- and Subbasin-Boundary Fault Zones (**Pl. F1-5**)

I. Groundwater Basin/Intrabasin-Boundary Fault Zones (fz) A. Mesilla and El Parabién Basins - Mesilla Basin (MeB) CBfz—Chamberino fz EVfz—El Vergel fz EPfz—East Potrillo fz ERfz—East Robledo fz FGfz—Fitzgerald fz MBfz—Mid-Basin fz MDfz—Mastodon fz MVfz—Mesilla Valley fz NRfz—Noria fz SPfz—San Pablo fz SSfz—Sierra Sapello fz TTfz—Tortugas fz - El Parabién Basin (EPB) EFfz—El Faro fz EGfz—El Girasol fz LCfz—Los Cuates fz B. Southern Jornada and Rincon Valley Basins - Southern Rincon Valley Basin (SJB) TNfz—Tonuco fz WTfz—Ward Tank fz - Southern Jornada Basin (SJB) EJfz—East Jornada fz Jfz—Jornada fz C. Hueco Bolson and Tularosa Basin - Northwestern Hueco Bolson (NWHB) FMfz—Franklin Mountain fz SJfz—Sierra Juárez fz - Southwestern Tularosa GW Basin (SWTB) OMfz—Organ Mountains fz SAMfz—San Andres Mountains Fz D. Western-Border Basins - Cedar-Corralitos Upland Basin (CCUB) CHfz—Cedar Hills fz WRfz—West Robledo fz WTfz—Ward Tank fz - Northeastern Mimbres Basin (MbB) WTfz—Ward Tank fz WRfz—West Robledo fz - Malpais Basin (MpB) LPfz—La Peña fz	II. Inter-basin Uplift Fault Zones (fz)—Boundary and Interior A. Aden-Robledo Uplift (ARU) - ERfz—East Robledo fz - WRfz—West Robledo fz B. Doña Ana Mountain Uplift (DAMU) - Jfz—Jornada fz - MVfz—Mesilla Valley fz - TTfz—Tortugas fz C. East Potrillo Uplift (EPU) - EPfz—East Potrillo fz - MRfz—Mount Riley fz D. El Aguaje Uplift (EAU) - EFfz—El Faro fz - LPfz—La Peña fz E. Franklin Mountains Uplift (FMU) - FMfz—Franklin Mountains fz - WFfz—West Franklin fz F. Organ Mountain Uplift (OMU) - EJfz—East Jornada fz - OMfz—Organ Mountains fz G. Robledo Mountain Uplift (RMU) - ERfz—East Robledo fz - WRfz—West Robledo fz H. Sierra Juárez Uplift (SJU) - SJfz—Sierra Juárez fz - EVfz—El Vergel fz I. Sierra Sapello Uplift - SSfz—Sierra Sapello fz - LCfz—Los Cuates fz J. Southern San Andres Mtns (SAMU) - EJfz—East Jornada fz - SAMfz—San Andres Mountains fz K. Tortugas Uplift (TtU) - Jfz—Jornada fz - TTfz—Tortugas fz III. Inter-basin Corridor Boundary-fault zones (fz) A. Border Tank Corridor (BTC) - LPfz—La Peña fz - MRfz—Mount Riley fz B. Fillmore Pass Corridor (FPC) - FMfz—Franklin Mountains fz - MVfz—Mesilla Valley fz C. Méndez-Vergel Corridor (MVC) - EVFZ—El Vergel fz - SSfz—Sierra Sapello fz
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Pl. F1-6. Pliocene and Early Pleistocene geomorphic setting of the ARG distributive fluvial system (DFS- red lines) that terminated in the Lake Cabeza de Vaca (LCdV) basin complex of Strain (1966, 1971). Schematic depiction of ARG distributary channel-belt in the southeastern B&R province (adapted from Hawley 1975, Fig. 2). Explanations of the symbols that show the general positions of primary Distributive Fluvial System (DFS)-apex and channel-belt-segments of ancestral rivers with fluvial-deltaic termini in the LCdV basin complex on **Table F1-3**. The Rios Casas Grandes (violet), Santa Maria and Carmen (pink and orange), and the Mimbres River (yellow) remain as the major surface and subsurface flow fluvial contributors to ephemeral lake-plain remnants of Late Quaternary Paleo-Lake Palomas: Lagunas Guzman, Santa Maria and Patos, and El Barreal-Salinas de Union. Only parts of the Mesilla Basin and Hueco Bolson have surface/subsurface connection with Rio Grande at present. (*cf.* **Pls. F1-2** and **F1-3**; Hawley 1975, Gile et al. 1981, Connell et al. 2005, Castiglia and Fawcett 2006, Weissmann et al. 2011, Davidson et al. 2013, and Nichols 2015). 2018 Google Earth® image base.

Table F1-3. Explanation of **Plate F1-6** alpha-numeric symbols for Pliocene and Early Pleistocene Distributive Fluvial Systems (DFSs) of ancestral rivers with fluvial-deltaic termini in the Paleo-Lake Cabeza de Vaca complex (LCdV) and Bolson de los Muertos (BdLM)

A. APEX AREA OF THE ANCESTRAL RIO GRANDE-CAMP RICE FM DFS (ARG-DFS) IN THE SOUTHERN JORNADA BASIN, HUECO BOLSON, AND LOS MUERTOS BASIN (BdLM) —RED LINES

- a1. Eastern Rincon Valley head of the ARG-DFS distributary-channel complex in the Southern Jornada Basin.
- a2. Upper Selden Canyon head of the ARG-DFS distributary-channel complex in the central and eastern Mesilla Basin area.
- a3. Lower Selden Canyon head of the ARG-DFS distributary-channel complex in the western Mesilla Basin area.
- a4. Cedar-Corralitos Basin head of the ARG-DFS distributary-channel complex in the northwestern Mesilla and northeastern Mimbres Basin areas.
- a5. Fillmore Pass head of the ARG-DFS distributary-channel complex in the western Tularosa Basin and northwestern Hueco Bolson area (**Fig. 1-15**, Seager 1981 [Fig. 84]).
- a6. South-central Mesilla Basin head of the ARG-DFS distributary-channel complex in the El Parabién Basin-Paso del Norte area.
- a7. Southeastern Mesilla Basin head of the ARG-DFS distributary-channel complex in the El Parabién Basin, Méndez-Vergel Corridor, and southwestern Hueco Bolson area.
- a8. Southwestern Mesilla Basin head of the ARG-DFS distributary-channel complex in the El Parabién Basin and the northeastern LCdV-BdLM.
- a9. South-central termini of ARG-DFS fluvial-deltaic distributaries in the northeastern LCdV-BdLM.
- a10. Southwestern termini of ARG-DFS fluvial-deltaic distributaries in the northwestern LCdV-BdLM.

B. APEX AREA OF THE ANCESTRAL RIO MIMBRES-UPPER GILA GP DFS (ARM-DFS—YELLOW LINES) IN THE NORTHERN LCdV-BdLM

- b1. Southeastern Mimbres Basin head of the ARM-UGDFS fluvial-deltaic distributaries.
- b2. Southern termini of ARM-DFS fluvial-deltaic distributaries in the northern LCdV-BdLM.

C. APEX AREA OF THE ANCESTRAL RIO CASAS GRANDES-BOCA GRANDE DFS (ARCG-DFS—VIOLET LINES) IN THE NORTHWESTERN LCdV-BdLM

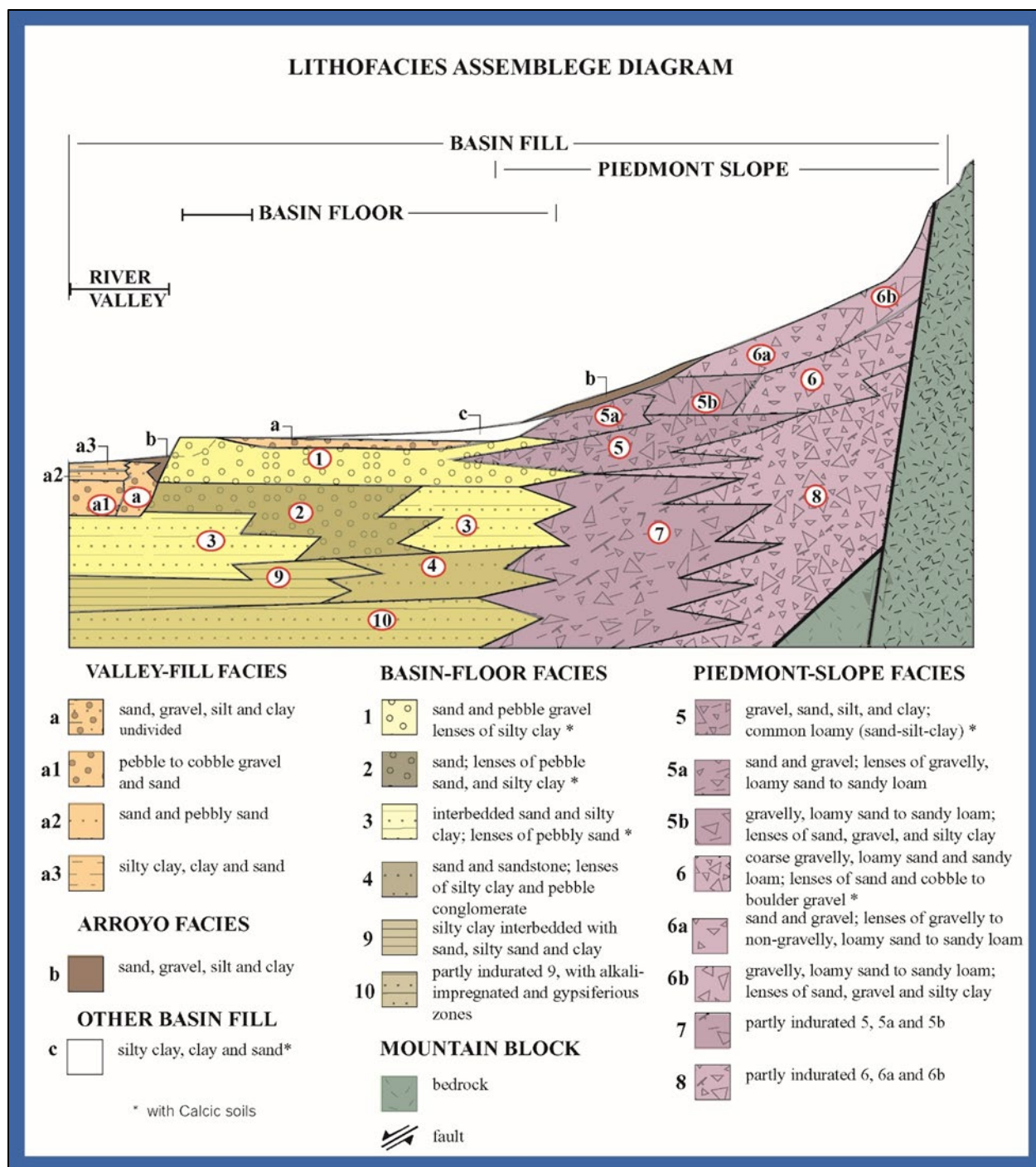
- c1. Head of ARCG-BGDFS fluvial-deltaic distributaries in the northwestern LCdV-BdLM.
- c2. Eastern termini of ARCG-DFS fluvial-deltaic distributaries in the northwestern LCdV-BdLM.

D. APEX AREA OF THE ANCESTRAL RIO SANTA MARIA DFS (ARSM-DFS—PINK LINES) IN THE SOUTHWESTERN LCdV-BdLM

- d1. Eastern termini of ARSM-DFS fluvial-deltaic distributaries south of Laguna Santa Maria.
- d2. Western termini of ARSM-DFS fluvial-deltaic distributaries south of Laguna Fresnal.

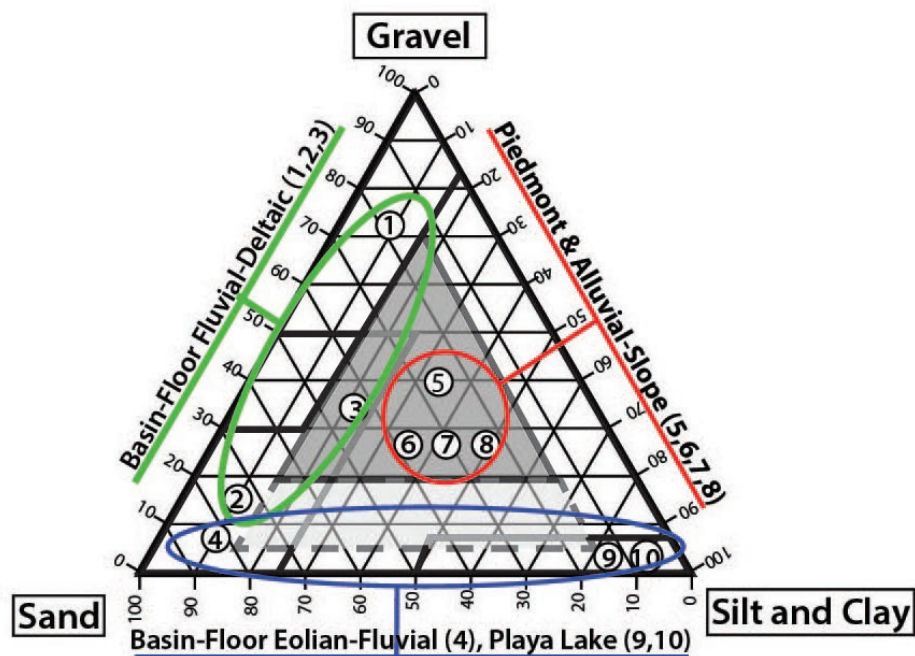
E. APEX AREA OF THE ANCESTRAL RIO CARMEN DFS (ARC-DFS—ORANGE LINES) IN THE SOUTHEASTERN LCdV-BdLM

- e1. Eastern termini of ARC-DFS fluvial-deltaic distributaries in the southeastern LCdV-BdLM near Villa Ahumada and Laguna Patos.
- e2. Western termini of ARC-DFS fluvial-deltaic distributaries northwest of Carrizal in the southeastern LCdV-BdLM.



Pl. F1-7. Schematic distribution patterns of major lithofacies assemblages (LFAs) in intermontane-basin and river-valley fills of the RG-rift province. Modified from Hawley and others (1995, Fig. 6) and Hawley and Kernodle (2000). See **Plate 1-8** and **Tables F1-4** to **F1-6**.

Dominant Lithofacies Assemblage (LFA)



Primary Hydrostratigraphic Unit (HSU) Components

USF-2,4: 1,2,3,9

MSF-2, 4: 2,3,9,10

LSF: 4,7,8,9,10

USF-1,3: 5,6

MSF-1,3: 7,8

General Properties

Provenance:

Local: 5,6,7,8

Extrabasinal/Local: 1,2,3,9,10

Non-to Partly Indurated: 1,2,3,4,5,6,9,10

Partly Indurated to Indurated: 7,8

Pl. F1-8. Idealized triangular diagram of dominant textural classes in lithofacies assemblages (LFAs) 1 to 10; and primary LFA composition of SFG Hydrostratigraphic Units (HSUs) - USF/MSF/LSF. See **Plate F1-7** and **Tables F1-4** to **F1-6**.

Table F1-4. Summary of depositional setting and dominant textures of major lithofacies assemblages (LFAs) in Santa Fe Group basin fill (1-10) and Rio Grande Valley fill (a-c) in the intermontane basins of the Rio Grande rift tectonic province. Modified from Hawley and Kernodle (2000). *See Plates F1-7 and 8, and Tables F1-5 and F1-6.*

Lithofacies	Dominant depositional settings and process	Dominant textural classes
1	Basin-floor fluvial plain	Sand and pebble gravel, lenses of silty clay
2	Basin-floor fluvial, locally eolian	Sand; lenses of pebbly sand and silty clay
3	Basin-floor, fluvial-overbank, fluvial-deltaic and playa-lake; eolian	Interbedded sand and silty clay; lenses of pebbly sand
4	Eolian, basin-floor alluvial	Sand and sandstone; lenses of silty sand to clay
5	Distal to medial piedmont-slope; alluvial fan	Gravel, sand, silt, and clay; common loamy (sand-silt-clay)
5a	Distal to medial piedmont-slope, alluvial fan; associated with large watersheds; alluvial-fan distributary-channel primary; sheet-flood and debris-flow secondary	Sand and gravel; lenses of gravelly, loamy sand to sandy loam
5b	Distal to medial piedmont-slope, alluvial fan; associated with small steep watersheds, debris-flow sheet-flood, and distributary-channel	Gravelly, loamy sand to sandy loam; lenses of sand, gravel, and silty clay
6	Proximal to medial piedmont-slope, alluvial-fan	Coarse gravelly, loamy sand and sandy loam; lenses of sand and cobble to boulder gravel
6a	Like 5a	Sand and gravel; lenses of gravelly to non-gravelly, loamy sand to sandy loam
6b	Like 5b	Gravelly, loamy sand to sandy loam; lenses of sand, gravel, and silty clay
7	Like 5	Partly indurated 5
8	Like 6	Partly indurated 6
9	Basin-floor-alluvial flat, playa, lake, and fluvial-lacustrine; distal-piedmont alluvial	Silty clay interbedded with sand, silty sand, and clay
10	Like 9, with evaporite processes (paleophreatic)	Partly indurated 9, with gypsiferous and alkali-impregnated zones
a	River-valley, fluvial	Sand, gravel, silt, and clay
a1	Basal channel	Pebble to cobble gravel and sand (like 1)
a2	Braided plain, channel	Sand and pebbly sand (like 2)
a3	Overbank, meander-belt oxbow	Silty clay, clay, and sand (like 3)
b	Arroyo channel and valley-border alluvial-fan	Sand, gravel, silt, and clay (like 5)
c	Basin floor, alluvial flat, cienega, playa, and fluvial-fan to lacustrine plain	Silty clay, clay, and sand (like 3,5, and 9)

Table F1-5. Summary of major sedimentary properties that influence groundwater-flow and aquifer-production potential of Lithofacies Assemblages (LFAs) 1 to 10 in Santa Fe Group basin fill. Modified from Haase and Lozinsky (1992). *See Plates F1-7 and 8, and Table F1-4.*

Lithofacies	Ratio of sand plus gravel to silt plus clay ¹	Bedding thickness (meters)	Bedding configuration ²	Bedding continuity (meters) ³	Bedding connectivity ⁴	Hydraulic conductivity (K) ⁵	Groundwater production potential
1	High	>1.5	Elongate to planar	>300	High	High	High
2	High to moderate	>1.5	Elongate to planar	>300	High to moderate	High to moderate	High to moderate
3	Moderate	>1.5	Planar	150 to 300	Moderate to high	Moderate	Moderate
4	Moderate to low*	>1.5	Planar to elongate	30 to 150	Moderate to high	Moderate	Moderate
5	Moderate to high	0.3 to 1.5	Elongate to lobate	30 to 150	Moderate	Moderate to low	Moderate to low
5a	High to moderate	0.3 to 1.5	Elongate to lobate	30 to 150	Moderate	Moderate	Moderate
5b	Moderate	0.3 to 1.5	Lobate	30 to 150	Moderate to low	Moderate to low	Moderate to low
6	Moderate to low	0.3 to 1.5	Lobate to elongate	130 to 150	Moderate to low	Moderate to low	Low to moderate
6a	Moderate	0.3 to 1.5	Lobate to elongate	30 to 150	Moderate	Moderate to low	Moderate to low
6b	Moderate to low	0.3 to 1.5	Lobate	<30	Low to moderate	Low to moderate	Low
7	Moderate*	0.3 to 1.5	Elongate to lobate	30 to 150	Moderate	Low	Low
8	Moderate to low*	>1.5	Lobate	<30	Low to moderate	Low	Low
9	Low	>5	Planar	>150	Low	Very low	Very low
10	Low*	>5	Planar	>150	Low	Very low	Very low

¹High >2; moderate 0.5-2; low <0.5
²Elongate (length to width ratios >5); planar (length to width ratios 1-5); lobate (asymmetrical or incomplete planar beds).
³Measure of the lateral extent of an individual bed of given thickness and configuration.
⁴Estimate of the ease with which groundwater can flow between individual beds within a particular lithofacies. Generally, high sand + gravel/silt + clay ratios, thick beds, and high bedding continuity favor high bedding connectivity. All other parameters being held equal, the greater the bedding connectivity, the greater the groundwater production potential of a sedimentary unit.
⁵High 10 to 30 m/day; moderate, 1 to 10 m/day; low, <1 m/day; very low, <0.1 m/day.
*Significant amounts of cementation of medium to coarse-grained beds (as much as 50%)

Table F1-6. Summary of major sedimentary properties that influence groundwater-flow and aquifer-production potential of Lithofacies Assemblages (LFAs) a to c in post-SFG RG-valley and basin fills. Modified from Hawley and Kernodle (2000). *See Plates F1-7 and 8, and Table F1-4.*

Lithofacies	Ratio of sand plus gravel to silt plus clay ¹	Bedding thickness (meters) ³	Bedding configuration ²	Bedding continuity (meters) ³	Bedding connectivity ⁴	Horizontal hydraulic conductivity (K) ⁵	Groundwater production potential
a	High to moderate	>1.5	Elongate to planar	>300	High to moderate	High to moderate	High to moderate
a1	High	>1.5	Elongate to planar	>300	High	High	High
a2	High to moderate	>1.5	Planar to elongate	150 to 300	Moderate to high	Moderate	Moderate
a3	Moderate to low	>1.5	Planar to elongate	30 to 150	Moderate to high	Moderate to low	Moderate to low
b	Moderate to low	0.3 to 1.5	Elongate to lobate	<300	Moderate	Moderate to low	Moderate to low
c	Low to moderate	0.3 to 1.5	Elongate to lobate	30 to 150	Low	Low	Low

¹High >2; moderate 0.5-2; low <0.5
²Elongate (length to width ratios >5); planar (length to width ratios 1-5); lobate (lenticular or discontinuous planar beds).
³Measure of the lateral extent of an individual bed of given thickness and configuration.
⁴Estimate of the ease with which groundwater can flow between individual beds within a particular lithofacies. Generally, high sand + gravel/silt + clay ratios, thick beds, and high bedding continuity favor high bedding connectivity. All other parameters being held equal, the greater the bedding connectivity, the greater the groundwater production potential of a sedimentary unit.
⁵High, 10 to 30 m/day; moderate, 1 to 10 m/day; low, <1 m/day; very low, <0.1 m/day.

Pl. F1-10. Definitions of Divisions of Geologic Time used in this Report.

ERA	Period	Epoch (u/m/l*)	Age (years**)
CENOZOIC (Cz)			
	Quaternary (Q)		
		Holocene (Qu)	0-11,400
		<i>Historic</i>	0-1580 CE
		Pleistocene	11,400-2.6 Ma
		Late (Qu)	11,400-126 ka
		Middle (Qm)	126 ka-780 ka
		Early (Ql)	780 ka-2.6 Ma
	Tertiary (T)		
		Late: Neogene	
		Pliocene (Tu)	2.6-5.3 Ma
		Late	2.6-3.6 Ma
		Early	3.6-5.3 Ma
		Miocene (Tu)	5.3-23 Ma
		Late	5.3-11.6 Ma
		Middle	11.6-16 Ma
		Early	16-23 Ma
		Early: Paleogene	
		Oligocene (Tm)	23-34 Ma
		Eocene (Tl)	34-55.8 Ma
		Paleocene (Tl)	55.8-65.5 Ma
MESOZOIC (Mz)			
	Cretaceous (K)		65.5-145.5 Ma
	Jurassic (Jr)		145.5-199.6 Ma
	Triassic (Tr)		199.6-251 Ma
PALEOZOIC (Pz)			
	Permian (P, Pzu)		251-299 Ma
	Pennsylvanian (Pn, Pzu)		299-318 Ma
	Mississippian (M, Pzu)		318-359 Ma
	Devonian (D, Pzl)		359-416 Ma
	Silurian (S, Pzl)		416-444 Ma
	Ordovician (O, Pzl)		444-488 Ma
	Cambrian (C, Pzl)		488-542 Ma
PRECAMBIAN-PROTEROZOIC (XY)			542 Ma-2.5Ba
PRECAMBIAN-ARCHEAN			2.5-3.85 Ba

*u/m/l = upper/middle/lower – rock[litho]-stratigraphic units

**Ba=billion years, Ma=million years, and ka=thousand years

Modified from Koning and Read (2010, Table 2)

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**PART F2—Space and High-Altitude
Photographs and Images (Plates F2-1
to F2-9).**

**Plate F2-1.
Apollo 6 mission,
multispectral 502
series (4/5/1968),
stereoscopic
space photo
(frame VI-1447).
Centers over area
of White Sands
Missile Range
(WSMR) Hq.**



Plate F2-2. Apollo 9 mission (3/9/1969), SO-65 series multispectral space photo (cropped frame AS-22-3460). About 190 km above mean sea level (amsl). Centered over El Paso del Norte of the Rio Grande and the El Paso/ Cd. Juárez Metro area.

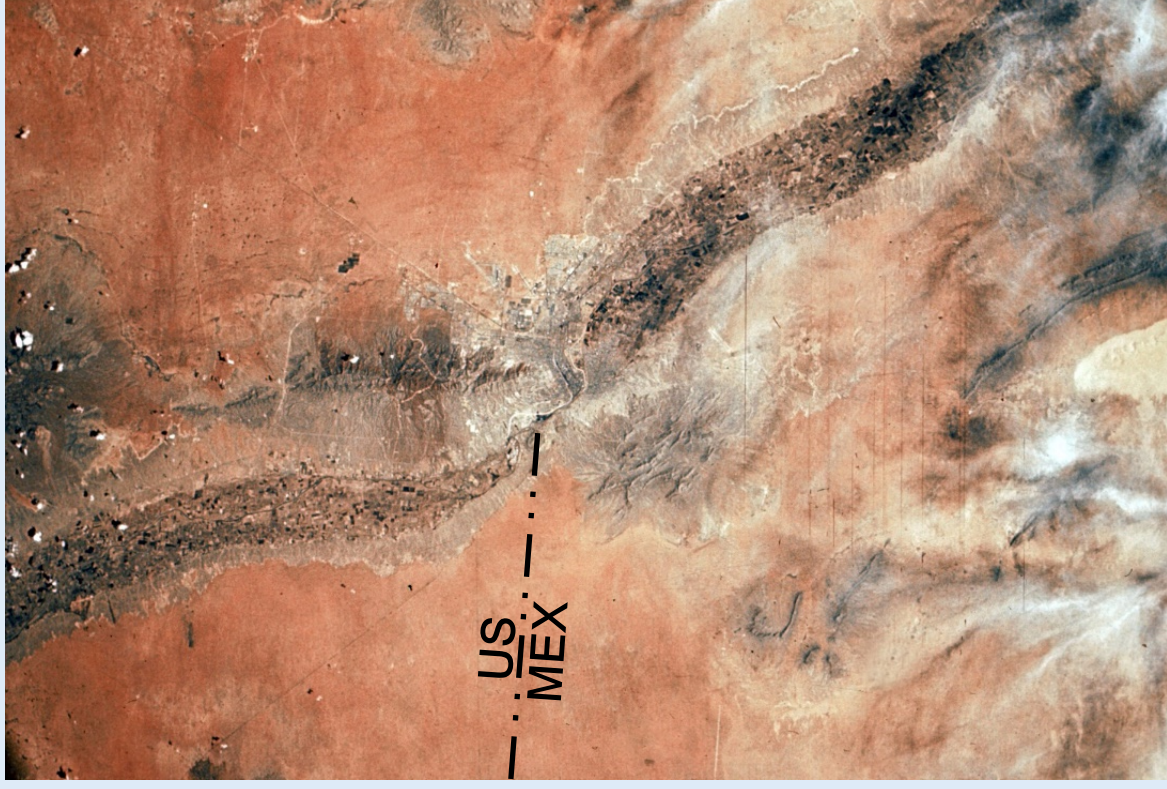


Plate F2-3. Apollo 9 mission (3/9/1969), multispectral SO-65 series, stereoscopic space photo (frame AS-22-3757). Centered over Columbus, NM and Puerto Palomas, Chihuahua.

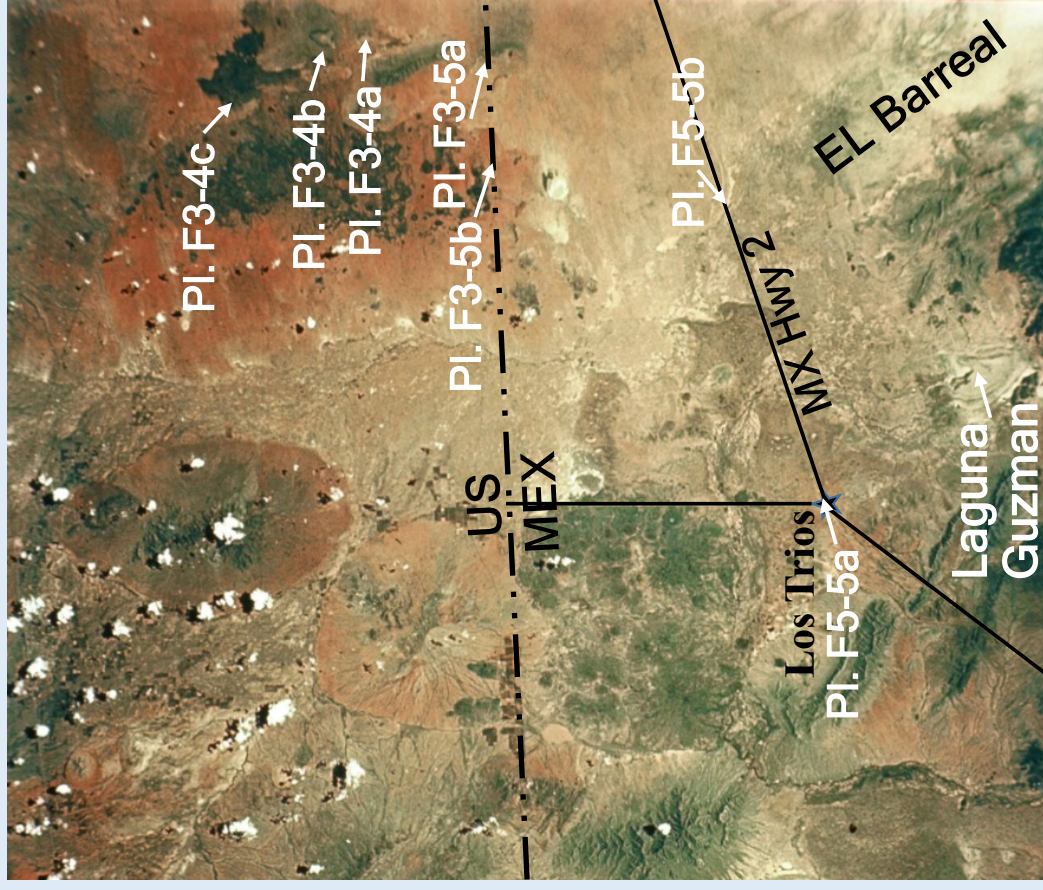


Plate F2-4 (Title). Index map of the binational/tristate region covered by parts of 1969 Apollo 9 mission space photos (F2-2 and F2-3; 2013 NM WRRRI compilation on GoogleEarth® image-base. Major landscape features include: 1) the Florida and Tres Hermanas Mtns. in the image's NW (Luna County) part; 2) the West Potrillo (basaltic volcanic field) and the East Potrillo Mtns., SE Mesilla GW Basin in its north-central part; 3) the southern Mesilla Valley, Franklin Mtns, and western edge of the Hueco Bolson in its NE part; 4) Sierras Juarez, Sapello, Presidio and Samalayuca, the Médanos de Samalayuca in its SE part; 5) El Barreal area of Bolsón de los Muerto in its south-central part; and 6) the lower Rio Casas Grande fluvial-deltaic plain and Laguna Guzman its southwestern corner.

PL. F2-4

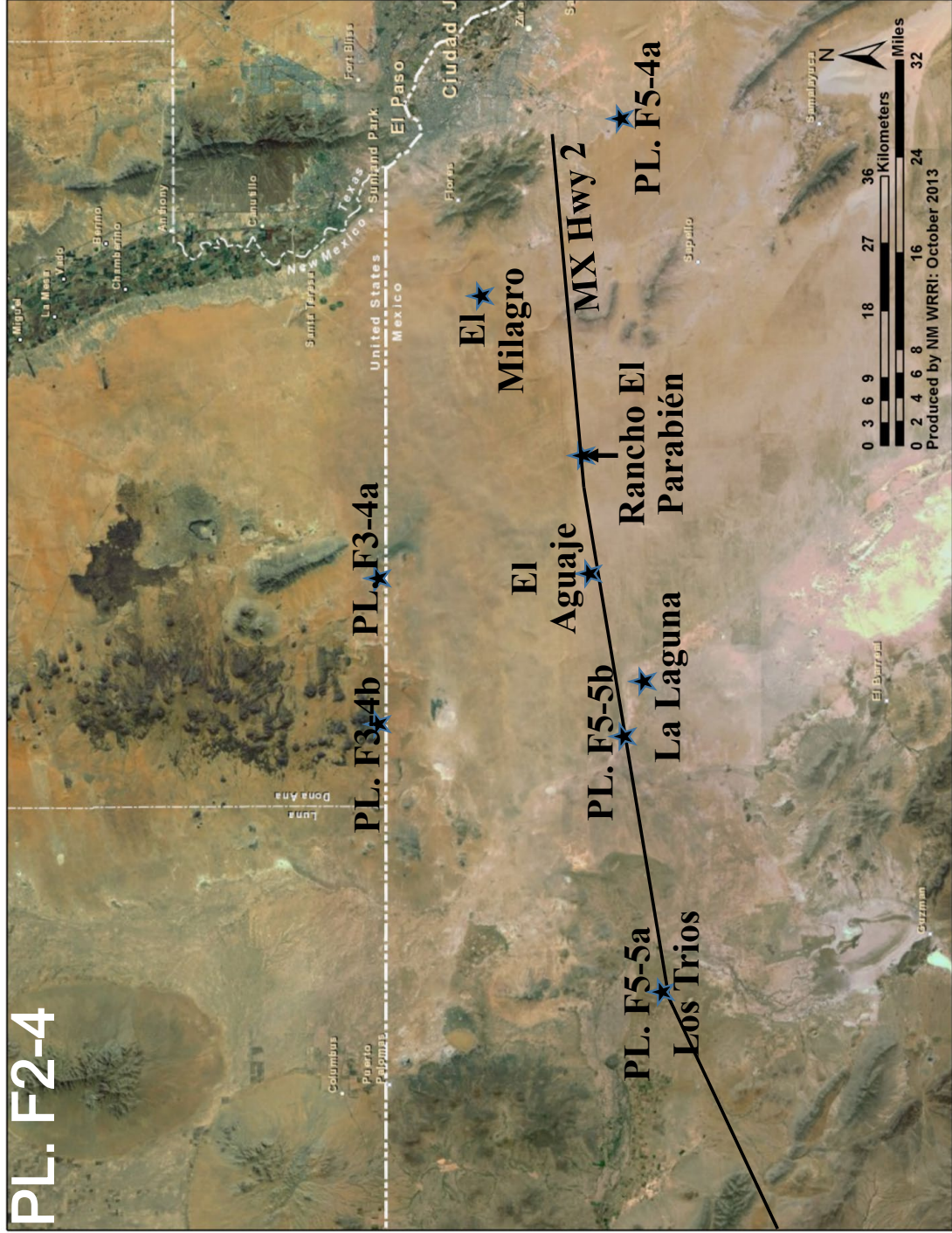


Plate F2-5. Landsat-5 Color-IR Image of the Mesilla Basin Region; with Shaded Overlay that includes the Mesilla (Ctr.) and Northern El Parabien (SW) GW Basins.

Line A——A' Shows Hydrogeologic Cross-Section I—I' Position (Report PL. 5i)

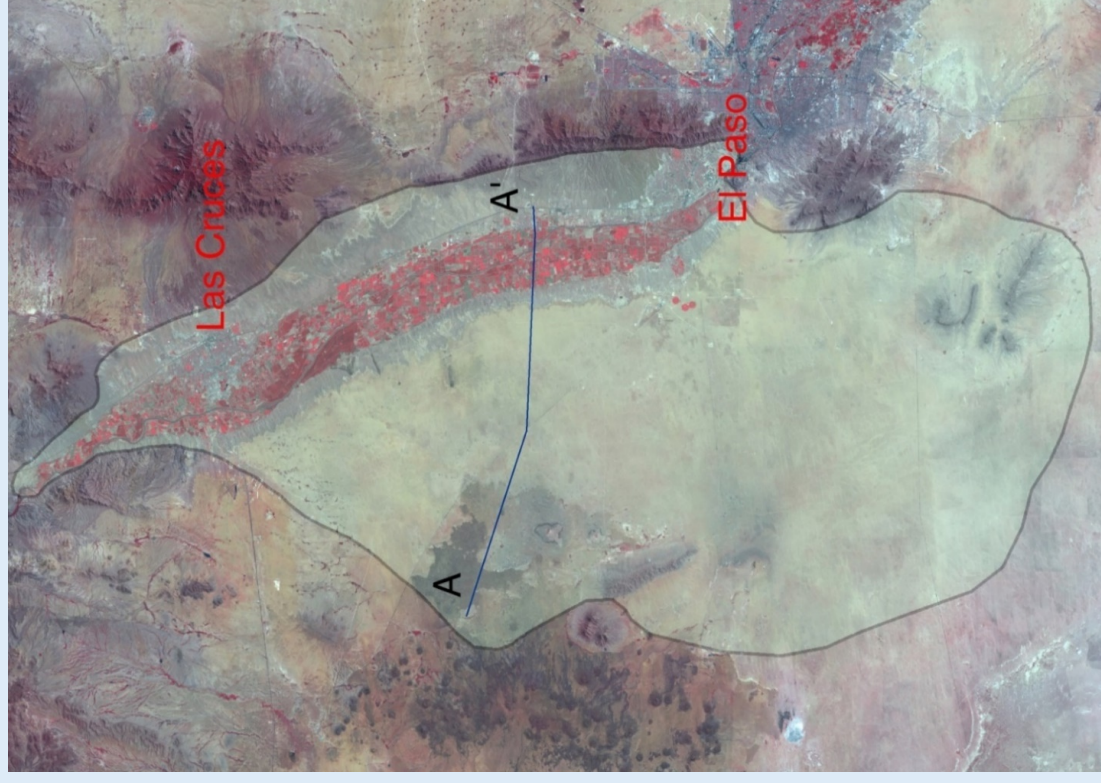


Plate F2-6 (UTEP compilation). Landsat-5TM gray-scale image centered on El Parabién Basin of Jiménez and Keller (2000). Blue line (misabeled “SW Terraces”) shows general position of ARG distributary channel between Sierras Juárez (NE) and Sapello (SW). Approximate pluvial-Lake Palomas high shoreline is mislabeled “Camel Mountain Scarp Fault.”

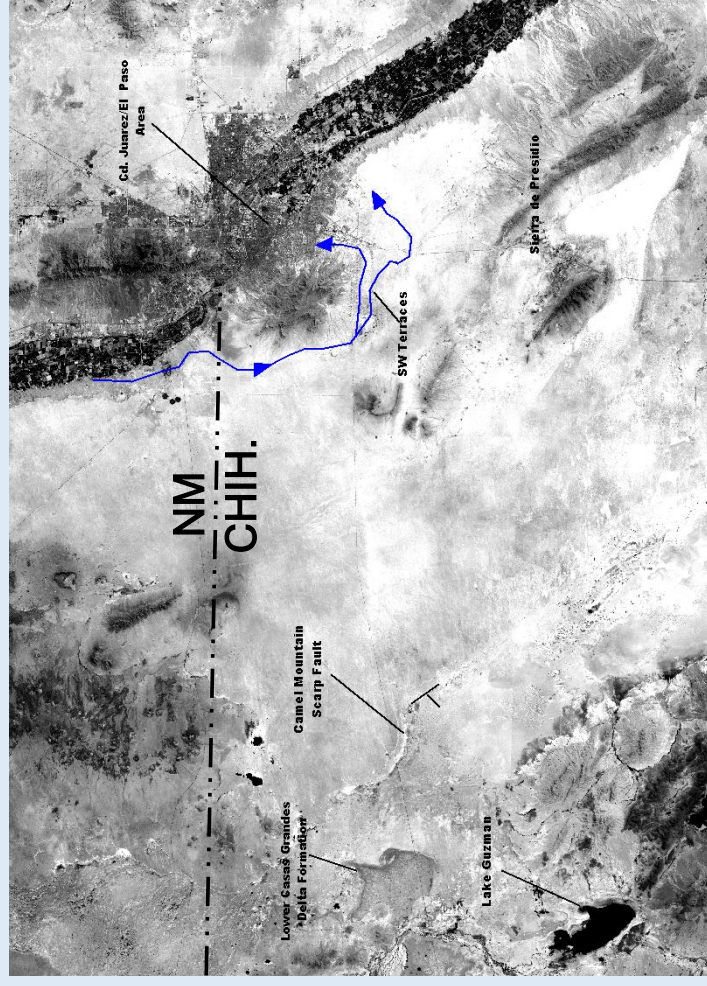


Plate F2-7. Landsat-5TM color-IR image centered on Ciudad Juárez. Hydrogeologic Cross Section GD' of Hawley and others (2009) is near Section “SW—NE.”

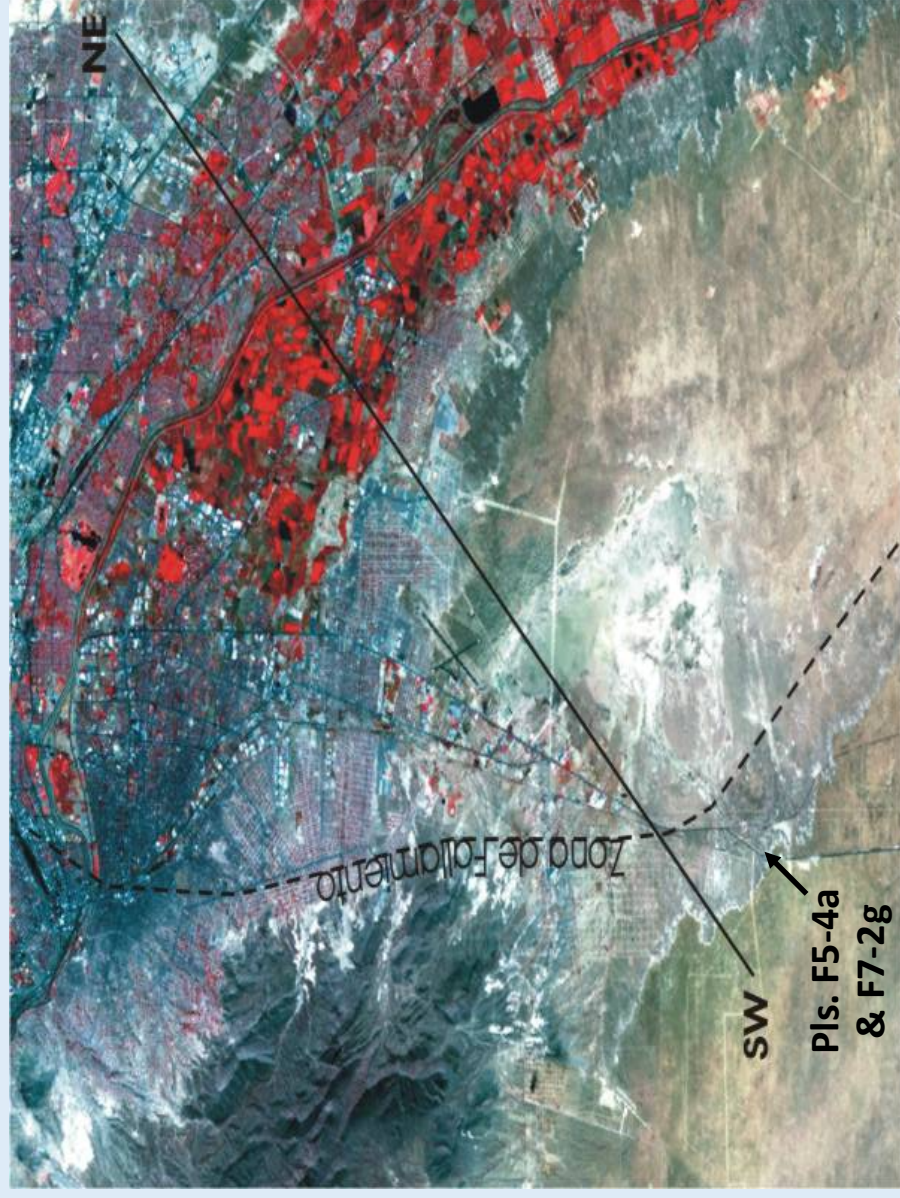


Plate F2-8. Landsat-5TM Color-IR Image of the Southern Jornada and Northern Mesilla Basin Area. Well-vegetated areas are in reddish colors, with water bodies in blue-gray.

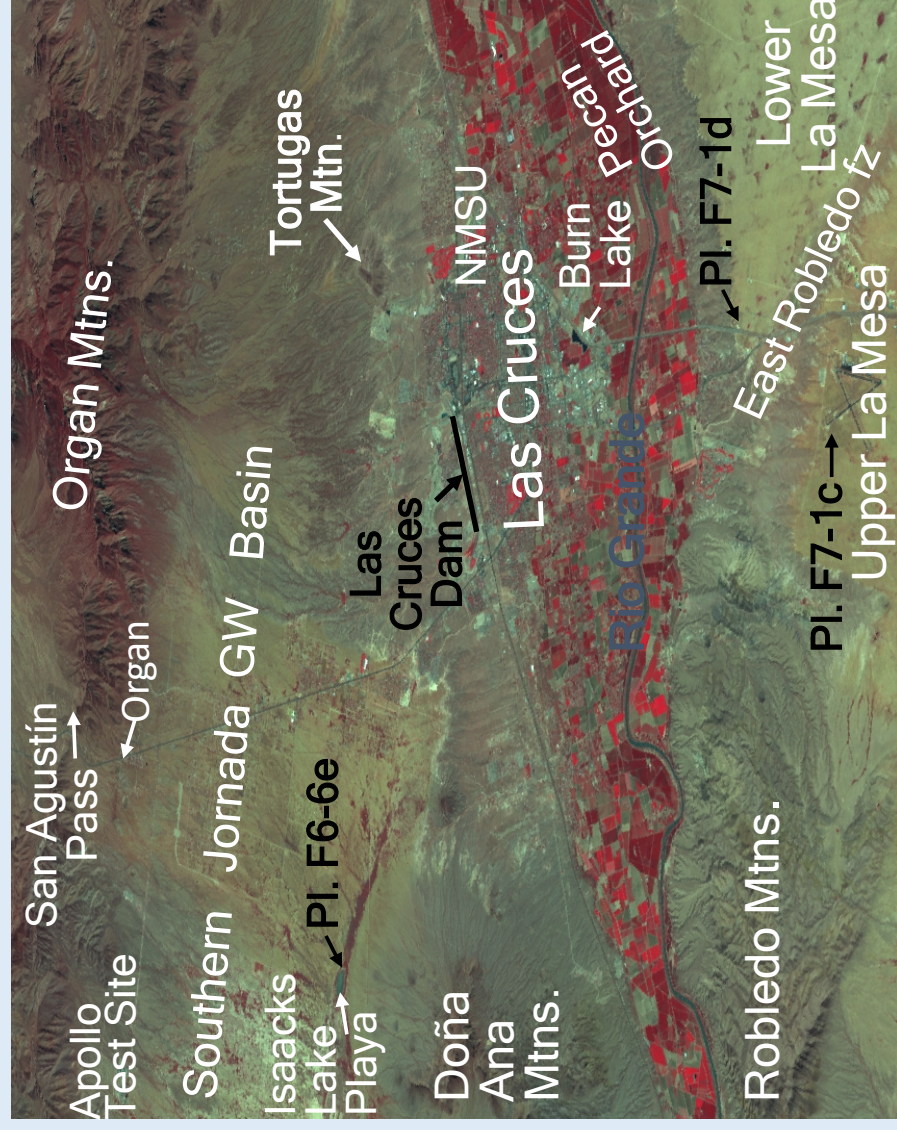
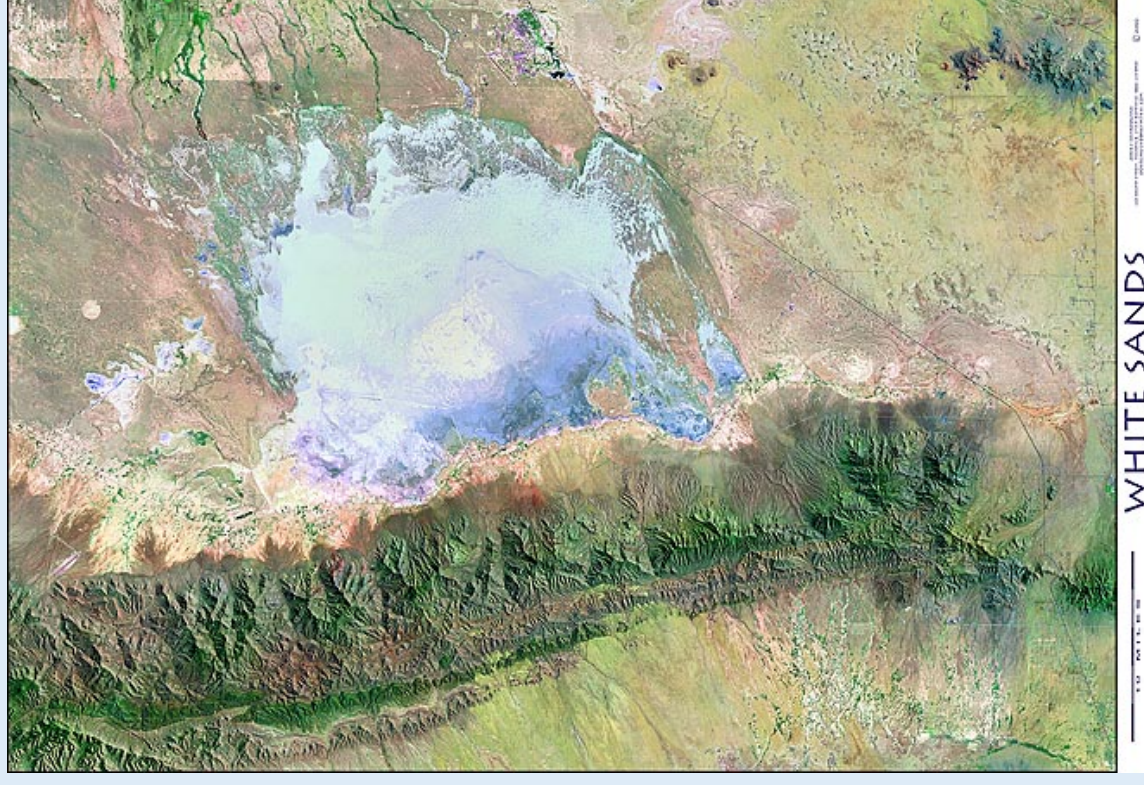


Plate F2-9. Landsat-ERTS Image of the Central Tularosa Basin Alkali Flat—White Sands Area, Southern San Andres Mtns., and Southeastern Jornada del Muerto Basin.

**2002 John C.
Dohrenwend®
Compilation**



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**PART F3—Plates F3-1 to F3-4 Series.
Low-Level Aerial Photographs of
Major Landscape, Cultural, and
Hydrogeologic Features in the
Southern Rio Grande Rift Region.**

**Plates F3-1a to F3-1j. USGS-NAQUA
Project—June 4, 1991, Rio Grande Valley
and Canyon Overflight Series: Elephant
Butte Reservoir to the Lower Mesilla
Valley. *See* Plate 1-3 RG Project Map.**

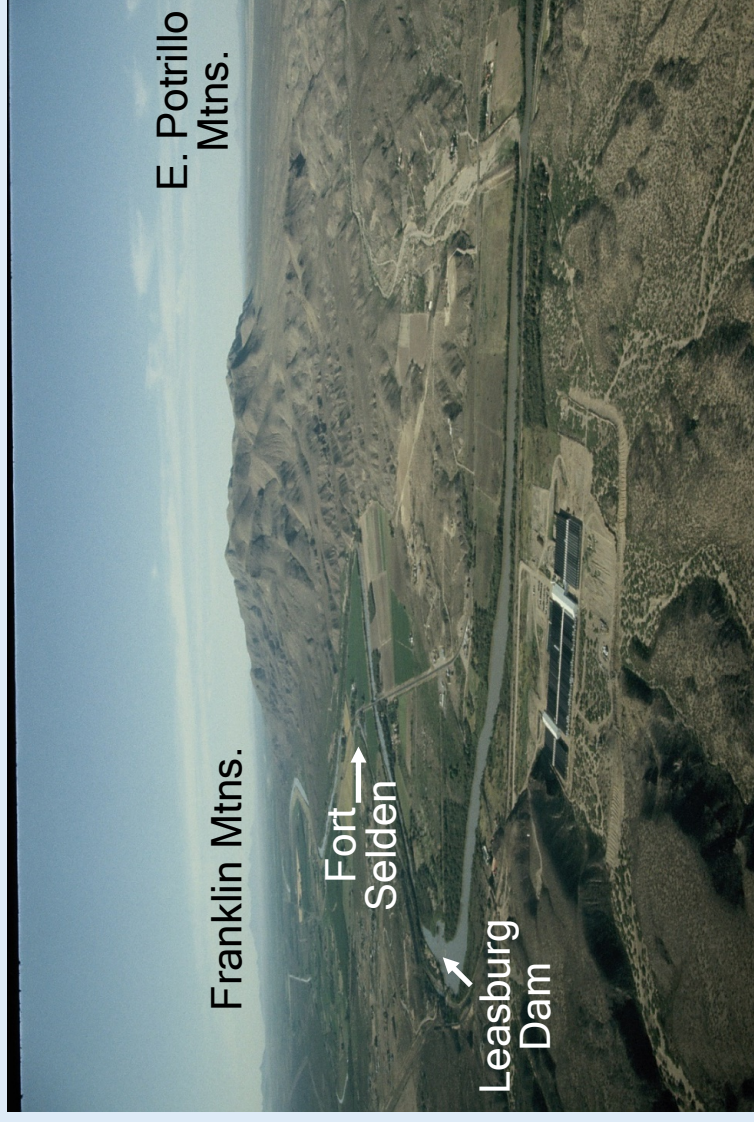
Pl. F3-1a (NM BMMR). View to SW from south end of Elephant Butte (EB) Reservoir toward northern Palomas Basin and southern Black Range. EB “Island” and Dam in foreground, with Rio Grande canyon reach between Dam and the City of T or C.



Pl. F3-1b (NM BMMR). View to W from Caballo Dam and Reservoir on the Rio Grande up Percha Creek Valley in the Palomas Basin (Pls. F5-3a and 3b). Southern Black Range (peak alt. 10,011 ft/3,051 m) is on the skyline.



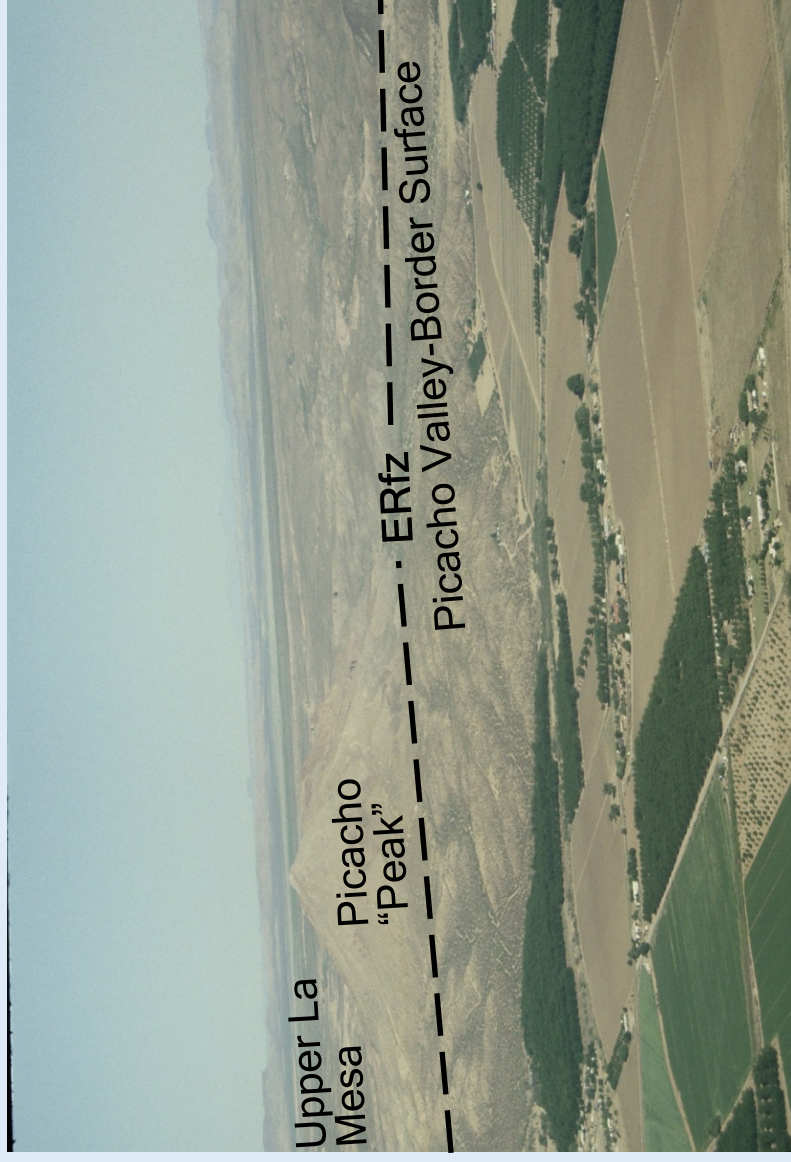
Pl. F3-1c (NM BMMR). View to South of lower Selden Canyon and upper Mesilla Valley of the Rio Grande. Radium Springs Geothermal Greenhouses in foreground upstream from Leasburg Dam. Robledo Mtns. in photo-center, with Cedar-Corralitos Upland Basin to the west.



Pl. F3-1d (NM BMMR). View of the East-Central Robledo Mtns. and East Robledo Fault Zone (ERfz) from the Leasburg Inflow Corridor (LBic) Area of the Upper Mesilla Valley (MeV); with Upper SFG Basin-Fill Exposed in Piedmont Area between Rio Grande and ERfz.



Pl. F3-1e (NM BMMR). Picacho “Peak”, ERfz, and the Picacho (Village) area of the Mesilla Valley; with the Rough and Ready, and Cedar Hills on skyline west of the Aden-Robledo Uplift (ARU) and the Corralitos Ranch Subbasin of the Cedar-Corralitos Upland Basin.



Pl. F3-1f (NM BMMR). Interstate Hwy. 10 west of the Rio Grande in Upper Mesilla Valley; with the Mesilla Basin-West Mesa area, Cedar-Corralitos Upland Basin, and the Rough and Ready Hills on the western skyline. The East Robledo Fault Zone (ERfz) forms the northwestern structural boundary of the Fairacres Subbasin (FASB) of the Mesilla GW Basin (MeB).



Pl. F3-1g (NM BMMR). Rio Grande Project-Mesilla Diversion Dam near Stahmann Farm Pecan Orchard. Western border of the Mesilla Valley, and potential site for managed aquifer recharge (MAR) in background.



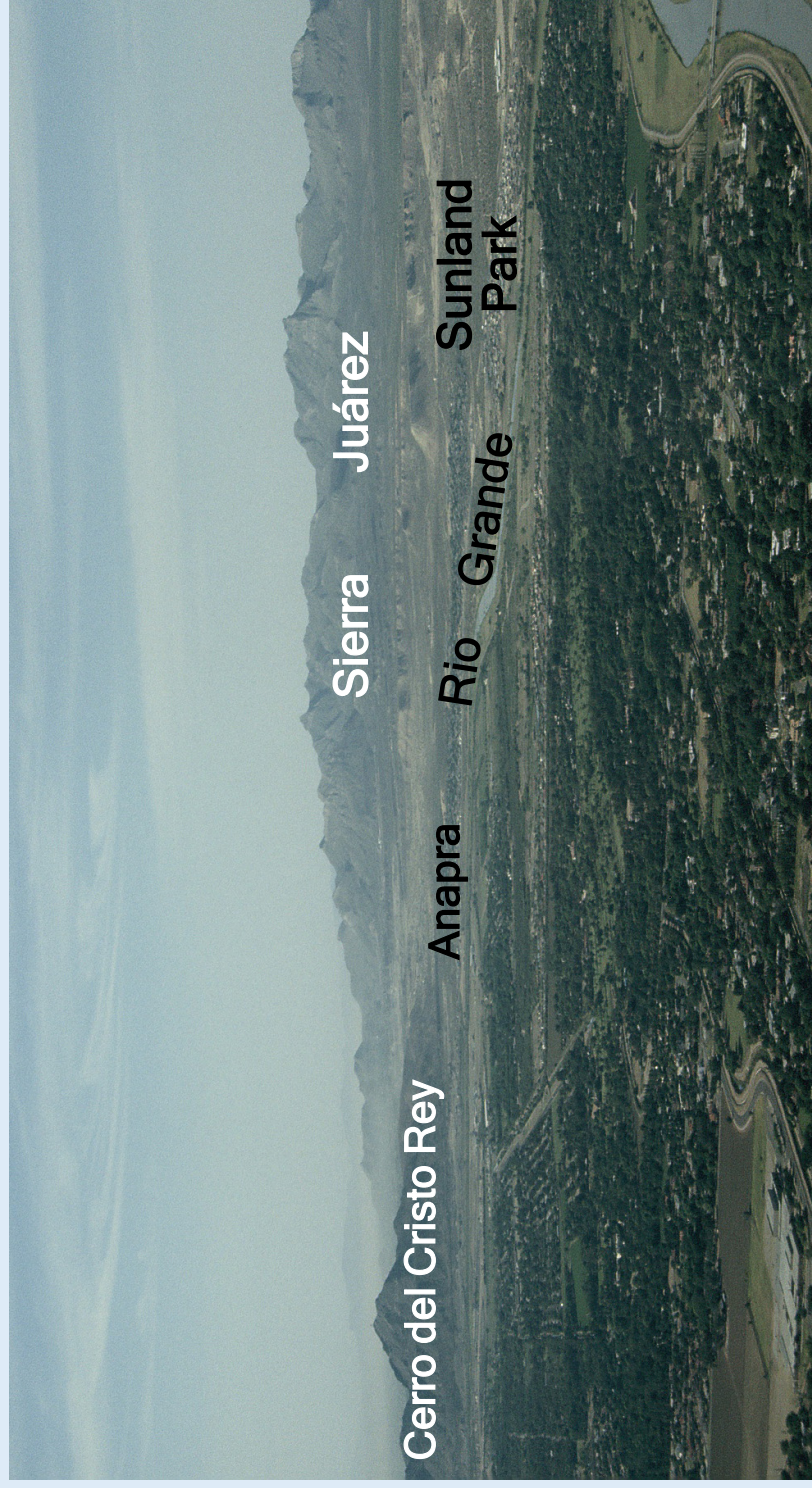
Pl. F3-1h (NMM BMMR). View to SW of the Stahmann Farms pecan orchard on the west-central Mesilla Valley floor, with the East Potrillo Mtns. on the western skyline. Basalt flows from the Santo Tomas, San Miguel, and Black Mesa volcanic centers partly cap Mesilla-Valley border and Mesilla Basin-West Mesa surfaces. See Pl. F3-2d.



P1. F3-1i. Upper SFG Camp Rice Fm (HSU-USF2) exposed on western MeV rim NW of Sunland Park. Early-stage Santa Teresa Industrial Park (STIP) Development in southern MeB-West Mesa Area, with western Sierra Juárez and Sierra Sapello on southern skyline in Mexico.



Pl. F3-1j (NM BMMR). Anapra and Sunland Park area of the Lower Mesilla Valley, with Cerro del Cristo Rey in left center and Sierra Juárez on the southern skyline.



Plates F3-2a to F3-2j. Mesilla Valley Area, and Contiguous RG-Rift Basins and Mountain Uplifts.

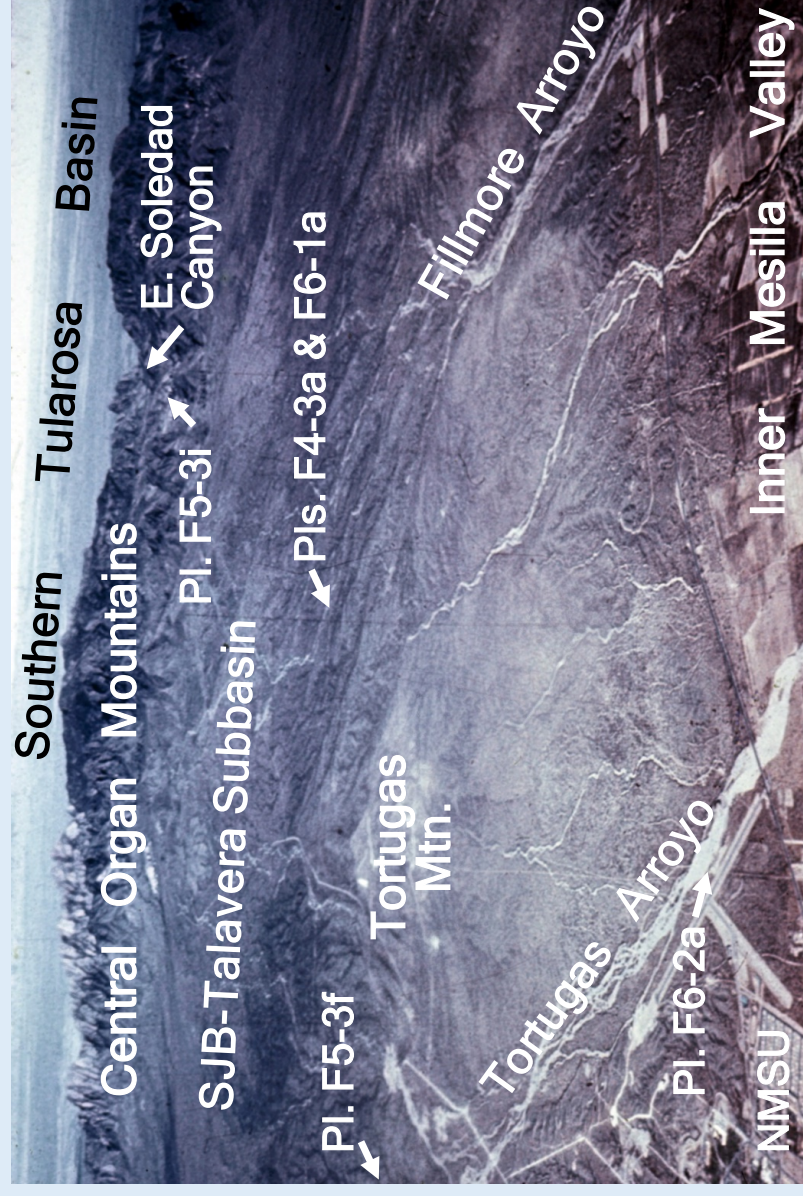
Pl. F3-2a (USDA-SCS; 7/12/1963). View to SW toward Mesilla Basin from Isaacks Lake Subbasin of the Southern Jornada GW Basin. Isaacks Lake Playa after 7/8-9/1963 storm event.



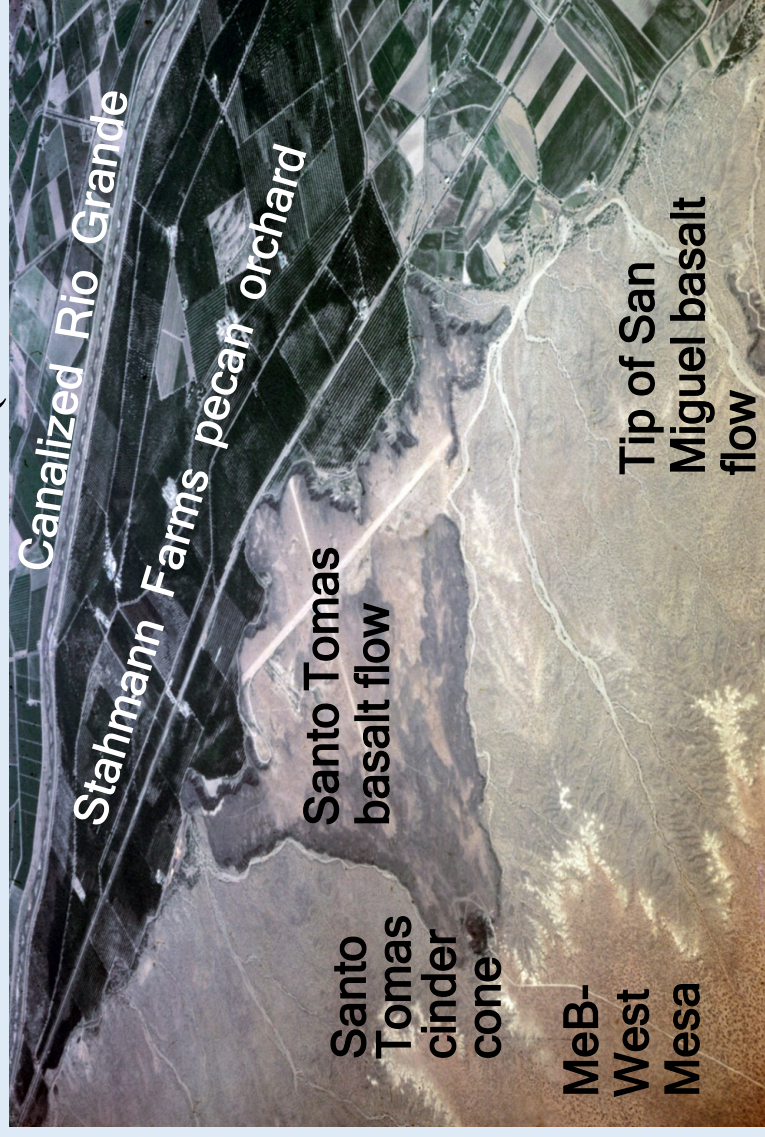
Pl. F3-2b (USDA-SCS; 9/1969). View across the Southern Jornada GW Basin (SJB) from the eastern edge of the inner Mesilla Valley, with the San Agustín and Organ Mtns. in the background. The SJB-Isaacks Lake and Talavera Subbasin boundary is shown with a dashed blue line, which also marks the approximate location of the drainage divide between the Jornada and Mesilla Basin surface-watersheds and GW-flow systems.



Pl. F3-2c (USDA-SCS; 6/1970). South end of the Southern Jornada GW Basin (SJB) and eastern edge of the inner Mesilla Valley; with Organ Mtns. and Tularosa Basin in background. See Pls. F3-2e; F4-3a; F5-3f, 3i and 7a; F6-1h.



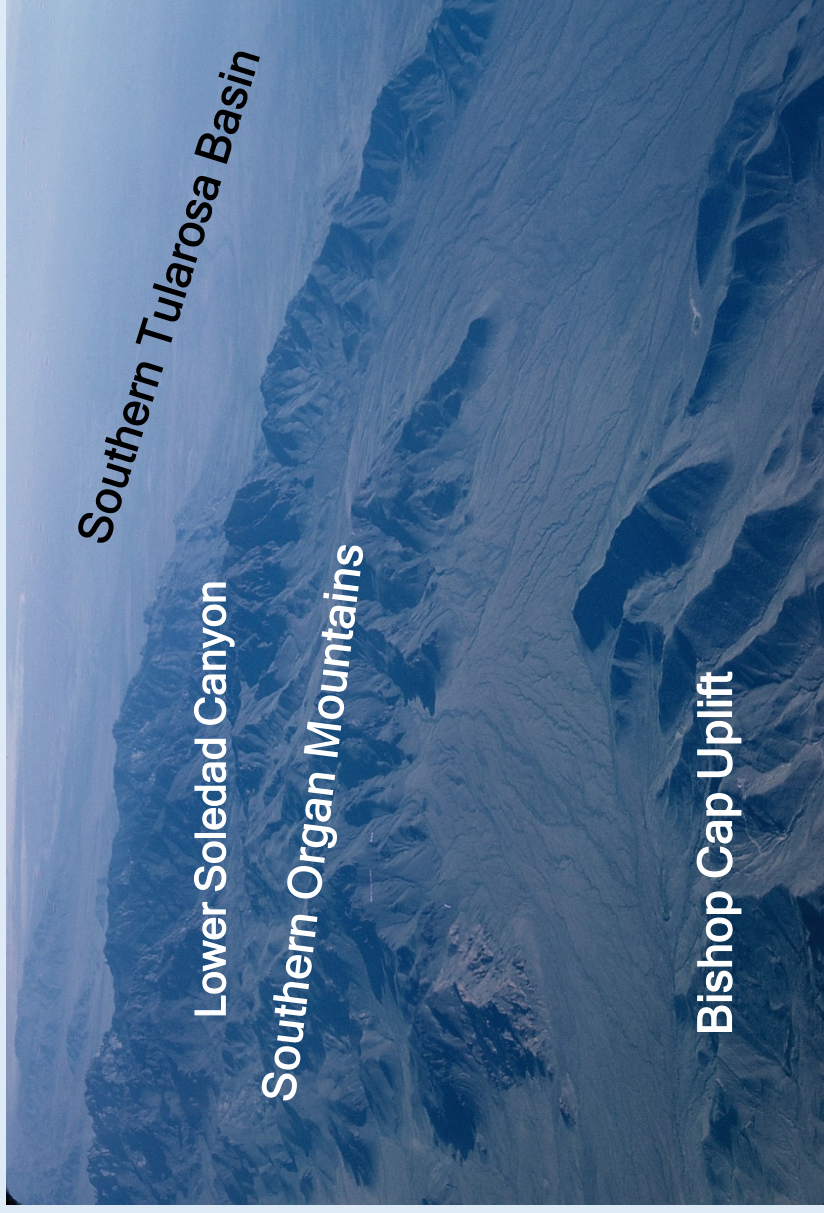
Pl. F3-2d (USDA/SCS-10/1968). The Santo Tomas basalt flow caps Camp Rice Fm and RG-terrace deposits in the MeV-border area W of the Stahmann Farm pecan orchard. The canalized reach of the Rio Grande is immediately downstream from the Mesilla Dam (Pls. F1-4 and F3-1g).



Pl. F3-2e (USDA-SCS; 9/15/1968). View from the south end of the Southern Jornada Basin and the Organ Mountains to the Southern San Andres Mtns., with the Tularosa Basin-White Sands area in the background. See Pls. F3-2b and F5-3f.



Pl. F3-2f (USDA-SCS; 9/15/1968). View from Bishop Cap Uplift and the Organ Mountains to the Southern San Andres Mtns., with the Tularosa Basin-White Sands area in the background.



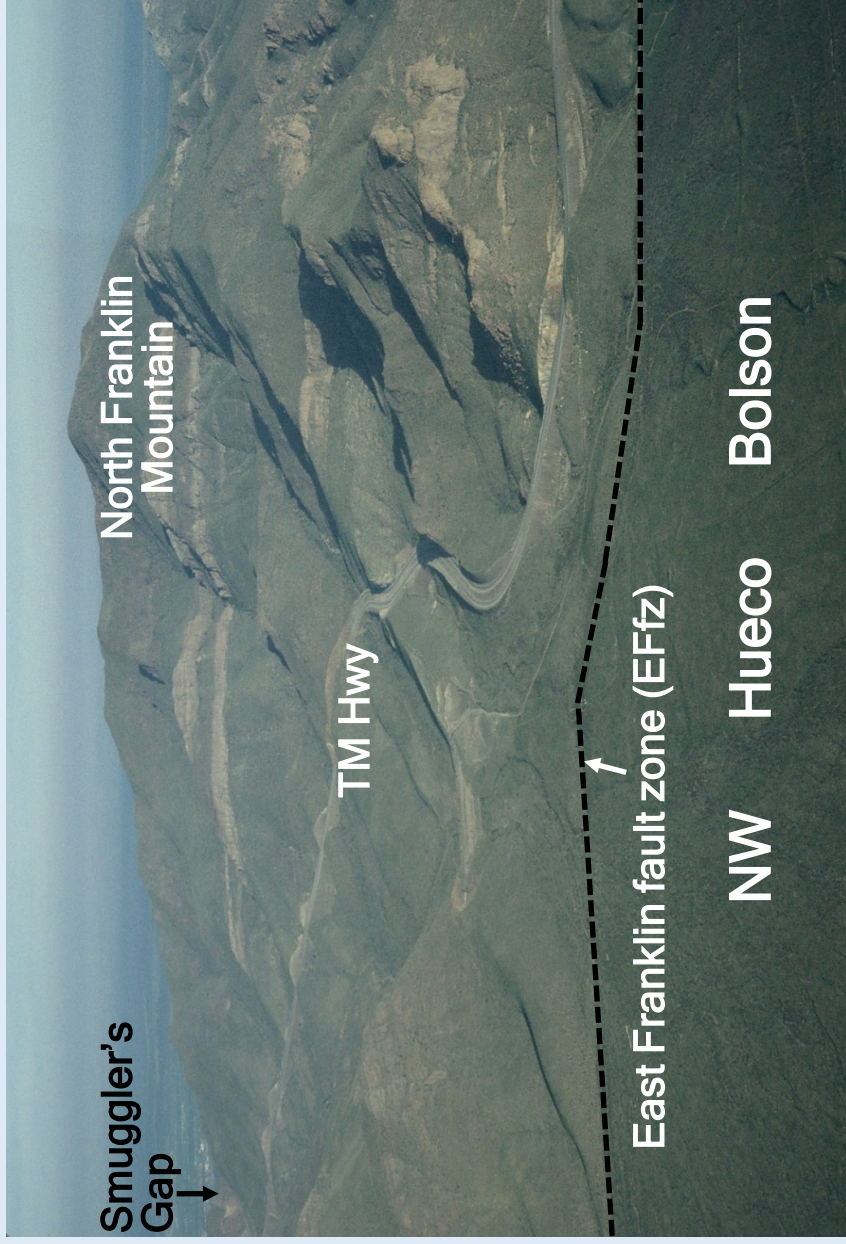
Pl. F3-2g (USDA-SCS; 9/15/1968). West-tilted Franklin Mountain fault-block complex between the Mesilla Basin and NW Hueco Bolson RG-rift structural depressions.



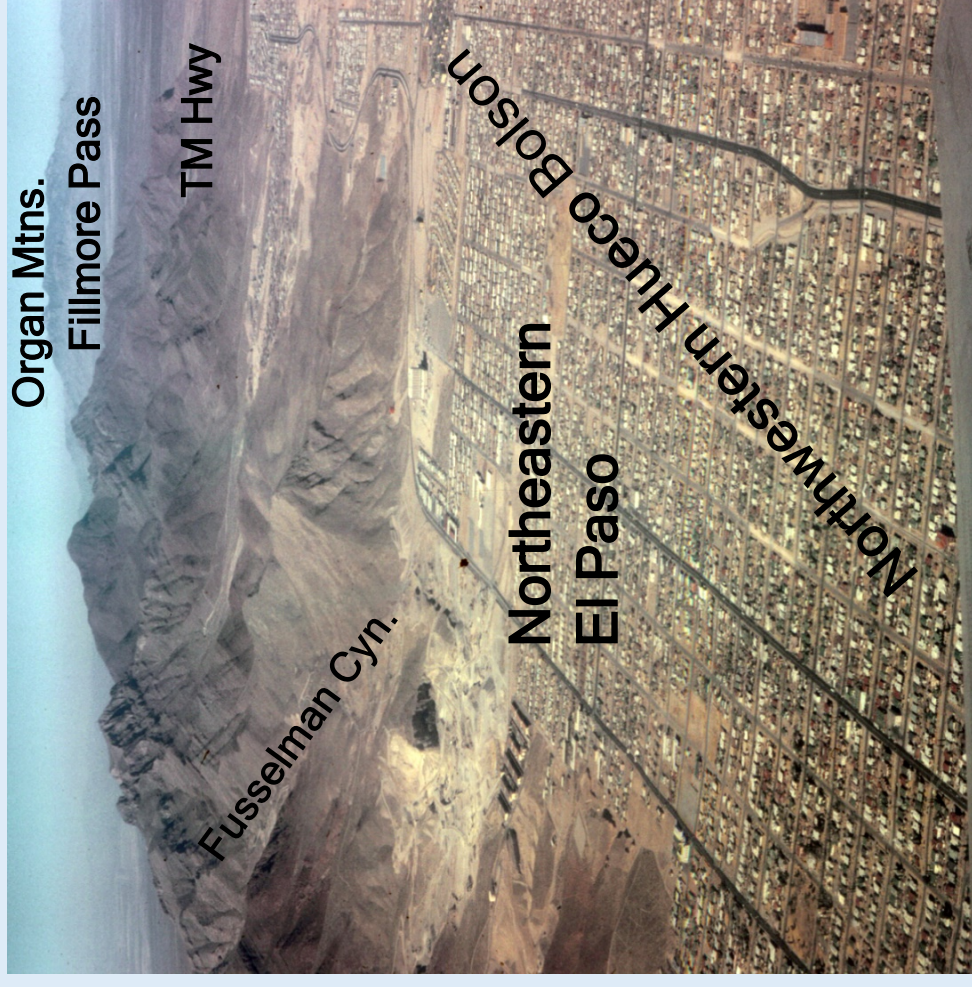
Pl. F3-2h (USDA-SCS; 9/15/1968). Anthony Gap pass between the northern and southern Franklin Mountains, and the northwestern Hueco Bolson and southeastern Mesilla Basins of the Rio Grande rift. See Pl. F7-2b.



Pl. F3-2i (NM BMMR; 8/21/1984). Transmountain (TM) Hwy at SE base of North Franklin Mtn. (7,192 ft/2,192 m) ascends towards Smuggler's Gap Pass (5,250 ft/1,600 m). Mesilla Basin on western skyline.



Pl. F3-2j (USDA-SCS; 3/4/1971). NW View of the Central Franklin Mtns. from NE part of El Paso and the NW Hueco Bolson. Organ Mtns. on northern skyline are located N of Fillmore Pass and E of the central Mesilla Basin.

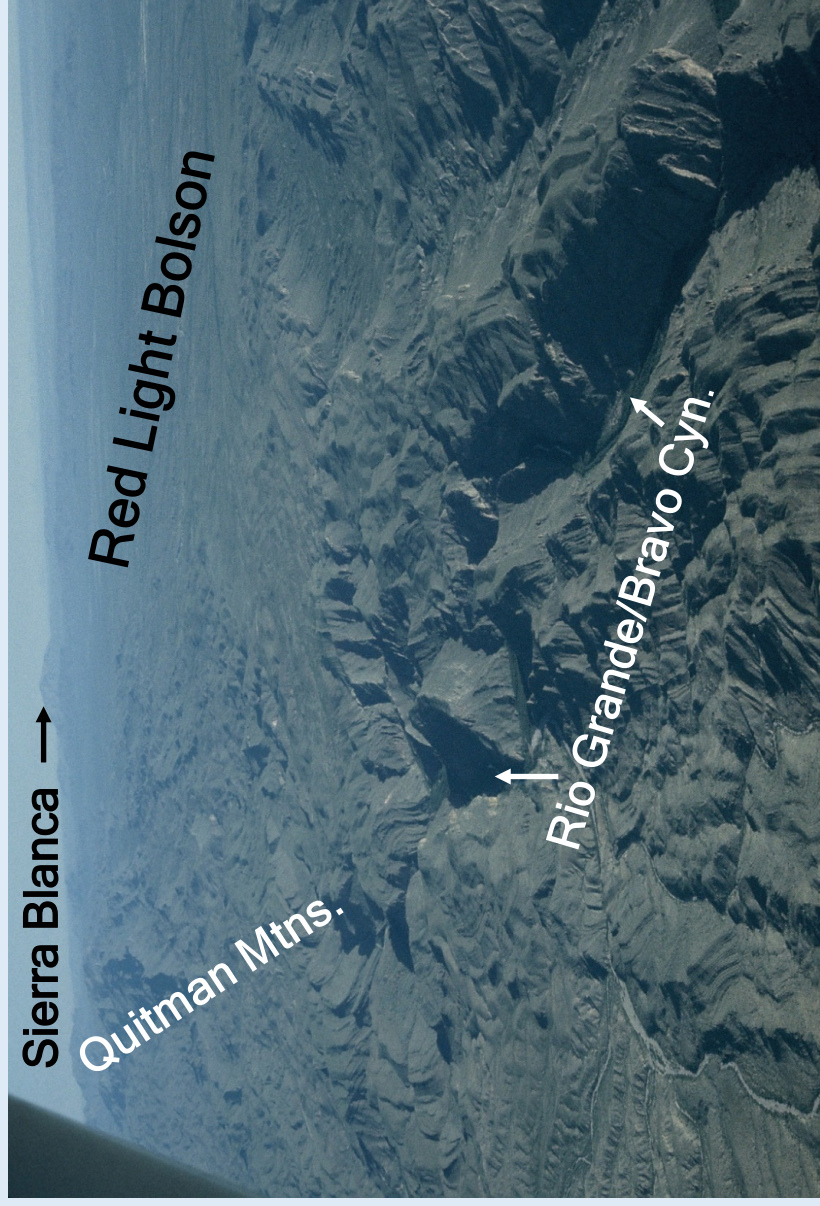


**Plates F3-3a to F3-3c. August 21, 1984,
USGS Overflight of the Rio Grande/Bravo
Valley and Canyon Area Between SE
Hueco Bolson and NW Presidio Bolson.**

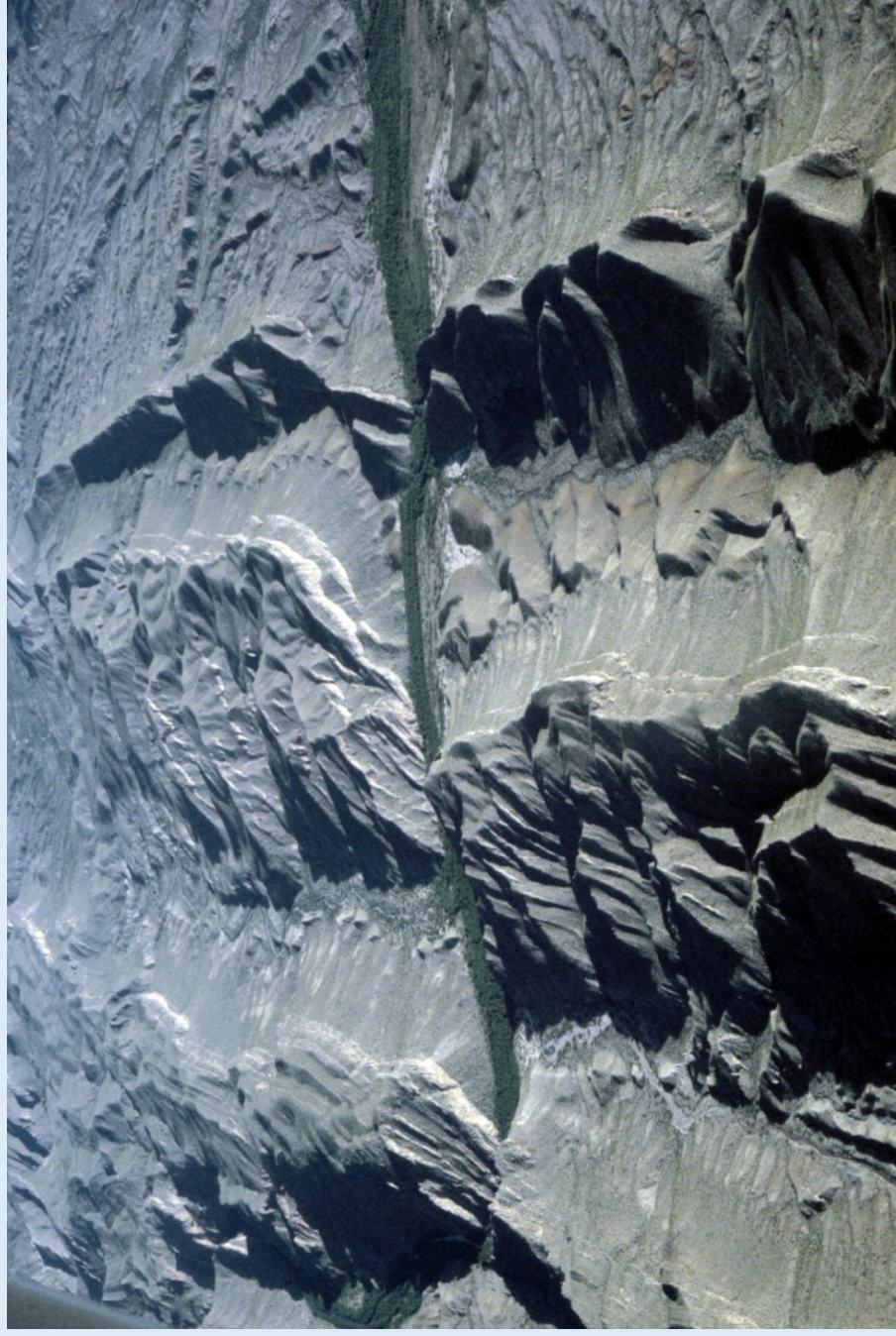
Pl. F3-3a (NM BMMR). Upper Fort Hancock and basal Camp Rice Fms of the Upper SFG are well exposed in badlands of the SE Hueco Bolson area near McNary and the Madden Arroyo section of the SP(UP) RR (Pl. F7-2a).



Pl. F3-3b (NM BMMR). Rio Grande/Bravo Canyon across Southern End of Quitman Mtns. Uplift SE of Indian Hot Springs. See Pl. F4-1m to 1o.



Pl. F3-3c (NM BMMR). View to SW across Rio Grande/Bravo Canyon in SE-Dipping Lower Cretaceous Sedimentary Rocks of the Indio Mtns.



**Plates F3-4a to F3-4e. USGS-NAQUA
Project—June 4, 1991, Rio Grande
Basin Overflight Series: Late-Pleistocene
Volcanic Features of the Mesilla Basin
West Mesa Area.**

**Pl. F3-4a (NM BMMR). Late Pleistocene Hunts Hole
hydromagmatic volcanic center (maar) in the Kilbourne-
Noria Subbasin of the MeB, with the East Potrillo
Mountains on the southwestern skyline. *See Pl. F2-3.***



Pl. F3-4b (NM BMMR). Late Pleistocene Kilbourne Hole hydromagmatic volcanic center in the Kilbourne-Noria Subbasin of the MeB; wth Sierra de Las Uvas, and the Robledo and Organ Mtns. on the northeastern skyline. See Pls. F2-3, and F7-3a to 3d.



Pl. F3-4c (NM BMMR). Aden Crater and Aden volcanic field (~19 ka) in the Aden Sector of the Aden-Robledo Uplift on the northwestern border the MeB. The Robledo, Doña Ana, San Andres and Organ Mtns. are on the northeastern skyline. See Pls. F2-3, F3-4d, and F7-3e.



Pl. F3-4d (NMI BMMR). Aden Crater and western Aden volcanic field in the Aden Sector of the Aden-Robledo Uplift; with Sierra de Las Uvas, Sleeping Lady Hills, Cedar-Corralitos Upland Basin, and the Robledo Mtns. on the northern skyline. See Pls. F2-3, F3-4c and 4e, and F7-3e.



Pl. F3-4e (NM BMMR). Aden Crater (~19 ka) in Foreground, with West Aden Hills and Aden Hills Uplifts on Northwestern Skyline. See Pls. F2-3, and F3-4c and 4d.



Plates F3-5a and F3-5b. Fall 2019
Border-Wall Overflight Series. Courtesy
of PBS-New Mexico in Focus—Our
Land: New Mexico’s Environmental
Past, Present and Future. *See*
APPENDIX H1.

Pl. F3-5a. Border Wall and Northern Rim of Potrillo Maar in Foreground. View to ESE Across the Southern Mesilla Basin and the Fluvial-Deltaic Plain of the Ancestral Rio Grande (ARG). The Franklin Mtns., and Sierras Juárez and Sapello are on the Eastern Skyline. See Pl. F7-2f.



Pl. F3-5b. Early impact of Border Wall construction where it crosses a typical Chihuahuan Desert (*Mesquite* scrub) landscape of the Malpais GW Basin at the southwestern edge of Doña Ana County. See Pls. F2-3 and F2-4.



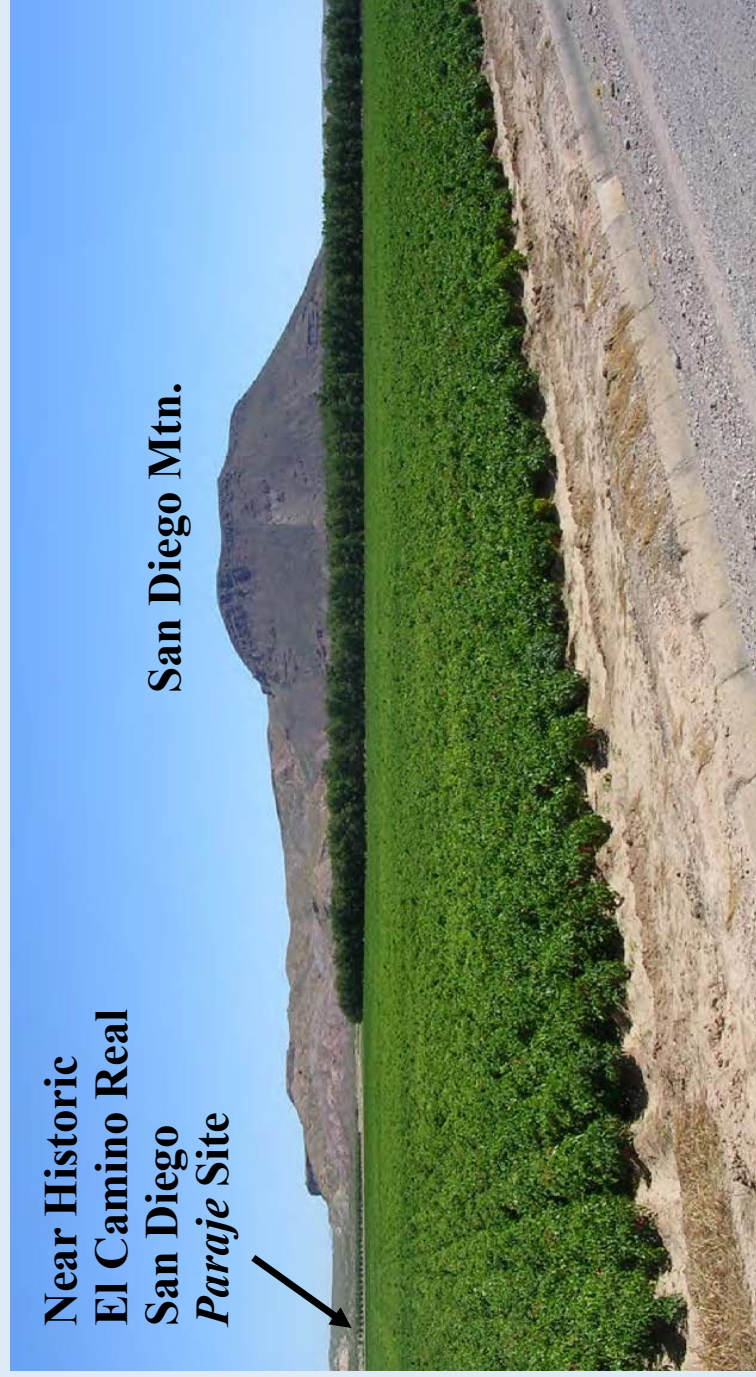
**PART F4—Plates F4-1 to F4-3 Series.
Land-Surface Photographs of Major
Geomorphic, Cultural and Hydrogeologic
Features in the Lower Rincon Valley,
Mesilla Basin, and Hueco Bolson Region.**

**Plates F4-1a to F4-1m (Slides 61 to 73).
Representative Geomorphic, Cultural,
and Hydrogeologic Features in the
Valleys and Canyons of the Rio Grande/
Bravo Fluvial System Between the
Lower Rincon Valley, NM and El Paso
del Norte.**

Pl. F4-1a (USDA-SCS; June 1963). View of San Diego Mtn. and the Tonuco Uplift from the eastern rim of the lower Rincon Valley and the western edge of the Southern Jornada GW Basin (SJB), with the Robledo Mtns. on the SW skyline. Jeep is on La Mesa Surface petrocalcic soil that caps Upper SFG-ARG basin fill (HSU-USF2, LFA 1-2).



Pl. F4-1b (R.T. Hanson-USGS; 9/15/2004). Hayner Farms chili field and pecan orchard in lower Rincon Valley of the Rio Grande. The summit of San Diego Mtn. (Tonuco Uplift) on the eastern skyline is underlain by Lower SFG conglomerates of the type Hayner Ranch Fm (HSU-LSF/*LSF* 8).



Pl. F4-1c (NM BMMR; 5/1989). Bean field on lower Rincon Valley floor is bordered on the SW by bluffs with exposures of light reddish-brown beds of the Middle SFG-Rincon Valley Fm that are capped by Upper SFG-Camp Rice Fm (ARG and piedmont facies).



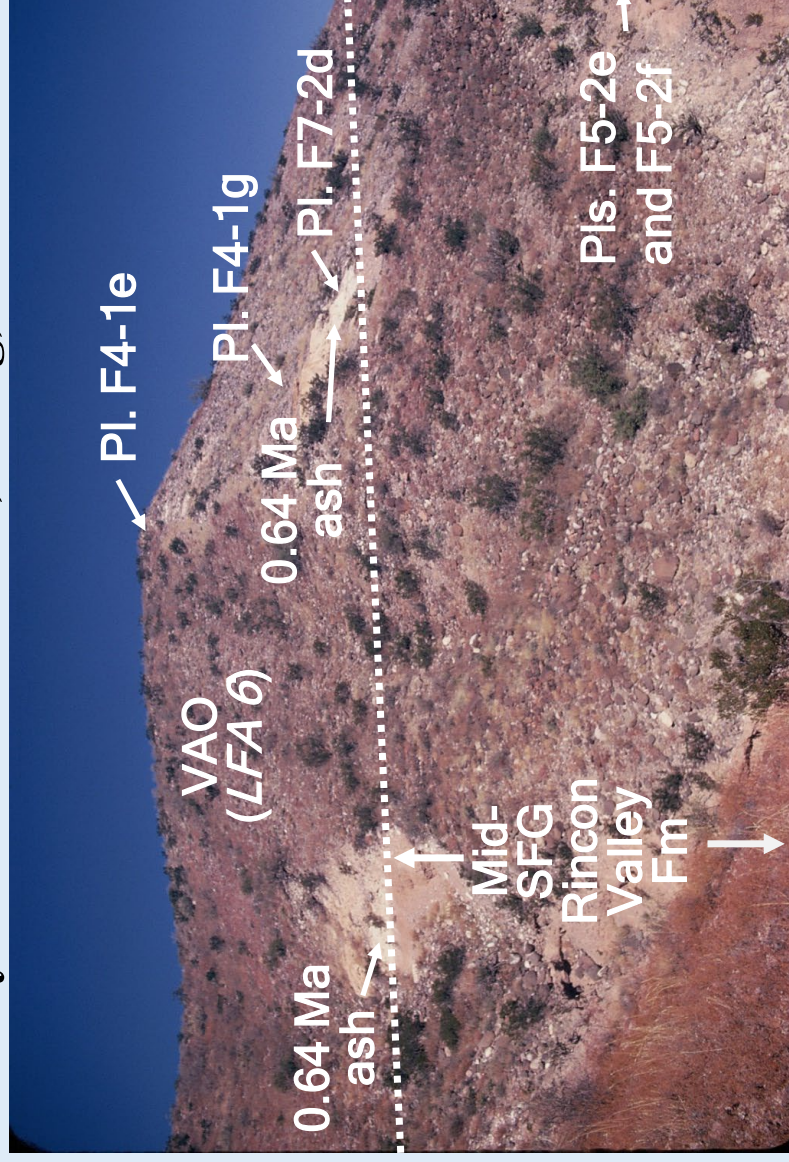
PL. F4-1d (NM WRR1, 4/2/2007). Bank-full Rio Grande at the lower end of the Rincon Valley and head of Selden Canyon. San Diego Mtn. and the northern Selden Hills are on the northern skyline. See Pl. F4-1b.



Pl. F4-1e (NM WRRRI, 5/26/2000). View of the SE end of Rincon Valley and head of Selden Canyon from the rim of VAO-capped Ash Mine Mesa (Pl. F4-1d). San Diego Mtn., Tonuco Uplift, and the NW Selden Hills are on the northern skyline. See Pls. F4-1b, 1d and 1f.



Pl. F4-1f (USDA-SCS; 1972). Eastern face of Ash Mine Mesa at edge of Selden Cyn and mouth of Broad Cyn. Older fan alluvium (VAO) caps 0.64 Ma Lava Creek Ash and RG- terrrace deposits that are unconformable on the Middle SFG Rincon Valley Fm. See Pls. F4-1e, F4-1g, F5-2e and F7-2d.



Pl. F4-1g (NM WRRI; 5/26/2000). View of the upper end of Selden Canyon from the eastern edge of Ash Mine Mesa. Older Broad Cyn. fan gvl. (VAO-LFA 6) caps reworked bed of 0.64 Ma Lava Creek B Ash in foreground. San Diego Mtn., Tonuco Uplift, and northern Selden Hills are on the northern skyline. See Pls. F4-1e and F4-1f.



Pl. F4-1h (NM WRRI; 5/21/2007). View to NE across the upper Mesilla Valley of the Rio Grande. Middle- to late-Quaternary valley-border deposits flanking the Robledo Mtns. are in the foreground, with the Doña Ana Mtns. on the skyline. See Pl. F4-1i.



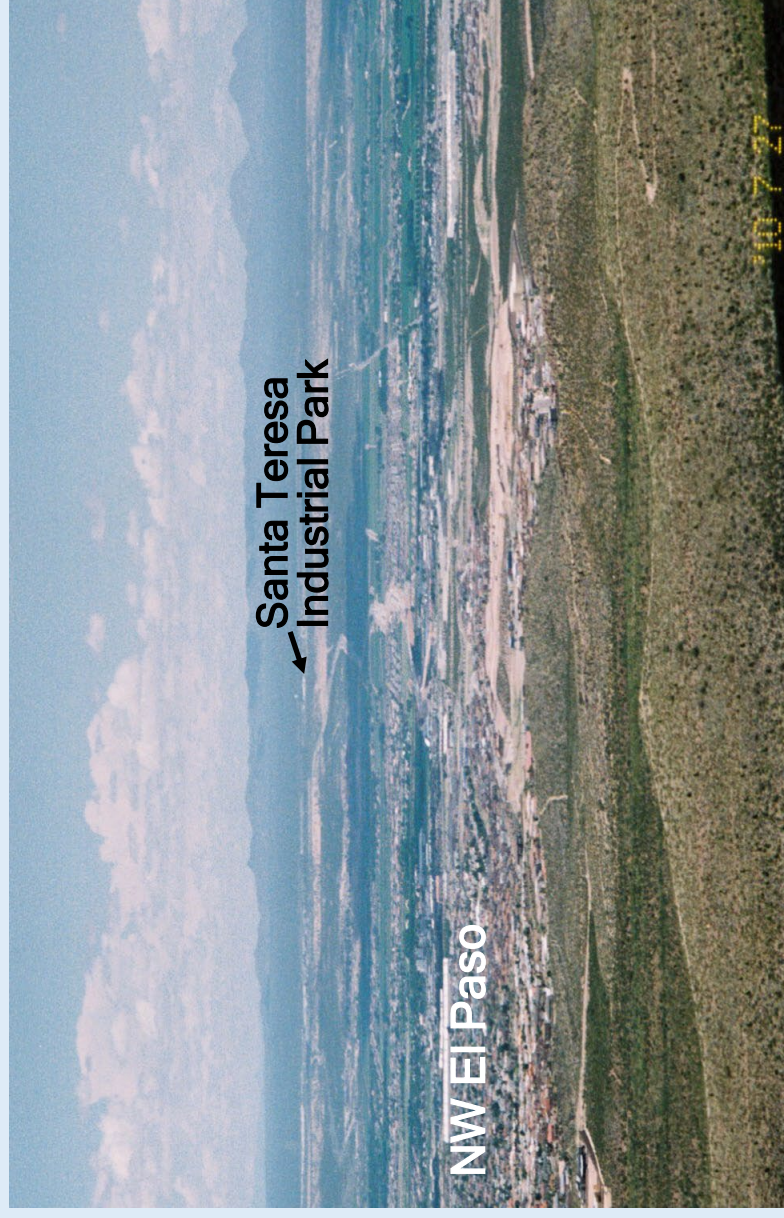
Pl. F4-1i (NM WRRRI, 5/21/2007). View of the Rio Grande channel and floodplain in the upper Mesilla Valley in the area of Pl. F4-1h. Middle- to late- Quaternary valley-border deposits flanking the Robledo Mtns. are on the northern skyline.



Pl. F4-1j (HAWLEY GEOMATTERS, 7/27/10). View to N across the Mesilla Valley from Smuggler's Gap in the Franklin Mtns. The Transmountain Hwy. is in the foreground, with the Robledo Mtns. on the NW skyline. See Pls. F3-2h and F3-2j.



Pl. F4-1k (HAWLEY GEOMATTERS, 7/27/10). View to W across the southern Mesilla Basin from Smuggler's Gap in the Franklin Mtns., with the southern Mesilla Valley in the foreground. The East Potrillo Mtns. and Mt. Cox and Riley peaks are on the skyline. See Pls. F3-1i, F3-3a and F3-4a.



Pl. F4-1I (HAWLEY GEOMATTERS, 7/27/10). View across the SE end of the Mesilla Valley and the upper El Paso del Norte from Smuggler's Gap. Cerro del Cristo and Sierra Juárez are in the background. See Pls. F3-1j and F4-1m.



PL. F4-1m (HAWLEY GEOMATTERS, 7/27/10). The Rio Grande at Courchesne Bridge and Gaging Station at SE end of the Mesilla Valley and head of El Paso del Norte. Cerro del Cristo Rey is on the SW skyline. Hydrologist James Hogan at lower left.



**Plates F4-2a to F4-2g (Slides 75 to 81).
Representative Geomorphic, Cultural, and
Hydrogeologic Features in the Valleys and
Canyons of the Rio Grande/Bravo Fluvial
System Between Southeastern Hueco
Bolson and Indian Hot Springs.**

Pl. F4-2a (NM WRRRI; 5/18/2003). The Rio Grande/Bravo at low stage near SE end of the Hueco Bolson and below the Fort Quitman Gaging Station (see Pl. F1-4). Hydrologist Barry Hibbs sampling water-salinity levels in foreground, with the Quitman Mountains on the southeastern skyline.



Pl. F4-2b (NM WRRI; 5/18/2003). The Rio Grande/Bravo at low stage between Fort Quitman Gaging Station and Indian Hot Springs. Hydrologists Chris Eastoe and Barry Hibbs are on the US-bank of the “Rio Pequeño,” with the Quitman Mountains in the northeast background.



PL. F4-2c (NM WRRRI; 5/18/2003). Chris Eastoe sampling one of the spring pools at Indian Hot Spring, Texas; with the southern Quitman Mtns. on the NE skyline. See Pls. F3-3b, and F4-2e to F4-1g.



Pl. F4-2d (NM WRRI; 5/18/2003). Entering Eastern Chihuahua Across the International Rio Grande/Bravo “Footbridge” at Indian Hot Springs. See Pl. F4-2e.



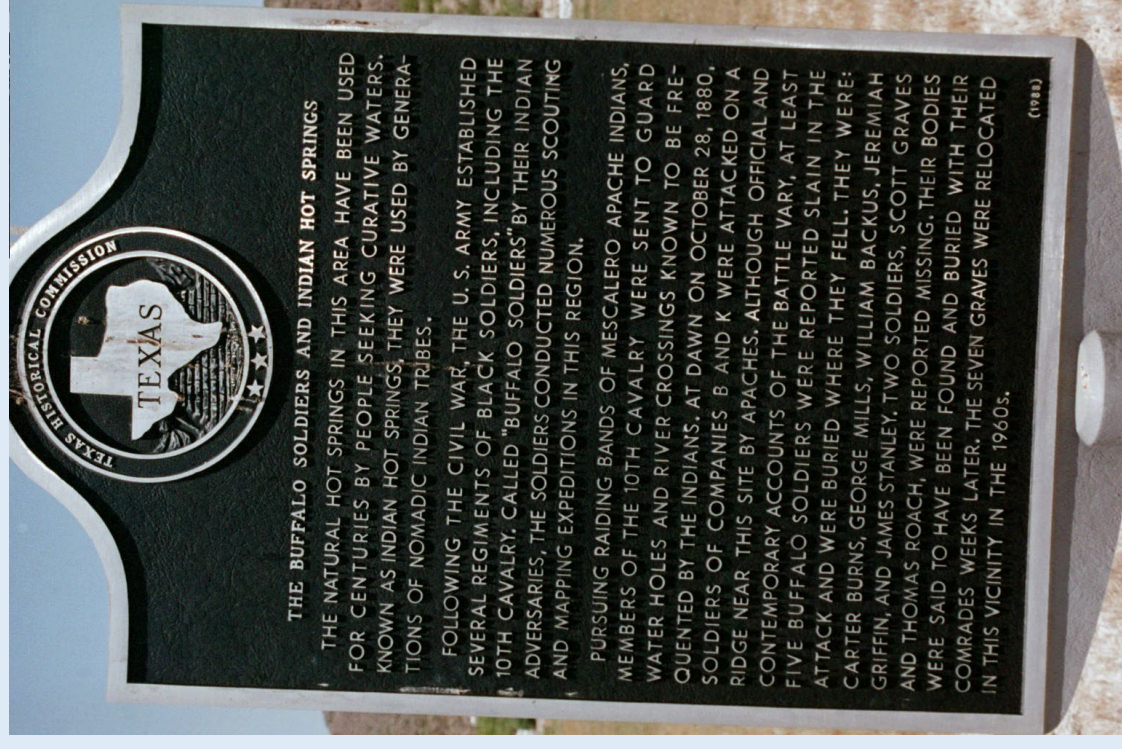
Pl. F4-2e (NM WRRI; 5/18/2003). View Eastward from the “US-Abutment” of the International Rio Grande/Bravo “Footbridge” at Indian Hot Springs, with southern end of Quitman Mtns. in background. See Pls. F4-2c and F4-2f)



Pl. F4-2f (NM WRR1; 5/18/2003). Texas Historical Commission “Buffalo Soldiers” Monument at Indian Hot Springs, with southern end of Quitman Mtns. on the northern skyline. See Pls. F4-2c and F4-2e.



**Pl. F4-2g (NM WRRRI;
5/18/2003). Texas
Historical Commission
Monument to the
“Buffalo Soldiers” of the
U.S. Army 10th Cavalry
at Indian Hot Springs
“Three-Flags” site. See
Pls. F4-3e and F4-3f.**

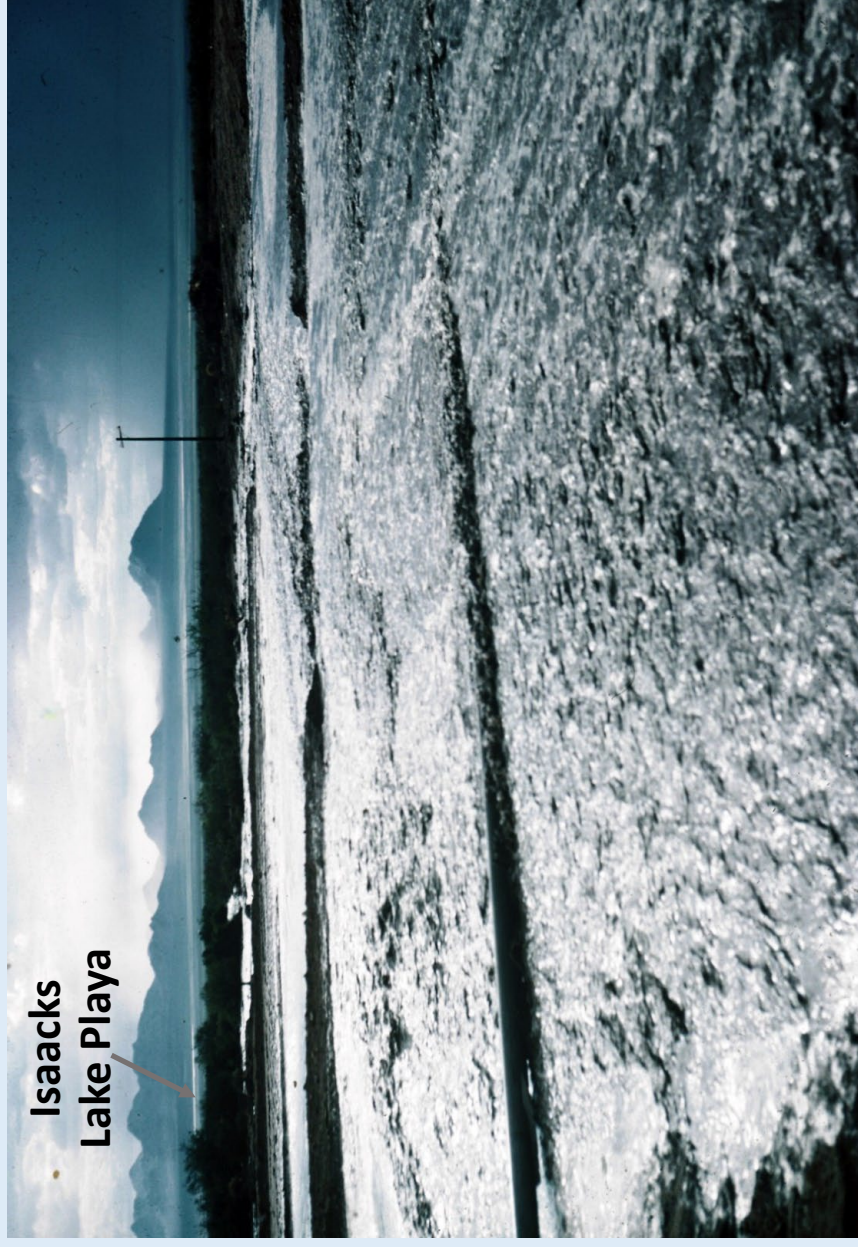


**Pls. F4-3a and 3b (Slides 83 and 84).
Representative Quaternary
Geomorphic and Hydrogeologic
Features on Piedmont Slopes of the
Southern Jornada GW Basin (SJB).**

Pl. F4-3a (USDA-SCS; 6/1963). Fillmore Arroyo channel on piedmont slope in the Talavera Subbasin of the SJB. Photo site about 3 mi (5 km) east of Tortugas Mtn. USDA-SCS Soil Scientist Leland (Lee) Gile in foreground, with Organ Mtns. on eastern skyline (peak alt.: 9,012 ft/2,747 m). See Pl. F6-1a.



Pl. F4-3b (USDA-SCS; 8/1963). Afternoon arroyo flash flood on upper piedmont slope at E edge of Isaacks Lake Subbasin in Southern Jornada Basin. About 3 mi (5 km) NNW of the village of Organ, with Doña Ana Mtns. on western skyline.



**Part F5—Plates F5-1 to F5-5 Series.
Representative Hydrostratigraphic Units
(HSUs) and Lithofacies Assemblages (LFAs)
in Santa Fe Group (SFG) Basin-Fill Deposits.**

**Plates F5-1a and F5-1b. Representative
Exposures of the Lower SFG-Hayner Ranch
Formation (HSU-LSF, LFAs 7 and 8) in the
Eastern Rincon Valley Area.**

Pl. F5-1a (NM BMMR; 5/23/1988). View to S across the East Tonuco Corridor (ETNC), with steeply dipping conglomeratic sandstones of the “Type” Hayner Ranch Fm (HSU-LSF, LFAs 7 and 8) in the foreground. The Robledo Mtns. and northern Selden Hills are on the skyline. *See* Pl. F5-2c.

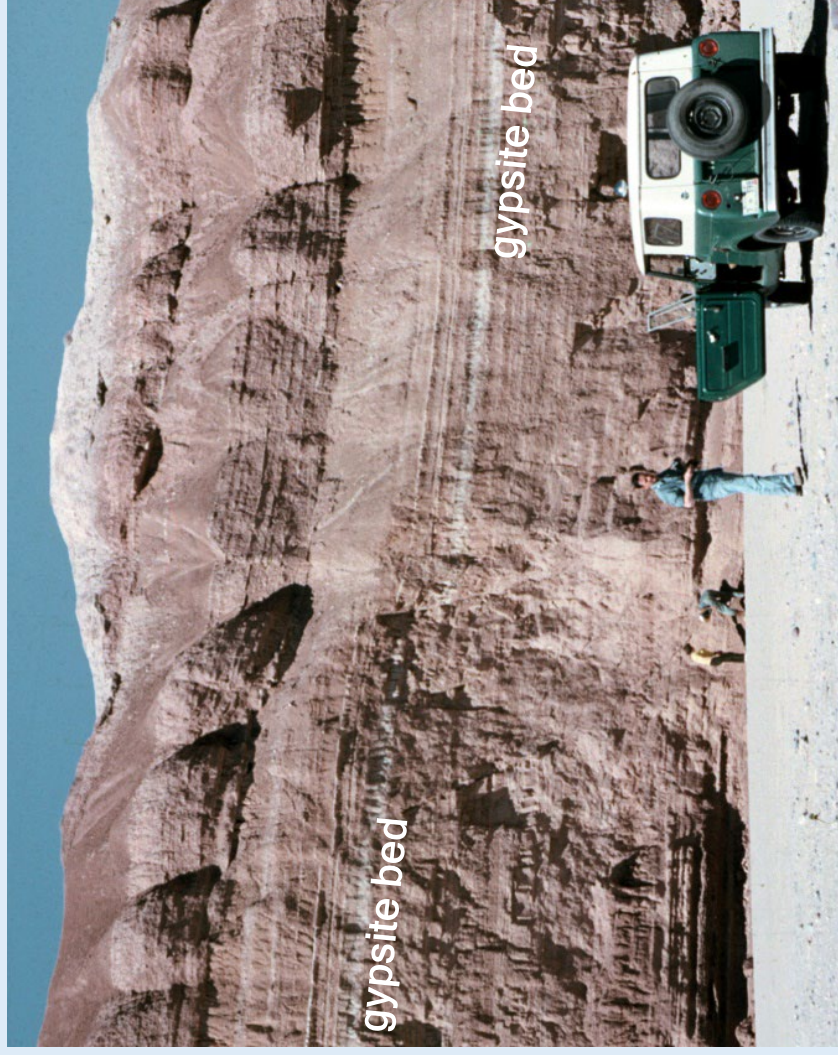


PL. F5-1b (USDA-SCS; 4/1965). Johnson Springs Arroyo exposure of S-dipping conglomerate beds near base of the Hayner Ranch Fm (HSU-LSF, LFA 8). Photo site about 3 mi (4.8 km) NE of Hatch at SW edge of the Rincon Hills.



**Plates F5-2a to F5-2f. Representative Exposures
of Middle SFG Hydrostratigraphic Unit (HSU-
MSF) and its Lithofacies Assemblages (LFAs) in
the Southern Palomas Basin and Northern
Selden Canyon Areas.**

Pl. F5-2a (USDA-SCS; Spring 1969). Gypsiferous Rincon Valley Fm mudstone beds in the (MSF2, LFA 10) exposed in N wall of Arroyo Cuervo in SE Palomas Basin, about 10 mi (16 km) NW of Hatch. Note minor compaction deformation.



Pl. F5-2b (NM BMMR; 4/8/1981). I-25 roadcut exposure of W-dipping gypsiferous mudstone beds (w/ small-scale fault offsets) in “type-area” of the Rincon Valley Fm (HSU-MSF2, LFA 10). The Rincon Hills are on the NE skyline. Photo site is between I-25 MPs-36 and 37.



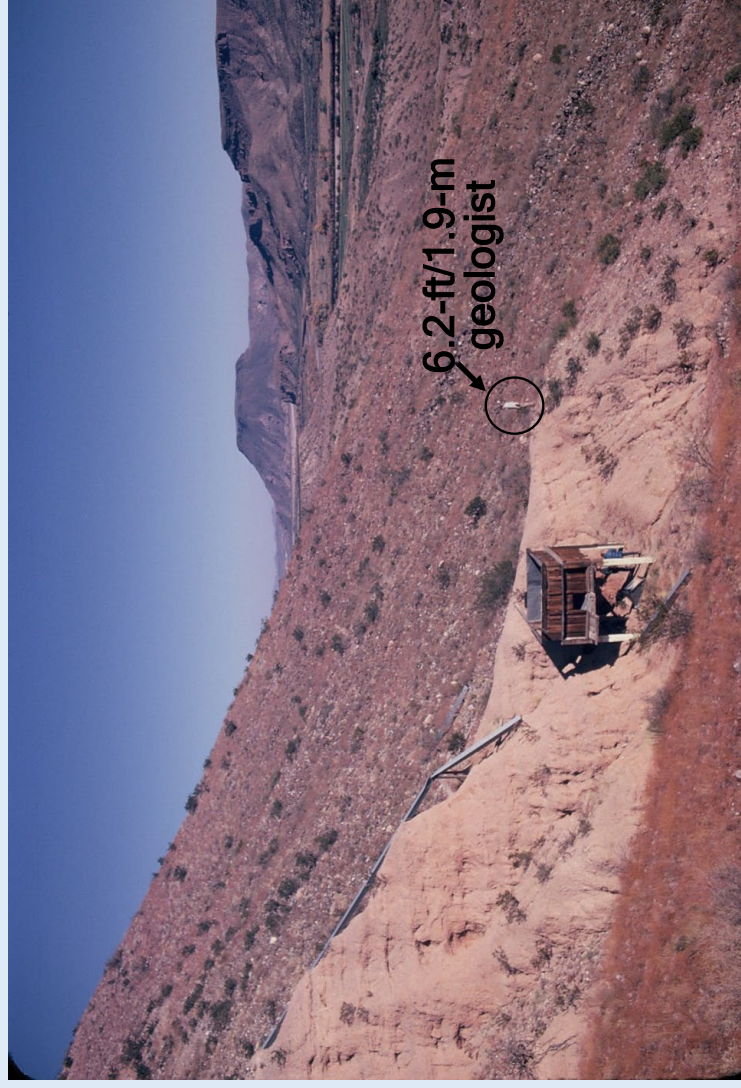
Pl. F5-2c (USDA-SCS; Summer 1968). Exposures of interbedded sandstone and mudstone of the Rincon Valley Fm (HSU-MSF 2, LFAs 3 and 9) in the East Tonuco Corridor between the lower Rincon Valley and Southern Jornada Basins. The Tonuco Uplift is on the northern skyline.



Pl. F5-2d (USDA-SCS; 4/1965). Tongue of Selden Basalt (~9.5 Ma) in conglomeratic-mudstone of the Middle SFG-Rincon Valley Fm (MSF1, LFA 7) exposed in NW wall of lower Broad Canyon. Photo site is about 0.5 mi (0.8 km) SW of northern Selden Canyon.



Pl. F5-2e (USDA-SCS; 1972). View from upper Selden Canyon rim, with San Diego Mtn. and the northern Selden Hills on the NE skyline. Exposure of the Middle SFG-Hayner Ranch Fm pebbly mudstone (MSF1-*LEA* 5) on the eastern slope of Ash Mine Mesa (see PLS. F4-1c and F5-2f).



Pl. F5-2f (USDA-SCS; Spring 1972). Sediment and paleo-mag sampling of Middle SFG-Rincon Valley Fm exposure at Ash Mine Mesa site (Pl. F5-1e; see Pls. F4-1d, F5-2b and F7-2d).



**Plates F5-3a to F5-3i (Slides 97 to 105).
Representative Exposures of the Upper SFG
Palomas and Camp Rice Fms in the Palomas-
and Mesilla-Basin Areas (HSU USF).**

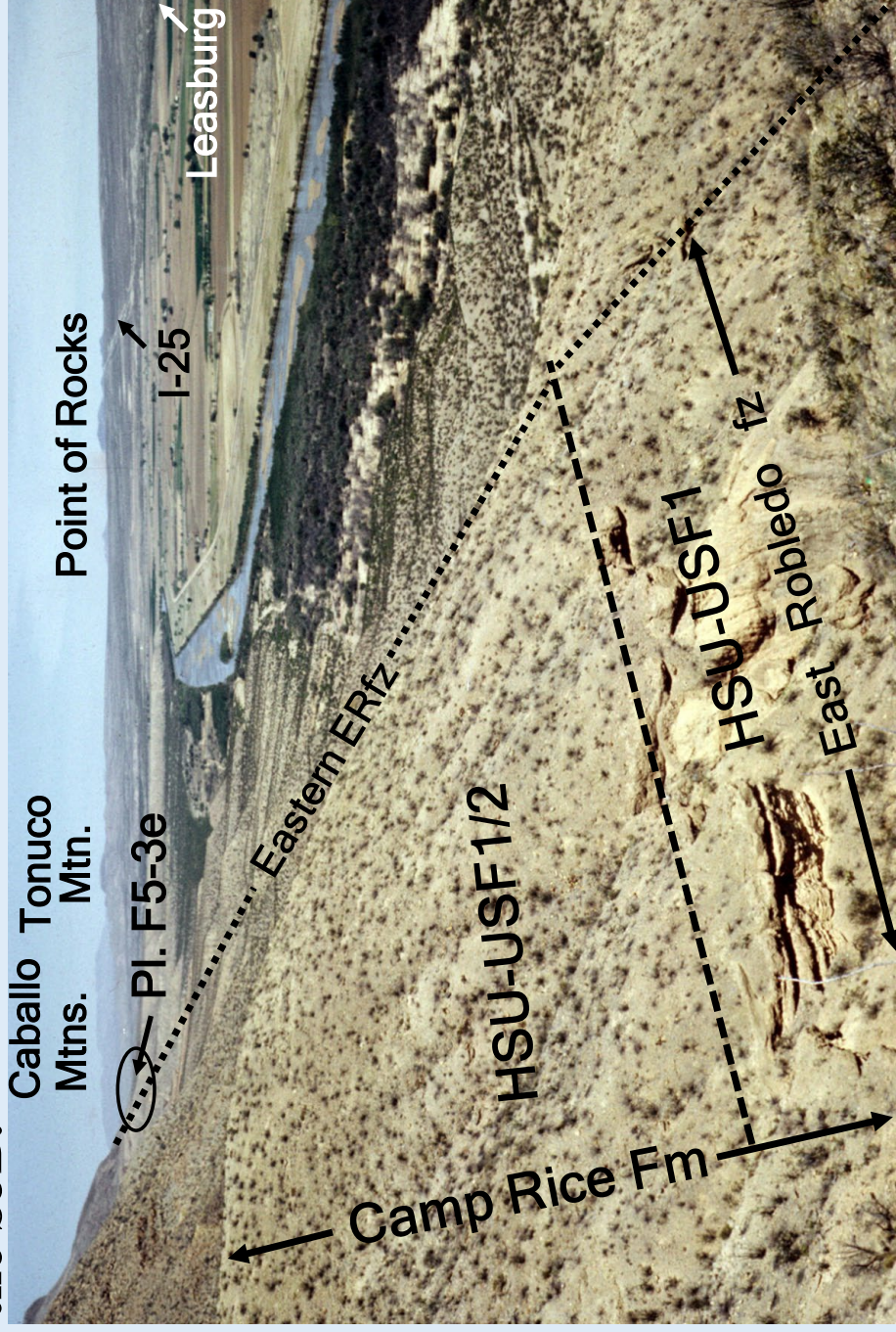
**Pl. F5-3a (NM WRRRI;
3/10/2016). Palomas Fm
piedmont facies (USF1/
LFA 5) exposed in the
south wall of Percha
Creek Valley about 6 mi
(10 km) west of Caballo
Dam. General southern
Palomas Basin setting in
Pl. F3-2b; and details of
outcrop behind geologist
Dan Koning in Pl. F5-3b.**



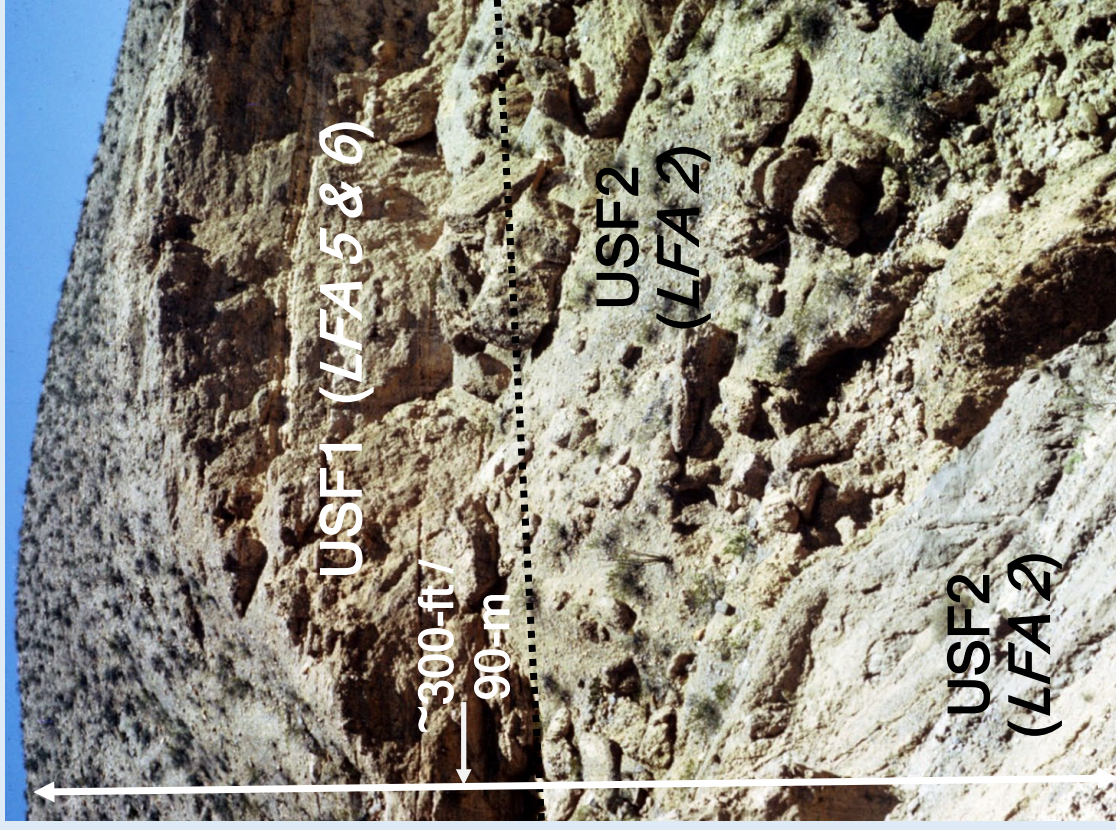
Pl. F5-3b (NM WRRRI; 3/10/2016). Percha Creek recharging the Palomas Fm-piedmont facies aquifer (USF1, LFA 5). Southern Palomas Basin about 6 mi (10 km) west of Caballo Dam. See Pl. F5-3a.



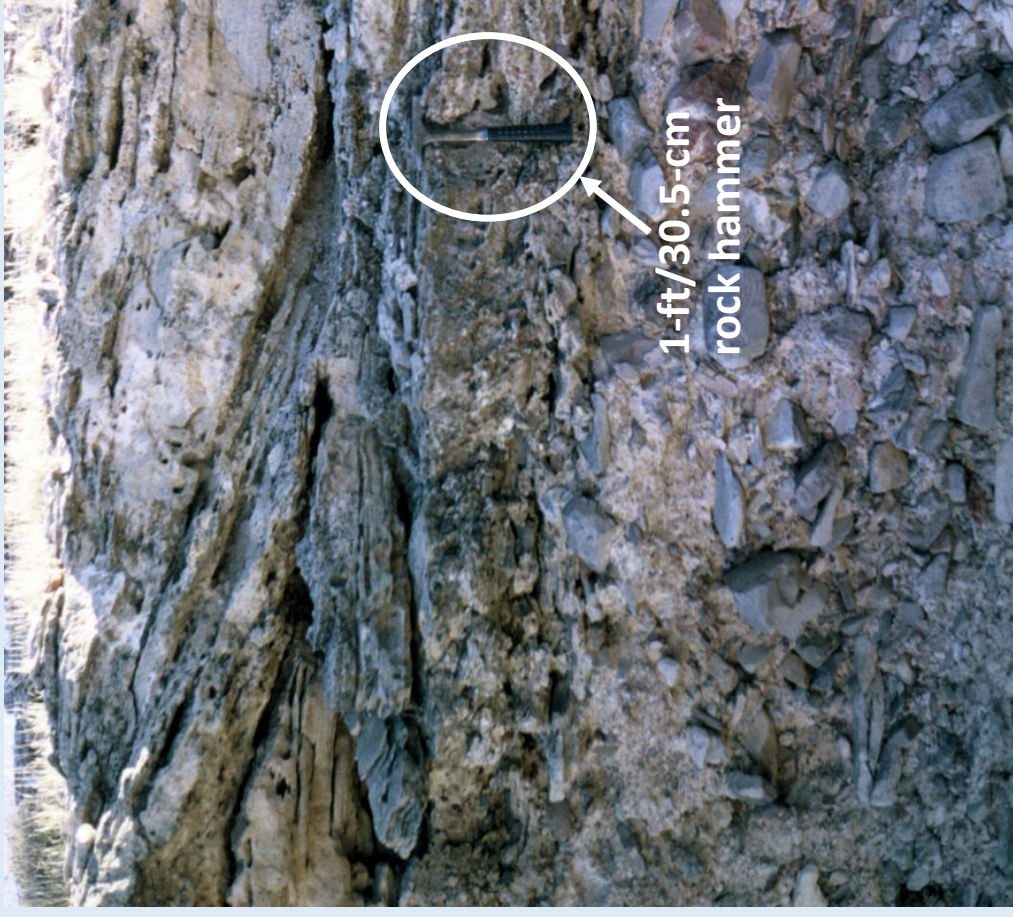
Pl. F5-3c (USDA-SCS; Spring 1968). View across Upper Mesilla Valley from the western edge of the East Robledo fault zone to the Experimental Range Subbasin of the SJB.



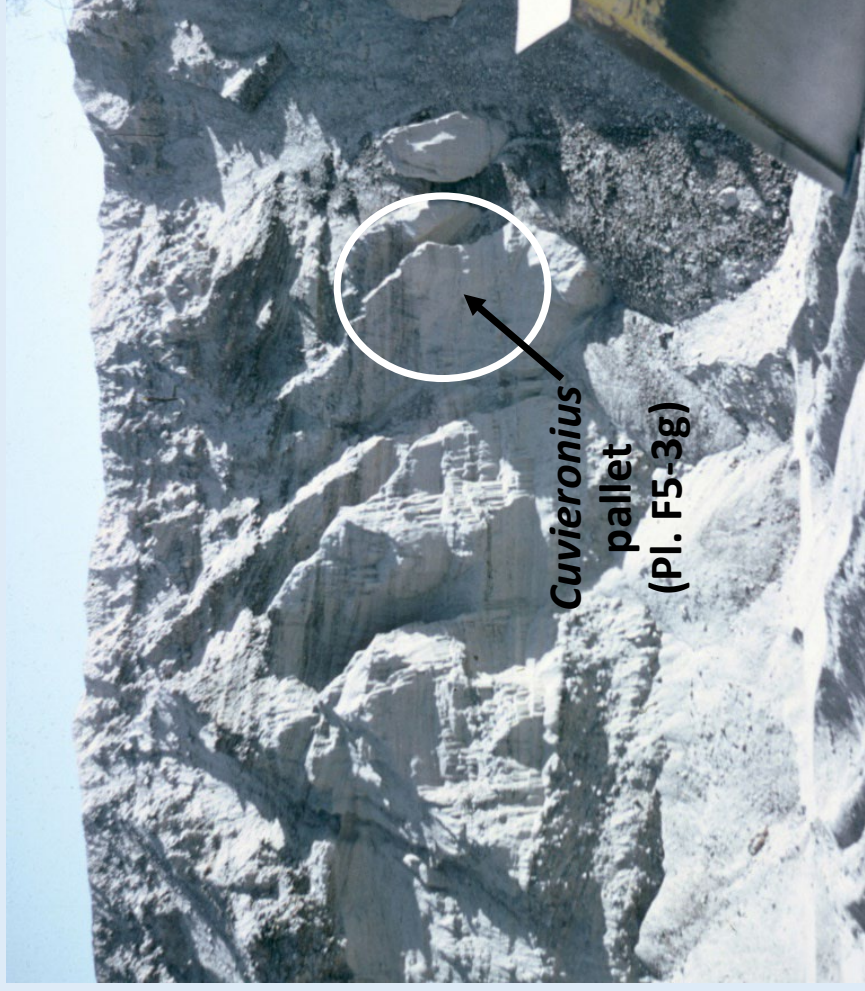
Pl. F5-3d (USDA-SCS; Spring 1968; photo-site location on Pl. F5-3e). Upper SFG Camp Rice Fm (HSU-USF) exposed on hanging wall of ERfz at base of the northern Robledo Mtns. Partly indurated fan-piedmont deposits (USF1, LFAs 5 and 6) conformably overlie pebbly-sand ARG channel facies (USF2, LFA 2).



Pl. F5-3e (USDA-SCS; April 1965). Basal Upper SFG-Camp Rice Fm (USF2/USF1) Exposed at Head of Faulkner Cyn. Arroyo in the NE Corralitos Ranch Subbasin of the Cedar-Corralitos Upland Basin. Rock hammer is at contact between USF2 (ARG) facies sandstone, and Robledo Mtn.-source USF1 fanglomerate (LFA 8).



Pl. F5-3f (USDA-SCS; 12/1965). Sand & gravel-pit exposure of Upper SFG Camp Rice Fm-ARG channel facies (USF2, LFA 2). Photo site on eastern Mesilla Valley border north of Tortugas Mtn. See Pls. F3-2c and F5-3g.



Pl. F5-3g (USDA-SCS; 12/1965). Upper pallet of the Early Pleistocene mastodont *Cuvieronius* collected from the Inman Sand & Gravel Pit site shown in Pl. F5-3f.



Pl. F5-3h; 5/22/2007). Upper SFG Camp Rice Fm-ARG channel facies (USF2, LFA 1) on western Mesilla Valley rim near the NMSU Lower La Mesa trench site (Pl. F7-1e). Southern Organ Mtns., Bishop Cap, and Fillmore Pass, are on the southeastern Skyline.



**Pl. F5-3i (USDA-SCS; 10/1971). Upper SFG Camp Rice Fm
piedmont-alluvial facies (USF1, LFA 6) exposed in fan-head
trench in the western Soledad Canyon section of the
Central Organ Mtns. See Pl. F3-2c for photo-site location.**



**Plates F5-4a and F5-4b (Slides 107 and 108).
Exposures of Basin-Floor Lithofacies
Assemblages *LFA-3* and *LFA-10* in Camp Rice
and Fort Hancock Fm (HSU-USF2) in the Hueco
Bolson Area.**

Pl. F5-4a (UACJ; 1/14/2003). SW Hueco Bolson mesa-rim exposure of sandy Upper SFG-Camp Rice Fm of mixed fluvial and eolian origin (USF2, LFA 3). John Hawley and John Kennedy at Pan-American Hwy. site, about 10 km South of the Cd. Juarez Airport. See Pl. F7-1f for “mesa-caprock” petrocalcic-soil detail.



Pl. F5-4b (NM BMMR; 3/26/1994). Gypsiferous lacustrine facies of the Fort Hancock Fm (USF2, LFA 3/10) exposed in lower Nealy Cyn. White layer is an altered volcanic ash-fall bed of probable early- to mid-Pliocene age. Photo site is about 1 mi (1.6 km) from the Rio Grande/Bravo, and 4 mi (6.4 km) SSE of the Fort Quitman Gaging Station (Pl. F1-4). See Gustavson (1991, Fig. 14).



**Plates F5-5a and F5-5b (Slides 110 and 111).
Exposures of Upper SFG Hydrostratigraphic
Units (USF2) and Basin-Floor Lithofacies
Assemblages (LFAs) in the Northern Bolsón
de Los Muertos Area.**

Pl. F5-5a (NM WRRRI; 6/5/2009). Gravel-pit exposure of ancestral Rio Casas Grandes channel deposits (USF2, LFA 1) capped by petrocalcic soil. Photo site NE of Mex. Fed. Hwy. 2 - Palomas Hwy. junction at Seis de Enero [Los Trios] (see Pls. F2-3 and F2-4).



Pl. F5-5b (NM WRRRI; 6/5/2009). Ancestral Rio Mimbres fluvial-deltaic deposits (USF2, LFA 2 and 3) exposed in NE rim of the El Barreal ephemeral (playa)-lake plain in the background. The Mex. Hwy. 2 photo site about 5 mi (8 km) WNW of Rancho La Laguna (*see* Pl. F2-4).



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Part F6—Plates F6-1 to F6-3 Series. Land-Surface Photographs of Representative Hydrostratigraphic Units (HSUs) and Lithofacies Assemblages (LFAs) in Post-Santa Fe Group Basin- and Valley-Fill Deposits.

Plates F6-1a to F6-1f (Slides 114-119). Post-SFG Hydrostratigraphic Units and Lithofacies Assemblages in the Southern Jornada Basin.

PL. F6-1a (USDA-SCS; 6/1963). Exposure of Middle Pleistocene arroyo-channel gravel (HSU-VAO, LFA 6) in N bank of Fillmore Arroyo. The deposit is capped with a thin stage-IV petrocalcic soil. Photo site about 1-mi (1.6 km) SE of Tortugas Mtn. in the SJB-Talavera Subbasin. See Pls. F3-2c and F4-3a for specific site location.



**PL. F6-1b (NM
WRRRI; 5/23/2012).
NMSU Soil-pit
exposure of Middle
Pleistocene fan-
piedmont gravel
(HSU-PAO, LFA 6).
The deposit is capped
with a thin, stage-IV
petrocalcic soil.
Photo site about 0.5
mi (0.8 km) E of the
NE Doña Ana Mtns.
in the SJB-Isaacks
Ranch Subbasin.**



Pl. F6-1c (NM BMMR; 8/1982). Initial NMSU Soil-Moisture Research Proj. excavation in piedmont-slope alluvial deposits. HSUs-PA/USF1 (LFA 5), with multiple buried soils, are exposed in 33-ft (10-m) trench. The photo site is in the SJB-Isaacks Ranch Subbasin; and the Mount Summerford (NE Doña Ana Mtns.) sediment-source area is in the background. See Pl. F6-1d for trench detail.



Pl. F6-1d (NMSU; 1983). Completed NMSU soil-moisture research excavation in piedmont-slope deposits derived from the Mount Summerford Area of the NE Doña Ana Mtns. About 33-ft (10-m) of HSUs-PA/USF1 (LFA 5), with multiple buried soils are exposed. See Pl. F6-1c for geomorphic setting.



**Pl. F6-1e (NM
WRRRI; 5/24/2007).
Floor of Isaacks
Lake playa, with the
San Agustín and
northern Organ
Mtns. on the eastern
skyline (Pls. F2-8,
F3-2a and F4-3b).
See Pl. F5-6f for
more-detailed view of
Vertisol exposed in
USDA-NRCS trench
in foreground.**

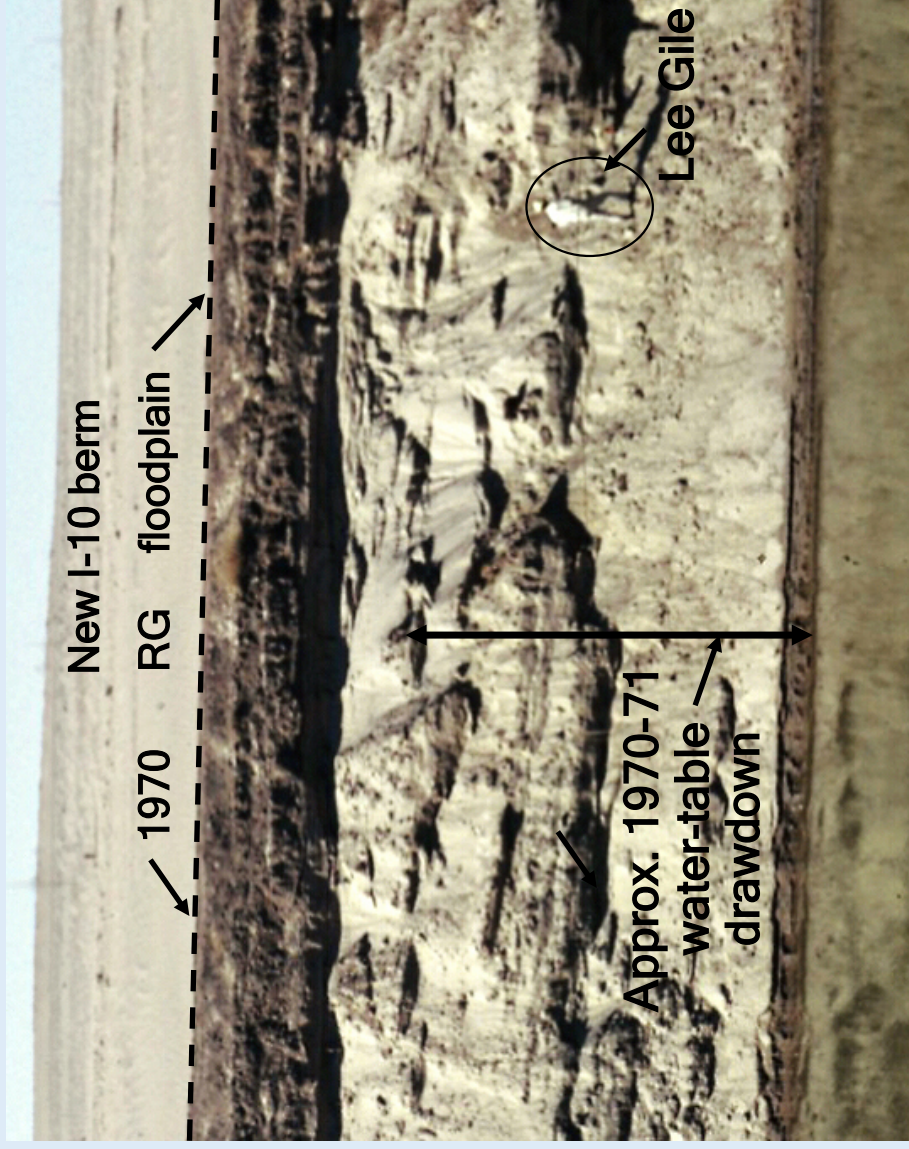


**Pl. F6-1f (NM
WRII; 5/24/2007).
Detail of Pl. F6-1e
trench exposure of
Vertisol in Isaacks
Lake playa, with
2-m tape. Soil
structure reflects
high shrink-swell
properties of clay-
rich (>60% <2 μ)
playa sediment.**



**Plates F6-2a to F6-2f (Slides 121-126).
Representative Exposures of Late Quaternary
Hydrostratigraphic Units and Lithofacies
Assemblages in the Inner Mesilla Valley.**

Pl. F6-2a (USDA-SCS; 3/1971). Historic RG-channel deposits exposed in Burn Lake (I-10) borrow-pit. See Pl. F2-8 for site location, and Pls. F6-2b to 2d for lower pit details.



Pl. F6-2b (USDA-SCS; 3/1971). Lee Gile (~6 ft, 2 in) photographing lower part of the Burn Lake borrow-pit exposure of Rio Grande channel deposits (HSU-RA, LFA a2; see Pls. F6-2a, 2c and 2d). Photo site about 1.5-mi (2.5-km) N of La Mesilla at NE edge of I-10 (Pls. F1-6, F2-8).



PL. F6-2c (USDA-SCS; 3/1971). Fragment of *cottonwood* log in the HSU-RA channel deposit (LFA a2) exposed in the Burn Lake borrow pit near photo-site PL. F6-2b. The ^{14}C age of the sampled wood is ≤ 200 yrs.



Pl. F6-2d (USDA-SCS; 3/1971). LFA a2 detail in HSU-RA, pebbly-sand deposit exposed in the Burn Lake (I-10) borrow pit near photo-site Pl. F6-2b. See Pls. F1-5 and F1-6, F2-8.



Pl. F6-2e (NM WRRRI; 4/1996). Late Quaternary (mostly Holocene) Fillmore Arroyo-channel fill (VAY, LFA b) exposed in excavation at SE edge of the NMSU Campus. The northern Organ Mtns. are on the NE skyline. See Pl. F6-2f for exposure detail, and Pl. F3-2c for site location information.



Pl. F6-2f (NM BMMR; 4/1996). Detail of Fillmore Arroyo-channel fill (HSU-VAY, LFA b) at the Pl. F5-7e photo site. Rock hammer in near the contact of Late Quaternary arroyo alluvium on the Upper SFG-Camp Rice Fm (USF2). See Pl. F1-7 for information on basic *LFA* a and b relationships.



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Part F7—Plates 7-1 to 7-4 Series. Land-Surface Photographs of Quaternary-Age Petrocalcic Soils, Volcanic-Ash Deposits, Volcanic-Eruptive Features, and Fault Zones.

**Plates F7-1a to F7-1g (Slides 129-135):
Petrocalcic Soils and Associated Soil-
Geomorphic Features.**

Pl. F7-1a (NMSU; 5/23/2007). View to the NW across SJB-Experimental Range Subbasin and Early Pleistocene fluvial plain of the ARG (La Mesa geomorphic surface). Retired soil scientist Lee Gile in USDA-ARS soil-test pit that exposes a stage-V petrocalcic horizon. See Pl. F7-1b for exposure details.



Pl. F7-1b (NM WRRRI; 5/24/2000). Degraded, stage-V petrocalcic soil exposed in 12-ft (3.7-m) deep USDA-ARS test-pit (Pl. F7-1a). The soil caps Upper SFG Camp Rice Fm ARG deposits that include Jemez Mtn.-derived clasts of 1.6 Ma Pumice. NRCs Soil Scientist, Carolyn Olsen is at right.



Pl. F7-1c (NM BMMR; 10/1981). Stage V petrocalcic soil capping Upper SFG-ARG deposits on Upper La Mesa Surface west of the East Robledo fault zone. Organ Mountains on skyline east of the Mesilla Valley. SCS soil scientist Lee Gile in drainage trench at Las Cruces Airport.



Pl. F7-1d (NM WRRJ; 5/17/2007). Mid-Pleistocene solution-pipe in stage-V petrocalcic soil exposed in south face of the airport-drainage trench shown in Pl. F7-2c.



Pl. F7-1e (NMSU; 7/18/1988). NMSU calcic-soil research trench at NE edge of Lower La Mesa surface, with East Robledo fz and Upper La Mesa surface on western horizon. John Hawley stands below a stage-IV petrocalcic soil (Pl. F7-1e) that overlies the Camp Rice Fm ARG facies (USF2, LFA 2). See Pls. F5-3h and F7-1f.



**Pl. F7-1f (NM WRRRI;
5/22/2007). Lower La
Mesa surface exposure
of Stage-IV petrocalcic
soil in upper part of
1988 NMSU calcic-soil
research trench shown
in Pl. F7-1e.**



Pl. F7-1g (UACJ; 1/14/2003). John Hawley at SW Hueco Bolson exposure of stage-III/IV petrocalcic soil that caps the Upper SFG-Camp Rice Fm deposits of mixed fluvial and eolian origin shown in Pl. F5-4a.



**Plates F7-2a to F7-2d (Slides 137-140).
Pleistocene Volcanic Ash-Fall Deposits that
are Interbedded with or Cap Upper Santa
Fe Gp Basin Fill.**

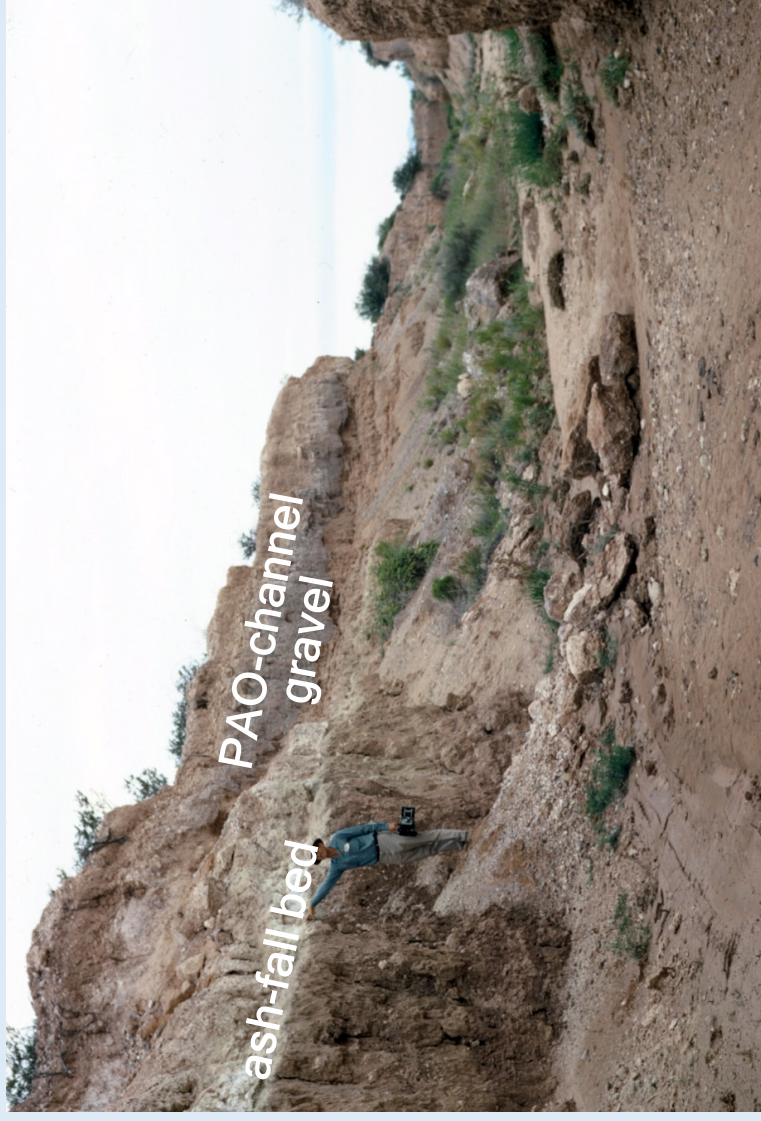
Pl. F7-2a (USDA-SCS; 3/1975). UTEP Biostratigrapher, W. S. (Bill) Strain at exposure of 2.1 Ma Huckleberry Ridge Ash-fall bed in SP[UP]RR-cut. Madden Siding site in SE Hueco Bolson near McNary (Pl. F3-3a). Ash bed is in the basal part of the Camp Rice Fm. near its erosional contact with the Fort Hancock Fm.



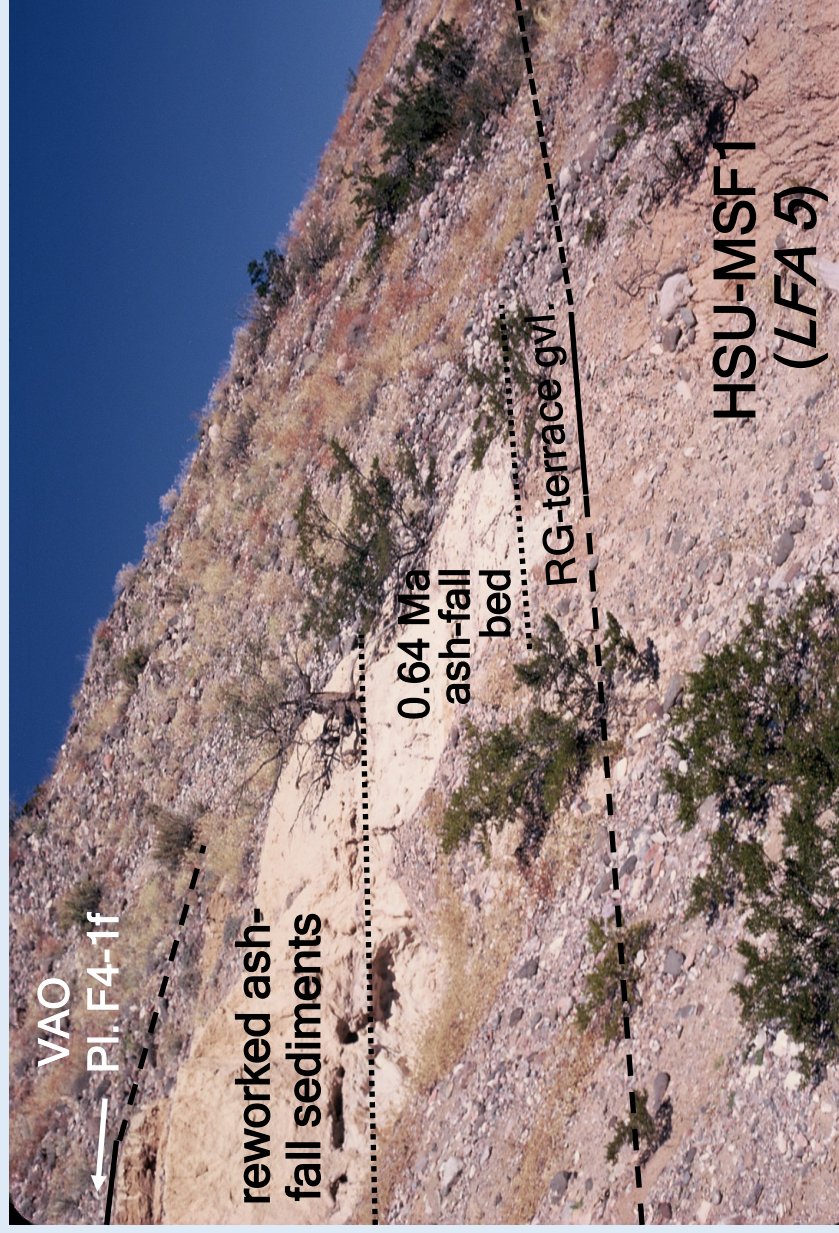
Pl. F7-2b (USDA-SCS; 10/1969). Bishop Ash-fall bed (~0.77 Ma) exposed in El Paso Natural-Gas pipeline cut W of Anthony Gap in the northern Franklin Mtns. The bed caps an eolian-sand unit in Camp Rice Fm piedmont-slope facies (USF1). Photo site shown in Pl. F3-2h.



Pl. F7-2c (USDA-SCS; 9/1969). Lee Gile points to base of Bishop Ash-fall bed (~0.77 Ma) exposed in Rincon Arroyo W of Grama Siding on the BNSFRR (~6 mi/10 km NNE of Rincon, NM. The bed overlies Upper SFG-Camp Rice Fm piedmont facies (USF1-LFA 5).



Pl. F7-2d (USDA-SCS; 1972). Lava Creek Ash-fall bed (~0.64 Ma) exposed in E face of Ash Mine Mesa in upper Selden Cyn. It caps the highest RG-terrace gravel here. See Pl. F4-1d.



**Plates F7-3a to F7-3f (Slides 142-147).
Pleistocene Basalt Flows and Mafic Eruptive
Material that Cap Upper Santa Fe Gp (SFG)
Basin Fill in the Western Mesilla Basin Area.**

Pl. F7-3a (USDA-SCS; 3/1965). East rim of Kilbourne Hole maar, with exposures of a Mid-Pleistocene basalt flow, and capping Late-Pleistocene vent-material and tuff-ring deposits, all of which disconformably overlie Camp Rice Fm-ARG fluvial-deltaic facies (USF2). See Pls. F3-3b, and F7-3b to 3d.



Pl. F7-3b (USDA-SCS; 3/1965). East-rim of Kilbourne Hole (Pl. F7-3a detail). Tuff-ring deposits partly cover a Mid-Pleistocene basalt flow that caps Camp Rice Fm-ARG fluvial-deltaic facies (USF2, LFA 3). See Pls. F7-3c and 3d.



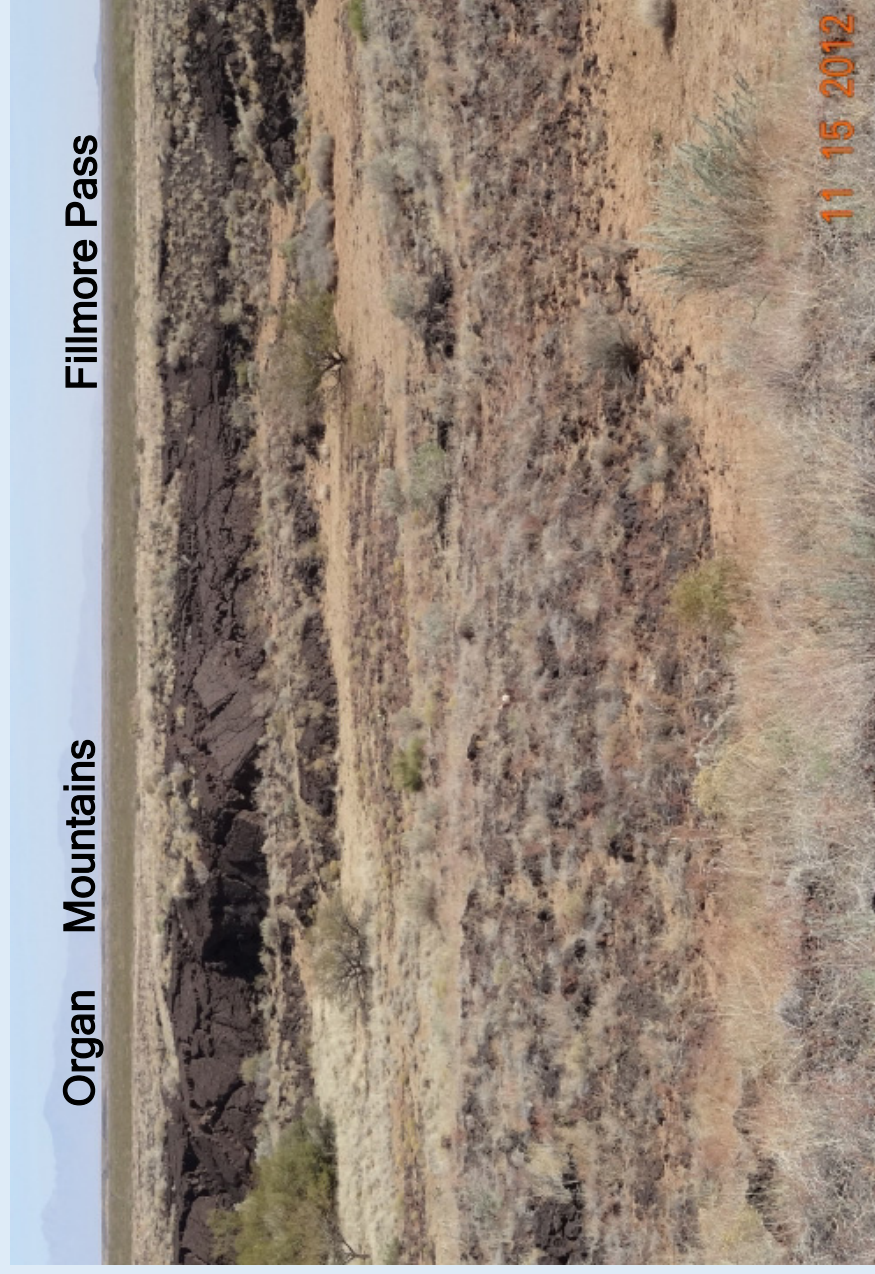
Pl. F7-3c (USDA-SCS; 3/1965). Kilbourne Hole SE rim detail-1 (with 7-ft/2-m tape). Basalt flow with Late Pleistocene tuff-ring cover partly buries Camp Rice Fm fluvial deltaic facies (USF2-LFA 3). See Pl. F7-3d.



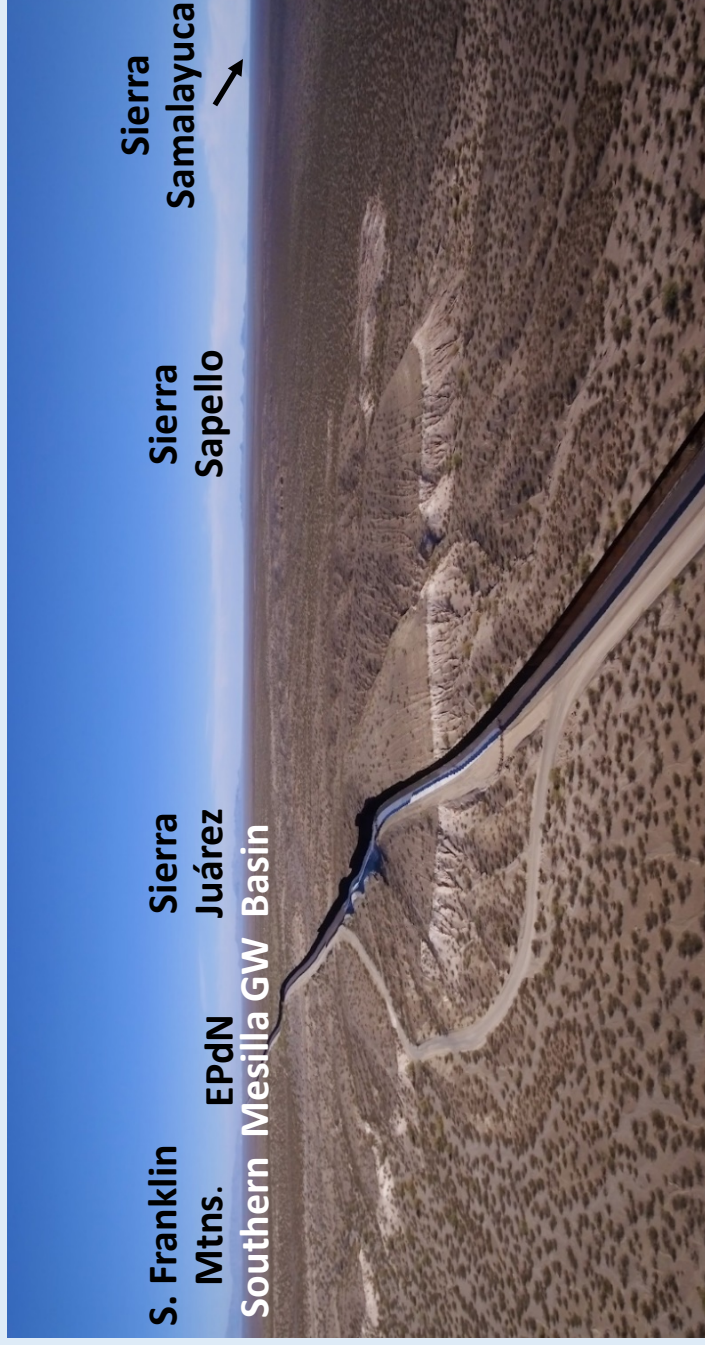
Pl. F7-3d (USDA-SCS; June 1969). Kilbourne Hole SE rim detail-2 (with 6-ft, 2-in man). Late Pleistocene base-surge tuff-ring facies and Mid-Pleistocene basalt-flow tongue are unconformable on Camp Rice Fm-ARG fluvial-deltaic facies (USF2-LFA 3) that has a La Mesa surface, stage- III calcic soil cap.



Pl. F7-3e (Chester Callahan; 11/15/2012). Basalt-flow collapse feature in Late-Pleistocene Aden volcanic field at the western edge of the central Mesilla GW Basin. See Pl. F3-3c.

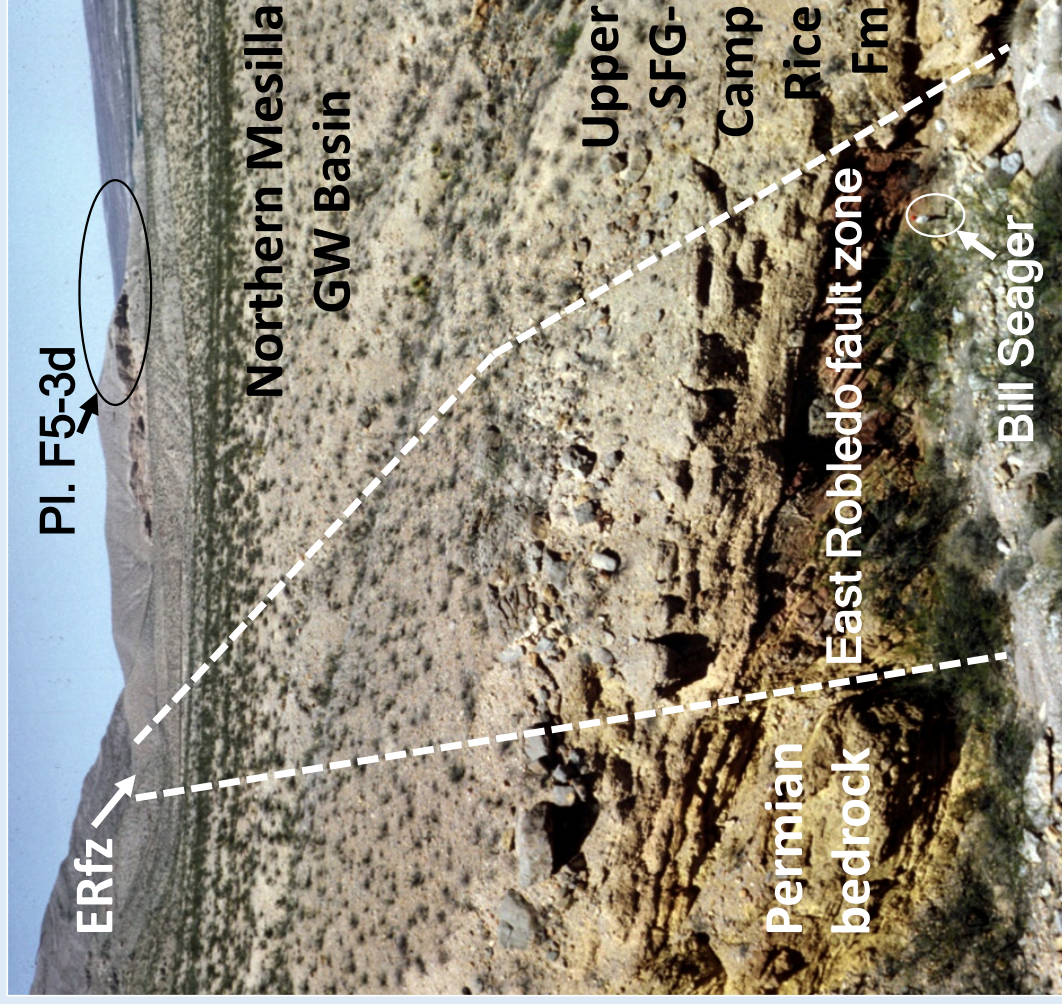


Pl. F7-3f (PBS-Our Land: New Mexico's Environmental Past, Present and Future; Fall 2019). Northern rim of Potrillo Maar at Border Wall crossing (see Pl. F3-4a). Late Pleistocene base-surge tuff deposits disconformably overlie Camp Rice Fm-ARG fluvial-deltaic facies (USF2-LFA 3), with capping La Mesa Surface petrocalcic soil (white band).

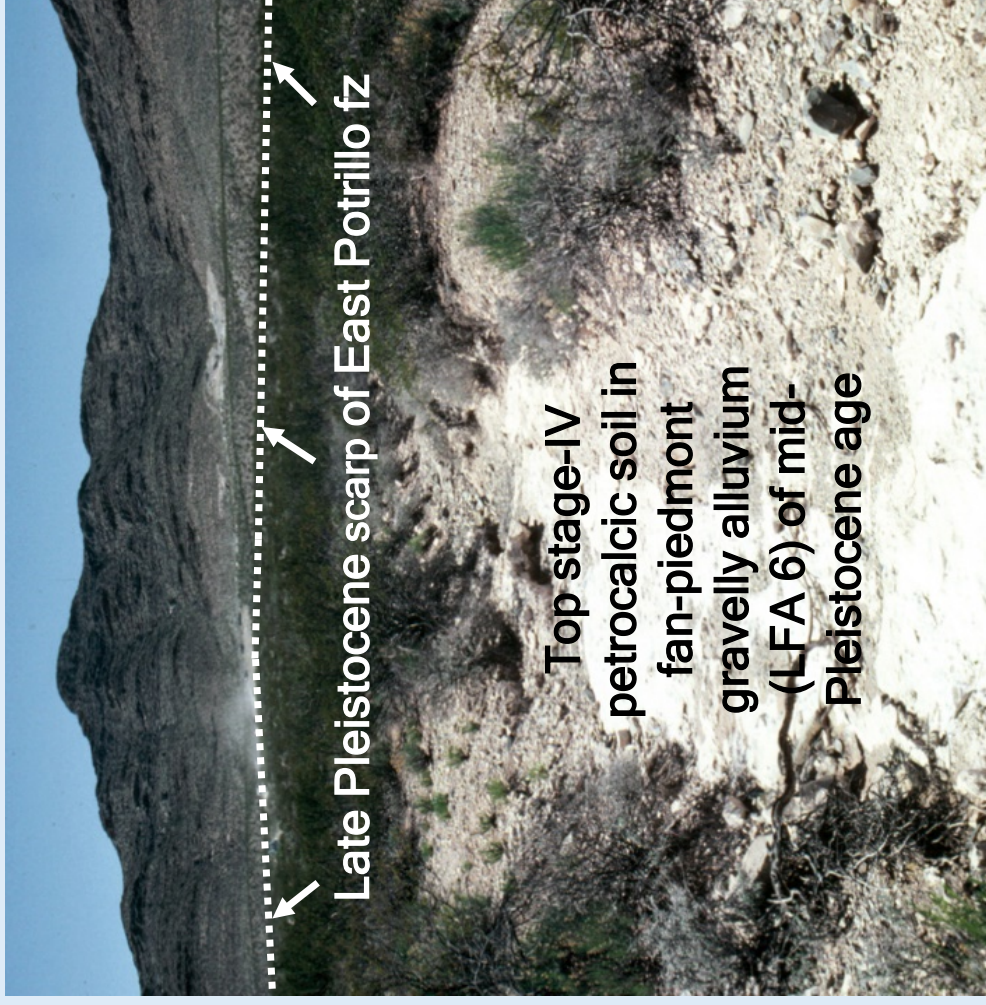


**Plates F7-4a to F7-4e Slides 149-153.
Quaternary Faults and Fault Scarps.**

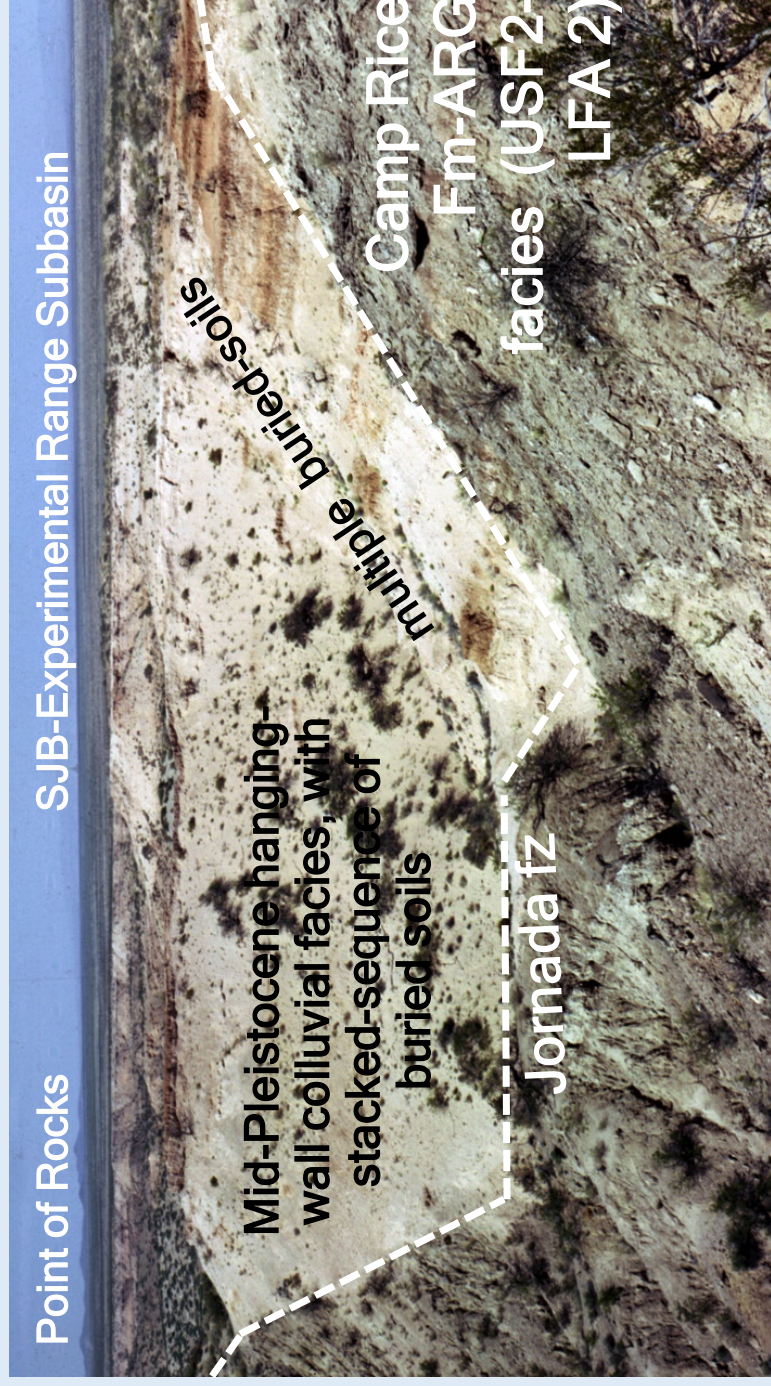
Pl. F7-4a (USDA-SCS; Spring 1968). Canyon-wall exposure of the East Robledo fz (ERfz) at the base of the Robledo Mtn. Uplift (RMU) and the W edge of the northern MeB. The youngest fault displacements involve Middle Pleistocene basin fill. See Pls. F3-1d and F5-3d.



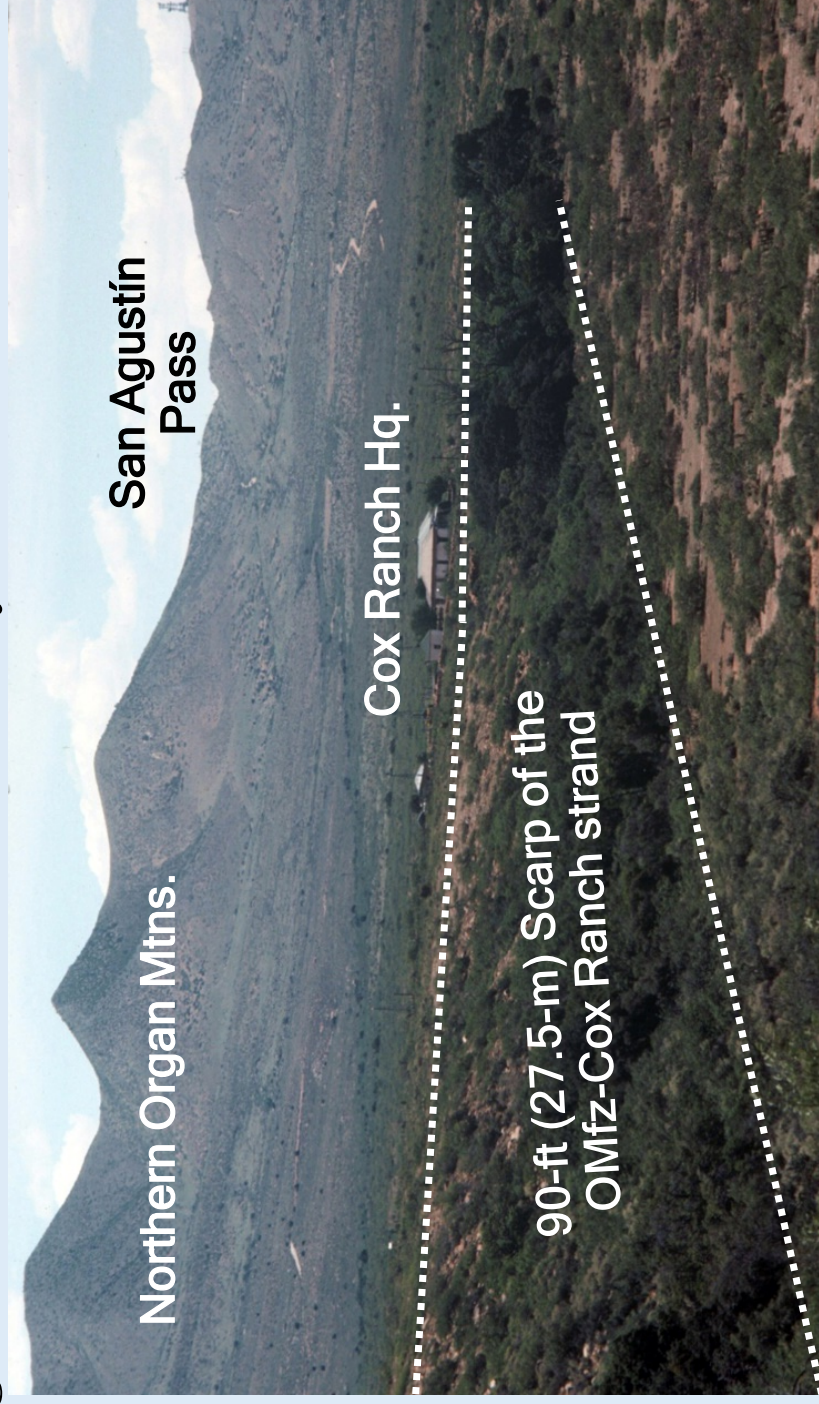
Pl. F7-4b (NM BMMR; 4/1981). East Potrillo fz (EPfz) at base of East Potrillo Mtn. Uplift (EPMU) and the SW edge of the southern Mesilla GW Basin. Youngest fault displacement involves Middle Pleistocene basin fill. See Pls. F3-1d and F5-3d.



Pl. F7-4c (USDA-SCS; April 1968). Exposure of Camp Rice Fm-ARG facies in foot-wall block of the Jornada fz at western edge of the SJB-Experimental Range Subbasin. The stacked sequence of buried soils in hanging-wall colluvium documents the episodic nature of fault displacement.



Pl. F7-4d (NM BMMR; 8/1987). Late Quaternary scarp of the Organ Mtns. fz (OMfz-Cox Ranch strand) at the SW edge of the Tularosa Basin. The northern Organ Mtns. and San Agustín Pass are on the western skyline. See Pl. F7-4e.



Pl. F7-4e (NM BMMR; 8/1987). Cox Ranch strand of the OMfz exposed in trench about 0.5 mi (0.8 km) SE of the Pl. F7-4d photo site, and at the western edge of the WSMR HQ area of the Tularosa Basin. At least 32 ft (10 m) of Holocene fault displacement is observed.





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