**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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**1**APPENDIX F *in* Hawley, J.W., Swanson, B.H., Walker, J.S., and Glaze, S.H., 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

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**F1. Index Maps and Diagrams (Plates F1-1 to F1-8) and Tables (Tbls. F1-1 to F1-6);   
with Names and Acronyms of Hydrogeologic Subdivisions and Fault Zones**

**Pl. F1-1 (p. 2; no. 23).** Index map of the binational/tristate Mesilla Basin regions that shows locations of the Study Area (beige rectangle), major landscape features in the northern Mexican Highland section of the Basin and Range province, and basins of the southern Rio Grande rift tectonic province. 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 Los Muertos-El Barreal and Laguna Guzman/Santa Maria basin complex, and the central Tularosa Basin. 2017 Google Earth® image-base.

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**Pl. F1-5 (p. 7; no. 28).** Index map for major hydrogeologic subdivisions of the Study Area (**Fig. F1-3**). 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 subdivisions are listed in **Tbl. F1-1** (Rpt. **TBL. 2**); and those for fault zones are listed on **Tbl. F1-3** (Rpt. **TBL. 3**).

**Table F1-1 (p. 8; no. 29).** Names and acronyms of hydrogeologic subdivisions shown on maps, cross- sections, and well-information spreadsheet (Rpt. **PLS. 1** to **8**, **TBLS. 1** to **3**).

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**Pl. F2-2 (no. 43).** Apollo 9 mission, multispectral SO-65 series, stereoscopic space photo (frame AS-22-3760); 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 Carrizzalillo 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 (**F2-8** and **F2-9**;2013 NM WRRI 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-AꞋ shows the approximate position of Hydrogeologic Cross-Section I-IꞋ (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 (mislabeled “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 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 ofPicacho “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).** TheAncestral 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)**

**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**.

**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**.

**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**.

**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).

**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**.

**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**.

**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 oftheRio 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 PleistoceneHunts 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 PleistoceneAden 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 1991 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 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.S*ee* **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**,and **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 7and8) 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 **s**ediment 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 F5-3f. 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). G**ypsiferous 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 7. 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] (**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 D1a**). 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 (**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% <2μ) 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 ScientistLeland 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 . *See* **Pl. F1-7** for information on basic LFA a and b relationships.

**Pl. F6-3d (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. F6-7f (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 F7-1f. 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. F7-2d (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 1988NMSU 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 F7-2f. 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 fallis 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 **Tbls. 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.

**F8. CITED REFERENCES**

Akerston, W.A., 1970, Interpretation of sediments and vertebrate fossils in fill of Red Light Bolson, southeastern Hudspeth County, Texas, *in* Geology of the southern Quitman Mountains area, Trans-Pecos Texas: Society of Economic Geologists and Mineralogists, Permian Basin Section, Guidebook, Pub. 70-11, p. 82-87. **(C2a)**

Albritton, C.C., Jr., and Smith, J.F., Jr., 1965, Geology of the Sierra Blanca area, Hudspeth County, Texas: U.S. Geological Survey Professional Paper 594-J, 131 p. **(C2a, D1, F1)**

Allen, B.D., Love, D.W., and Myers, R.G., 2009, Evidence for late Pleistocene hydrologic and climatic change from Lake Otero, Tularosa Basin, south-central New Mexico: New Mexico Geology, v. 31, no. 1, p. 9-25. **(C1, I1, I2)**

Baker, W.W., 1943, Final report on the construction of the canalization feature of the Rio Grande Canalization Project: International Boundary Commission (IBC), p. 4, 16, 18, 32. *See* *Glover 2018.* **(B3, E2)**

Beehner, T.S., 1990, Burial of fault scarps along the Organ Mountains fault, south-central New Mexico: Bulletin of the Association of Engineering Geologists, v. 27, no. 1, p. 1-19. *See Gile 1991.* **(C2b, C3, C4)**

Castiglia, P.J., and Fawcett, P.J., 2006, Large Holocene lakes and climate change in the Chihuahuan Desert: Geology, v. 34, no. 2, p. 113-116. *Seminal paper; but they still do not recognize the major contribution of Mimbres Basin/River system to pluvial Lake Palomas*. **(B2, C1, F3, I2)**

Collins, E.W. and Raney, J.A., 2000, Geologic map of west Hueco Bolson, El Paso region, Texas: The University of Texas at Austin, Bureau of Economic Geology, Miscellaneous Map No. 40, scale 1:100,000. **(C2b, F1)**

Collins, E., Haller, K.M., and Machette, M.N., compilers, 2015, Fault number 900, East Franklin Mountains fault, *in* Quaternary fault and fold database of the United States: U.S. Geological Survey website, accessed June 24, 2021 at <https://earthquakes.usgs.gov/hazards/qfaults> **(C2b, C4)**

Connell, S.D., Hawley, J.W., and Love, D.W., 2005, Late Cenozoic drainage development in the southeastern Basin and Range of New Mexico, southeasternmost Arizona and western Texas, *in* Lucas, S.G., Morgan, G., and Zeigler, K.E., eds., 2005, New Mexico’s Ice Ages: New Mexico Museum of Natural History & Science Bulletin No. 28, p. 125-150. **(C2b, I1, I3)**

Córdoba, D.A., 1969b, Hoja Ciudad Juárez 13 R-a (3) con Resumen de la Geología de la Hoja Ciudad Juárez de Chihuahua: Universidad Nacional Autónoma de México, Instituto Geología, Carta Geología de México, Serie de 1:100,000. *Reprinted as back-cover insert in Córdoba and others, 1969*. **(C2a, F3)**

Córdoba, D.A., Wengerd, S.A., and Shomaker, J.W., eds., 1969, Guidebook of the Border Region: New Mexico Geological Society Guidebook 20, 218 p. *See Road Log Section, p. 1-38.* **(C2a)**

[Davidson](https://www.sciencedirect.com/science/article/pii/S0169555X1200445X" \l "!), S.K., Hartley, [A.J., Weissmann, G.S., Nichols](https://www.sciencedirect.com/science/article/pii/S0169555X1200445X#!), G.J., and [Scuderi](https://www.sciencedirect.com/science/article/pii/S0169555X1200445X#!), L.A., 2013, Geomorphic elements on modern distributive fluvial systems: Geomorphology, v. 180-181, p. 82-85. **(D1)**

DeHon, R.A., 1965, Maare of La Mesa: New Mexico Geological Society, Guidebook 16, p, 204-209. **(C2a)**

DeHon, R.A. and Earl, R.A., 2018,The Aden lava flows, Doña Ana County, New Mexico: N. M. Geological Society Guidebook 69, p. 197-202. **(C2b)**

Drewes, H. and Dyer, R., 1993, Geologic map and structure sections of the Sierra Juárez, Chihuahua, Mexico: U.S. Geological Survey Miscellaneous Investigations Map I-2287, scale 1:12,500. **(C2b, F3)**

Dunbar, N.W., 2005, Quaternary volcanism in New Mexico, *in* Lucas, S.G., Morgan, G., and Zeigler, K.E., eds., New Mexico’s Ice Ages: New Mexico Museum of Natural History & Science Bulletin No. 28, p. 95-106. **(C2b)**

Eastoe, C.J., Hutchison, W.R., Hibbs, B.J., Hawley, J., and Hogan, J.F., 2010, Interaction of a river with an alluvial basin aquifer: Stable isotopes, salinity and water budgets: Journal of Hydrology, v. 395, p. 67-78. **(H1, H2)**

Eastoe, C.J., Hibbs, B.J., Granados Olivas, A., Hogan, J.F., Hawley, J., and Hutchison, W.R., 2008, Isotopes in the Hueco Bolson aquifer, Texas (USA) and Chihuahua (Mexico): Local and general implications for recharge sources in alluvial basins: Hydrogeology Journal, v. 16, no. 4, p. 737-747. **(H1, H2)**

Gile, L.H., 1986, Late Holocene displacement along the Organ Mountains fault in southern New Mexico - A summary: New Mexico Geology, v. 8, n. 1, p. 1-4. **(C2a, C3)**

Gile, L.H., 1987a, A pedologic chronology of Kilbourne Hole, southern New Mexico: I. Soils in tuff; II. Time of the explosions: Soil Science Society of America Journal, v. 51, p. 746-760. **(C2a, C3)**

Gile, L.H., 1990, Chronology of lava and associated soils near San Miguel, New Mexico: Quaternary Research, v. 33, p. 37-50. **(C2b, C3)**

Gile, L.H., 1991, Discussion, burial of fault scarps along the Organ Mountains fault, south-central New Mexico: Bulletin of the Association of Engineering Geologists, v. 27, no. 3, p. 325, 326. *See Beehner 1990*. **(C2b, C3)**

Gile, L.H., 1994b, Soils, geomorphology, and multiple displacements along the Organ Mountains fault in southern New Mexico: New Mexico Bureau of Mines and Mineral Resources Bulletin 133, 91 p. **(C2b, C3)**

Gile, L.H., Hawley, J.W., and Grossman, R.B., 1981, Soils and geomorphology in the Basin Range area of southern New Mexico – Guidebook to the Desert Project: New Mexico Bureau of Mines and Mineral Resources, Memoir 39, 222 p. <https://geoinfo.nmt.edu/publications/monographs/memoirs/39/> **(C2a, C3)**

Gile, L. H., Hawley, J. W., Grossman, R. B., Monger, H. C., Montoya, C. E., and Mack, G. H., 1995, Supplement to the Desert Project Guidebook, with emphasis on soil micromorphology: New Mexico Bureau of Mines and Mineral Resources, Bulletin 142, 96 p. **(C2b, C3)**

Glover, A., 2018, Levees of the Hatch and Mesilla Valleys: N. M. Geological Society Guidebook 69, p. 63-64. *See* Baker 1943. **(B3, E2)**

Goff, F., and Gardner, J.N., 2004, Late Cenozoic geochronology of volcanism and mineralization in the Jemez Mountains and Valles caldera, north-central New Mexico, *in* Mack, G.H., and Giles, K.J., eds., The Geology of New Mexico: A geologic history: New Mexico Geological Society, Special Publication 11, p. 295-312. **(B1, C2b)**

Gries, J.G., and Haenggi, W.T., 1970, Structural evolution of the eastern Chihuahua Tectonic Belt, *in*The Geologic Framework of the Chihuahua Tectonic Belt: Symposium in honor of Professor Ronald K. DeFord, West Texas Geological Society and University of Texas at Austin, p. 119-137. **(C2a, F1)**

Groat, C.F., 1972, Presido Bolson, Trans-Pecos Texas and adjacent Mexico: Geology of a desert basin aquifer system: Texas Bureau of Economic Geology Report of Investigation 76, 46 p. **(C2a, F1, I3)**

Gustavson, T.C., 1991a, Arid basin depositional systems and paleosols: Fort Hancock and Camp Rice Formations (Pliocene-Pleistocene) Hueco Bolson, West Texas and adjacent Mexico: University of Texas at Austin, Bureau of Economic Geology, Report of Investigations No. 198, 49 p. **(C2b, C3, I3)**

Haase, C.S., and Lozinsky, R.P., 1992, Estimation of hydrologic parameters, *in* Hawley, J.W., and Haase, C.S., compilers, Hydrogeologic framework of the northern Albuquerque Basin: New Mexico Bureau of Mines and Mineral Resources, Open File Report 387, p. VI-1 to VI-3. **(D1)**

Hawley, J.W., 1969b, Notes on the geomorphology and late Cenozoic geology of northwestern Chihuahua: New Mexico Geological Society Guidebook 20, p. 131-142. **(C2a, F3)**

Hawley, J.W., 1975a, Quaternary history of Doña Ana County region, south-central New Mexico: New Mexico Geological Society Guidebook 26, p. 139-150. **(C2a, F1, I3)**

Hawley, J.W., and Kennedy, J.F., 2004, Creation of a digital hydrogeologic framework model of the Mesilla Basin and southern Jornada del Muerto Basin: New Mexico Water Resources Research Institute Report No. 332, 105 p., with plates and appendix on CD ROM. <https://nmwrri.nmsu.edu/publications/technical-reports/tr-reports/tr-332.html> **(F1, H1)**

Hawley, J.W., and Kernodle, J.M., 2000, Overview of the hydrogeology and geohydrology of the northern Rio Grande basin – Colorado, New Mexico, and Texas, *in* Ortega Klett, C.T., ed., Proceedings of the 44th Annual New Mexico Water Conference: New Mexico Water Resources Research Institute Report No. 312, p. 79-102. **(D1)**

Hawley, J.W., Kennedy, J.F., Granados Olivas, A., and Ortiz, M.A., 2009, Hydrogeologic framework of the binational western Hueco Bolson-Paso del Norte area, Texas, New Mexico, and Chihuahua: Overview and progress report on digital model development: New Mexico Water Resources Research Institute Report No. 349, 45 p., 2 pls. <https://nmwrri.nmsu.edu/publications/technical-reports/tr-reports/tr-349.html> **(F1, H1)**

Hawley, J.W., Kottlowski, F.E., Seager, W.R., King, W.E., Strain, W.S. and LeMone, D.V., 1969, The Santa Fe Group in the south-central New Mexico border region, *in* Border Stratigraphy Symposium: New Mexico Bureau of Mines and Mineral Resources, Circular 104, p. 52-76. **(C2a, F1)**

Hawley, J.W., Hibbs, B.J., Kennedy, J.F., Creel, B.J., Remmenga, M.D., Johnson, M., Lee, M.M., and Dinterman, P., 2000, Trans-International Boundary aquifers in southwestern New Mexico: New Mexico Water Resources Research Institute, prepared for U.S. Environmental Protection Agency-Region 6 and International Boundary and Water Commission; Technical Completion Report-Interagency Contract X-996350-01-3, 126 p. <https://nmwrri.nmsu.edu/publications/pub-external-pages/trans-international-boundary-aquifers-in-southwest-new-mexico.html> **(C2b, D1, F1, I2)**

Henry, C.D., 1979, Geologic setting and geochemistry of thermal water and geothermal assessment, Trans-Pecos Texas: Texas Bureau of Economic Geology, Report of Investigations 96, 48 p. **(C2a, F1, H1, H2)**

Henry, C.D., and Price, J.G., 1984, Variations in caldera development in the Tertiary volcanic field of Trans-Pecos Texas: Journal of Geophysical Research, v. 91, p. 6213-6224. **(C2a)**

Henry, C.D., and Price, J.G., 1985, Summary of the tectonic development of Trans-Pecos Texas: University of Texas at Austin, Bureau of Economic Geology, Miscellaneous Map No. 36, scale 1:500,000, text 8 p. **(C2a, F1)**

Hoffer, J.M., 1971, Mineralogy and petrology of the Santo Tomas-Black Mountain basalt field, Potrillo volcanics, south-central New Mexico: Geological Society of America Bulletin, vol. 82, no. 3, p. 603-612. **(C2a)**

Hoffer, J.M., 2001a, Geology of Potrillo Maar*,* southern New Mexico and northern Chihuahua, Mexico, *in* Crumpler, L.S., and Lucas, S.G., eds., Volcanology in New Mexico: New Mexico Museum of Natural History and Science, Bulletin 18, p. 137-140. **(C2b, F1)**

Izett, G.A., and Wilcox, R.E., 1982, Map showing localities and inferred distributions of the Huckleberry Ridge, Mesa Falls, and Lava Creek Ash Beds (Pearlette family ash beds) of Pliocene and Pleistocene age in the western United States and southern Canada: U.S. Geological Survey Miscellaneous Investigations Map I-1325, scale 1:4,000,000. **(B1, C2a, I3)**

Izett, G.A., Obradovich, J.D., and Mehnert, H.H., 1988, The Bishop ash bed (middle Pleistocene) and some older (Pliocene and Pleistocene) chemically similar ash beds in California, Nevada and Utah: U.S. Geological Survey, Bulletin 1675, 37 p. **(B1, C2a)**

Jiménez, A.J., and Keller, G.R., 2000, Rift basin structure in the border region of northwestern Chihuahua: New Mexico Geological Society Guidebook 51, p. 79-83. **(C2b, C4, F1**, **H1)**

Jochems, A.P., 2017, Geologic map of the Arroyo Cuervo 7.5-minute quadrangle, Doña Ana and Sierra Counties, New Mexico: New Mexico Bureau of Geology and Mineral Resources, Open-File Geologic Map OF-GM 261, scale 1:24,000. **(C2b)**

Kelley, S.A., and Matheny, J.P., 1983, Geology of Anthony quadrangle, Doña Ana County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Geologic Map 54, scale 1:24,000. **(C2a)**

Koning, D.J., Jochems, A.P., and Cikoski, C., 2015, Geologic map of the Skute Stone Arroyo 7.5-minute quadrangle, Sierra County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-File Geologic Map 252, scale 1:24,000. CD-ROM. **(C2b)**

Kortemeier, C.P., 1982, Occurrence of Bishop Ash near Grama, New Mexico: New Mexico Geology, v. 4, No. 2, p. 22-24. **(B1, C2a)**

Leavy, B.D., 1987, Surface-exposure dating of young volcanic rocks using *in situ* buildup of cosmogenic isotopes: Socorro, NM Institute of Mining and Technology, doctoral dissertation, 167 p. **(B1, C2a)**

Lovejoy, E.M.P., 1976a, Geology of Cerro de Cristo Rey uplift, Chihuahua and New Mexico: New Mexico Bureau of Mines and Mineral Resources Memoir 31, 84 p. **(C2a, F1)**

Lovejoy, E.M.P. and Hawley, J.W., 1978, Southern rift guide 1, El Paso to New Mexico-Texas state line, *in* Hawley, J.W., compiler, Guidebook to Rio Grande rift in New Mexico and Colorado: New Mexico Bureau of Mines and Mineral Resources Circular 163, p. 57-71. **(C2a)**

Lucas, S.G., Corbett, L.L., and Estep, J.W., 1998, Cretaceous stratigraphy, paleontology, petrography, depositional environments, and cycle stratigraphy at Cerro de Cristo Rey, Doña Ana County, New Mexico: New Mexico Geological Society Guidebook 49, p. 197-203. **(C2b, F1)**

Lucas, S.G., Krainer, K., Spielmann, J.A., and Durney, K., 2010, Cretaceous stratigraphy, paleontology, petrography, depositional environments, and cycle stratigraphy at Cerro de Cristo Rey, Doña Ana County, New Mexico: New Mexico Geology, v. 32, no. 4, p. 103-130. **(C2b, F1)**

Lucas, S.G., Morgan, G.S, Estep, J.W., Mack, G.H., and Hawley, J.W., 1999, Co-occurrence of the Proboscideans Cuvieronius, Stegomastodon, and Mammuthus in the Lower Pleistocene of Southern New Mexico: Journal of Vertebrate Paleontology, v. 19, no. 3, pp. 595-597. **(B1, C1)**

Machette, M.N., 1985, Calcic soils of the southwestern United States, *in* Weide, D.L., ed., Quaternary soils and geomorphology of the American Southwest: Geological Society of America Special Paper 203, p. 1-21. **(C2a, C3)**

Machette, M.N., 1987, Preliminary assessment of paleoseismicity at White Sands Missile Range, southern New Mexico: Evidence for recency of faulting, fault segmentation, and repeat intervals for major earthquakes in the region: U.S. Geological Survey Open-File Report 87-444, 46 p. **(C2a, C4)**

Mack, G.H., 2018, Authigenic opal and calcite beds in axial-fluvial sediment of the Camp Rice Formation (Pliocene-lower Pleistocene), Rincon Hills – Third-day Road Log from Las Cruces to Rincon Hills: N. M. Geological Society Guidebook 69, p. 39-45. **(C2b)**

Mack, G.H., Salyards, S.L., and James, W.C., 1993, Magnetostratigraphy of the Plio-Pleistocene Camp Rice and Palomas formations in the Rio Grande rift of southern New Mexico: American Journal of Science, v. 293, p. 49-77. **(B1, C2b, I3)**

Mack, G.H., McIntosh, W.C., Leeder, M.R., and Monger, H.C., 1996, Plio-Pleistocene pumice floods in the ancestral Rio Grande, southern Rio Grande rift, USA: Sedimentary Geology, v. 103, p. 1-8. **(B1, C2b, I3)**

Monger, H.C., Daugherty, L.A., and Gile, L.H., 1991, A microscopic examination of pedogenic calcite in an Aridisol of southern New Mexico, *in* Occurrence, characteristics, and genesis of carbonate, gypsum, and silica accumulation in soils: Soil Science Society of America Special Publication No. 26, p. 37-60. **(C3)**

Moorhead, M.L., ed., 1954, Josiah Gregg [1844], Commerce of the prairies: University of Oklahoma Press, 469 p. **(A2, B3)**

Morgan, G.S., Hulbert, H.C., Jr., Gottlieb, E.S., Amato, J.M., Mack, G.H., Jonell, T.N., 2017, The tapir *Tapirus* (Mammalia: Perissodactyla) from the late Pliocene (early Blancan) Tonuco Mountain Local Fauna, Camp Rice Formation, Doña Ana County, southern New Mexico: New Mexico Geology, v. 39, no. 2, p. 28-39. **(C1, C2b)**

Morrison, R.B., 1969, Photointerpretive mapping from space photographs of Quaternary geomorphic feature and soil associations in northern Chihuahua and adjoining New Mexico and Texas: New Mexico Geological Society Guidebook 20, p. 116-129. **(C2a, C3, E1, F1, I2)**

Nichols, G., 2015, Stratigraphic architectureof fluvial distributive systems in Basins of internal drainage: Search and Discovery Article #51145 (2015), 42 p. pdf. *For related information contact author directly at Nautilus Ltd, Hermitage, Berkshire, United Kingdom* [*g.nichols@nautiuswold.com*](mailto:g.nichols@nautiuswold.com) **(D1)**

Reaser, D.F., 1982, Geometry and deformational environment of the Cineguilla-Quitman range in northeastern Chihuahua, Mexico and western Trans-Pecos Texas, USA, *in*Powers, R.B., ed., Geologic studies of the Cordilleran thrust belt, v. 1: Denver, Co., Rocky Mountain Association of Geologists, p. 425-449.   
**(C2a, F1)**

Reaser, D.F., and Underwood, J.R., Jr., 1980, Tectonic style and deformation environments in the Eagle-southern Quitman Mountains, western Trans-Pecos Texas, *in* Dickerson, P.W., Hoffer, J.M., and Callender, J.F., eds., Trans-Pecos region: New Mexico Geological Society Guidebook 31, p. 123-130. **(C2a, F1)**

Reeves, C.C., Jr., 1969, Pluvial Lake Palomas, northwestern Chihuahua, Mexico: New Mexico Geological Society Guidebook 20, p. 143-154. **(C2a, C4, F3, I2, I3)**

Reeves, C.C., Jr., and DeHon, R.A., 1965, Geology of Potrillo maar, New Mexico and northern Chihuahua, Mexico: American Journal of Science, v.263, p. 401-409. **(C2a, F1)**

Reynolds, R.L. and Larsen, E.E. 1972, Paleomagnetism of Pearlette-like air-fall ash in the midwestern and western United States: A means of correlating Pleistocene deposits: Geological Society of America, Abstracts with Programs, v. 4, no. 6, p. 405. **(C2a, C4)**

Sarna-Wojcicki, A.M., and Davis, J.O., 1991, Quaternary tephrochronology, *in* Morrison, R.B., ed., Quaternary non-glacial geology; Conterminous U.S.: Boulder, CO, Geological Society of America, The Geology of North America, v. K-2, p. 93-116. **(B1, C2b)**

Seager, W.R., 1975b, Geologic map and sections of south half of San Diego Mountain quadrangle, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Geologic Map 35, scale 1:62,500. **(C2a)**

Seager, W.R., 1981, Geology of the Organ Mountains and southern San Andres Mountains, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Memoir 36, 97 p. **(C2a)**

Seager, W.R., 1987, Caldera-like collapse at Kilbourne Hole Maar, New Mexico: New Mexico Geology, v. 9, no. 4, p. 69-73. **(C2a)**

Seager, W.R., 1995, Geology of southwest quarter of Las Cruces and northwest El Paso 1º x 2º sheets: New Mexico Bureau of Mines and Mineral Resources, Geologic Map 60, scale 1:125,000. **(C2b, C4)**

Seager, W.R., and Hawley, J.W., 1973, Geology of Rincon quadrangle, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 101, 56 p., map scale 1:24,000. **(C2a)**

Seager, W.R., and Mack, G.H., 1994, Geology of the East Potrillo Mountains and vicinity, Doña Ana County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 113, 27 p. **(C2b)**

Seager, W.R., and Mack, G.H., 2003, Geology of the Caballo Mountains, New Mexico: New Mexico Bureau of Geology and Mineral Resources Memoir 49, 136 p. **(C2b)**

Seager, W.R., and Mack, G.H., 2018*,* Geology of the Doña Ana Mountains, south-central New Mexico: A summary: N.M. Geological Society, Guidebook 69, p. 71-81. **(C2b)**

Seager, W.R., Clemons, R.E., and Hawley, J.W., 1975, Geology of Sierra Alta Quadrangle, Doña Ana County, New Mexico, New Mexico Bureau of Mines and Mineral Resources, Bulletin 102, 56 p., map scale 1:24,000. **(C2a)**

Seager, W.R., Hawley, J.W., and Clemons, R.E., 1971, Geology of San Diego Mountain area, Doña Ana County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 97, 38 p., map scale 1:24,000. **(C2)**

Seager, W.R., Hawley, J.W., and Mack, G.H., 2015 [1995 revision], Geologic map of Hatch 7.5-minute quadrangle, Doña Ana County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-File Geologic Map 213, scale 1:24,000. CD-ROM. <http://geoinfo.nmt.edu/publications/maps/geologic/ofgm/> **(C2b)**

Seager, W.R., Kottlowski, F.E., and Hawley, J.W., 1976, Geology of Doña Ana Mountains, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circular 147, 36 p., 2 tables, 13 figs., 3 sheets, scale 1:24,000. **(C2a)**

Seager, W.R., Kottlowski, F.E., and Hawley, J.W., 2008, Geologic Map of the Robledo Mountains and vicinity, Doña Ana County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-File Report 509, scale 1:24,000, CD-ROM. <http://geoinfo.nmt.edu/publications/maps/geologic/ofgm/> **(C2b)**

Seager, W.R., Thacker, J.O., and Kelley, S.A., 2021, Geologic map of the Selden Canyon 7.5 minute quadrangle, Dona Ana County, New Mexico: New Mexico Bureau of Geology and Mineral Resources Open-File Geologic Map OF-GM-290, scale 1:24,000. **(C2b)**

Seager, W.R., Clemons, R.E., Hawley, J.W., and Kelley, R.E., 1982, Geology of northwest part of Las Cruces 1º x 2º sheet, New Mexico: New Mexico Bureau of Mines and Mineral Resources Geologic Map, GM-53, scale 1:125,000, 3 sheets. **(C2a)**

Seager, W.R., Hawley, J.W., Kottlowski, F.E., and Kelley, S.A., 1987, Geologic map of east half of Las Cruces and northeast El Paso 1º x 2º sheets, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Geologic Map, GM-57, scale 1:125,000, 3 sheets. **(C2a)**

Seager, W.R., Kelley, S.A., Thacker, J.O., and Kelley, R.E., 2023, San Diego Mountain: A “Rosetta Stone” for Interpreting the Cenozoic Tectonic Evolution of South-Central New Mexico: New Mexico Geology, v. 44, no. 2, p. 23-62. **(C2b, I3)**

Seager, W.R., Shafiqullah, M., Hawley, J.W., and Marvin, R.F., 1984, New K-Ar dates from basalts and the evolution of the southern Rio Grande: Geological Society of America Bulletin, v. 95, no. 1, p. 87-99.   
**(C2a, I3)**

Strain, W.S., 1966, Blancan mammalian fauna and Pleistocene formations, Hudspeth County, Texas: Texas Memorial Museum, Bulletin 10, 55 p. **(B1, C2a)**

Strain, W.S., 1971, Late Cenozoic bolson integration in the Chihuahua tectonic belt, *in* The geologic framework of the Chihuahua tectonic belt: West Texas Geological Society, Publication No. 71-59, p. 167-173. **(C2a)**

Underwood, J.R., Jr., 1980, Physiographic features, Trans-Pecos region: New Mexico Geological Society   
Guidebook 31, p. 57-58. **(C2a, F1)**

Weissmann, G., Hartley, A., and Nichols, G., 2011, Alluvial facies distribution in continental sedimentary basins –Distributive fluvial systems, *in* Davidson, S., Leleu, S., and North, C., eds., Rock to rock record: The preservation of fluvial sediments and their subsequent interpretation: SEPM (Society for Sedimentary Geology), v. 79, p. 327-355. ISBN 978-1-56576-305 **(D1)**

Wierenga, P.J., Hills, R.G., and Hudson, D.B., 1991, The Las Cruces Trench Site: Experimental Results and One-Dimensional Flow Predictions. Water Resources Research, v. 27, p. 2695-2705. **(D2, H3)**

Wierenga, P.J., Hudson, D.B., Hills, R.G., Porro, I., Kirkland, M.R., and Vinson, J., 1990, Flow and Transport at the Las Cruces Trench Site; Experiment 1 and 2: U.S. Nuclear Regulatory Commission Report, NUREG/CR-5607, 413 p. **(D2, H3)**

Williams, W.J.W., 1999, Evolution of Quaternary intraplate mafic lavas using 3He surface exposure and 40Ar/39Ar dating, and detailed elemental He, Sr, Nd, and Pb isotopic signatures: Potrillo Volcanic Field, New Mexico, U.S.A., and San Quintín Volcanic Field, Baja California Norte, México: University of Texas at El Paso, doctoral dissertation, 195 p. **(B1, C2b, C4)**

Wilson, C.A., White, R.R., Orr, B.R., and Roybal, R.G., 1981, Water resources of the Rincon and Mesilla Valleys and adjacent areas, New Mexico: New Mexico State Engineer Technical Report 43, 514 p. **(H1, H2)**

Witcher, J.C., and Mack, G.H., 2018, Masson Farm Geothermal Greenhouses at Radium Springs: Third-day (C) Road Log from Las Cruces to Geothermal Greenhouses of the Masson Farm at Radium Springs: N.M. Geological Society Guidebook 69, p. 47-51. **(C2b, C4, H2)**

**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