

Preliminary Geologic Map of the South Spring Quadrangle, Chaves County, New Mexico.

By

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*Open-file Digital Geologic Map OF-GM 171***

Scale 1:24,000

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The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government or the State of New Mexico.

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OVERVIEW

The South Spring 7.5-minute quadrangle lies in southeast New Mexico on the southeastern outskirts of the city of Roswell. The area covered by the quadrangle, which extends from 33°15'N to 33°22'30"N and 104°22'30"W to 104°30'W, is approximately 158 km² (61 mi²). Relief is quite low as elevations range from approximately 1,049 m (3,442 ft) where the Pecos River flows out of the quadrangle to the east to the highest point on the western margin of the map, 1,107 m (3,632 ft). The majority of the quad contains the distal section of a large middle to late Pleistocene alluvial fan built predominantly by the Rio Hondo, which drains the high, glaciated, volcanic and limestone terrain of the Sacramento Mountains, some 120 km distant to the west. In the northeast corner of the quad, the Pecos River flows in its floodplain in from the north and out to the east. Three of the four Holocene to historic meanderbelts built by the river mapped on the Bitter Lake quad immediately to the north (McCraw, *et al.*, 2007) occupy this corner, along with the confluence of the modern Rio Hondo. As documented on the Bitter Lake quad, the large, braided, late Pleistocene fluviodeltaic fan of the Rio Hondo was abandoned in the Holocene, when the river started meandering, eventually building three meanderbelts up to present. These deposits are also found in the northeast corner of South Spring.

Both the alluvial valley and the large alluvial fan complex lie within the northern Roswell artesian basin, which are comprised of both a shallow alluvial aquifer and an underlying artesian aquifer within the Permian San Andres formation. These aquifers have supported extensive agriculture since the late 19th Century here. Artesian springs (e.g, South Spring) commonly exhibited perennial discharge in historic times, but are mostly now extinct due to aquifer pumping for agriculture (see Figure 1). Of the 8 springs mapped on the quad, all but the three along the Pecos River floodplain margin are now extinct.



Figure 1. Panorama of the extinct South Spring looking north to northeast. The spring used to issue out of the low-lying, gray, lacustrine sediments in the foreground-right, and flowed to the Pecos River, some 8 km distant to the north and east.

The Rio Hondo, which presently flows around the South Spring quadrangle, from the west to the northeast into the Roswell South quad and east through the Bitter Lake quad, built an extensive alluvial fan complex across Pecos River alluvial terraces during most of the Pleistocene. This fan complex covers an estimated area of 520 km², extending some 16 km from the western alluvial valley margin to its thin distal edges in the eastern part of South Spring quad. An obvious stream capture, located at the current site of the dry Twin Rivers reservoir, on the Hondo Reservoir 7.5-minute quadrangle, two quads

west of South Spring, turned the river into its present northeast channel. While the timing of the stream capture is unknown, it is clearly evident that the Rio Hondo used to debouch out of the Permian San Andres formation uplands onto the valley terrace floor via what is now referred to as Rocky Arroyo. Distinct fan lobes, old, abandoned channels, as well as modern ephemeral streams (formerly, historically spring-fed) comprise the majority of South Spring surficial deposits.

Both the Rio Hondo alluvial fan complex and the Pecos River alluvial terraces are underlain by Permian evaporites of the Seven Rivers formation (*Psr*). Part of the Artesia Group (Guadelupian), *Psr* gypsum is seen in the bluffs east of the Pecos River on the Bottomless Lakes quad, immediately east of South Spring, and is responsible for the “Bottomless Lakes” collapsed sinkholes. In the southeast quadrant of the map, the proximity of Seven Rivers gypsum to the surface accounts for the decline of agriculture, as well as other sinkholes and depressions, typical of a gypsum karstic landscape.

The majority of the quadrangle is privately owned and comprised of large agricultural fields and an extensive dairy farm industry. Access is quite good from U.S. Highway 285 and N.M. Highways 2, 353, and 254, which all either traverse or extend well into the map area. Numerous farm roads, usually following section lines, spread out from these. Part of the Pecos River floodplain falls under the jurisdiction of the U.S. Fish and Wildlife’s Bitter Lake National Wildlife Refuge (BLNWR), and this access is limited.

COMMENTS TO MAP USERS

This quadrangle map has been Open-filed in order to make it available to the public. The map has not been reviewed according to New Mexico Bureau of Geology and Mineral Resources standards, and due to the ongoing nature of work in the area, revision of this map is likely. As such, dates of revision are listed in the upper right corner of the map and on the accompanying report. ***The contents of the report and map should not be considered final and complete until published by the New Mexico Bureau of Geology and Mineral Resources.***

A geologic map graphically displays information on the distribution, nature, orientation, and age relationships of rock and surficial units and the occurrence of structural features such as faults and folds. Geologic contacts are irregular surfaces that form boundaries between different types or ages of units. Data depicted on this geologic map are based on field geologic mapping, compilation of published and unpublished work, and photogeologic interpretation. Locations of contacts are not surveyed, but are plotted by interpretation of the position of a given contact onto a topographic base map; therefore, the accuracy of contact locations depends on the scale of mapping and the interpretation of the geologist. Significant portions of the study area may have been mapped at scales smaller than the final map; therefore, the user should be aware of potentially significant variations in map detail. Site-specific conditions should be verified by detailed surface mapping or subsurface exploration. Topographic and cultural changes associated with recent development may not be shown everywhere.

The cross section is constructed based on exposed geology, and where available, subsurface and geophysical data. Cross sections are interpretive and should be used as an

aid to understand the geologic framework and not used as the sole source of data in locating or designing wells, buildings, roads, or other structures. Finally, the views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of either the State of New Mexico or the U.S. Government.

STRATIGRAPHY

The entire quadrangle is covered by surficial depositional units late Neogene in age. These sediments are differentiated into Pecos River alluvial valley floor deposits, Pecos River terrace alluvial deposits, and Rio Hondo alluvial fan complex deposits (which include old fan channel deposits). Collectively, they vary in thickness from ~30 m along the western and eastern margins of the quad to a maximum of ~55 m, roughly in the center (Lyford, 1973). They are underlain by Artesia Group (Guadalupian) Seven Rivers formation gypsum (*Psr*), which contain minor redbeds of siltstone and sandstone. As seen in the cross section constructed from well records, *Psr* is roughly 150 m thick and is in turn underlain by the base of the Artesia Group, the Queen and Grayburg formations, undifferentiated (*Pqg*). Lying beneath the Artesia Group are the Permian San Andres and Yeso formations (Leonardian).

Pecos River alluvial valley floor

The majority of the alluvium filling the valley floor was deposited by numerous braided channels of the Pecos River during the upper Pleistocene. These *Qabp* deposits form the basal unit of the valley, upon which Holocene Pecos River meanderbelts would be built. McCraw, *et al.* (2007) mapped 4 Pecos River meanderbelts on the Bitter Lake

quadrangle, immediately north of the South Spring quad; of these, only the oldest, *Hmp*₁, is not found on South Spring.

At the onset of the Holocene, the Rio Hondo also switched flow regimes, abandoning its braided fluviodeltaic fan (*Qabh*) to ultimately build 3 meanderbelts. The earliest two of these meanderbelts were built across the entire Pecos River floodplain (*Qabh* and *Qabp* deposits) during the early to middle Holocene, due to the fact that the Pecos River occupied collapsed karstic depressions along the eastern margin at this time (McCraw, *et al.*, 2007). These are mapped in the northeasternmost corner of the quadrangle. Responding to an avulsion of the Pecos River in the middle Holocene on the Bitter Lake quad to the north, the Rio Hondo abandoned these meanderbelts and was forced to turn south along the western edge of the floodplain, building a third meanderbelt over *Qabh*₁, which flowed into the Pecos River in the South Spring quad. Following channelization during the mid 20th Century, this meanderbelt has in turn been abandoned.

Pecos River alluvial terraces

Alluvial terraces of the Pecos River and its tributaries were first described in the classic study of Fiedler and Nye (1933). They recognized 3 terraces: (from lowest to highest) the Lakewood, the Orchard Park, and the Blackdom. The Lakewood terrace, with an elevation of 6 to 9 m above the floodplain, flanked the inset Pecos floodplain and extended up many of its western tributaries. McCraw, *et al.* (2007) further differentiated three distinct, low-lying (upper to uppermost middle(?) Pleistocene) “Lakewood terraces.” The highest and oldest of which (*Qlt*₁) would be Fiedler and Nye’s original. Surface tread elevations above the floodplain for these three are: <1-1.2 m, 1.2-6 m, and

6-9 m, respectively. The view in Figure 2 looks northeast across the Pecos River valley floor to the distant eastern Permian uplands from the lowest and youngest Lakewood terrace, Qlt_3 .



Figure 2. View of South Spring channel flowing across the Pecos River floodplain looking northeast. Photo taken from atop of youngest Lakewood terrace (Qlt_3). Eastern Permian upland bluffs, comprised largely of Seven Rivers formation (Psr) gypsum, seen in the distance.

On the South Spring quad, the Orchard Park terrace is largely buried by the Rio Hondo alluvial fan complex, and is only exposed in the north and east. Consisting of interbedded alluvial and eolian deposits and thus mapped as an alluvial-eolian complex ($Qoae$), it rises 1.5-3 m above the Lakewood terrace and 6-10.5 m above the Pecos floodplain (Fiedler and Nye, 1933). On the South Spring quad, $Qoae$ deposits lie primarily west of highly-gypsiferous soils and saline ground-waters, and thus support

extensive agriculture. Only along the bluffs, where *Qoae* is so choked with gypsum it forms gypsite, an indurated hyper-concentration of gypsum in the soil (Watson, 1983), is agriculture limited.

Rio Hondo alluvial fan complex

During most of the Pleistocene, the Rio Hondo debouched from the western uplands into the Pecos valley south of its current location. It flowed from approximately latitude 33°17'30" N, roughly due east through what is now known as Rocky Arroyo onto the Pleistocene valley floor, on the Hondo Reservoir quad, two quads west of the South Spring quad. From here, it built a very large alluvial fan complex out over Pleistocene Pecos River terraces. It prograded east until a stream capture occurred within the western uplands, sometime in the upper Pleistocene. This capture, located at the current site of the dry Twin Rivers reservoir, on the Hondo Reservoir 7.5-minute quadrangle, turned the Rio Hondo northeast into its present channel and cut off fluvial and sediment input to the distal reaches of its fan complex in the South Spring quad.

On the South Spring quad, four distinct fan lobes are mapped, prograding east to northeast (*Qahf₁₋₄*). Pedogenic carbonate also varies accordingly from the west to east, and northeast, from stage III+ to II. These fan lobes, and the Pleistocene channels dissecting them (discussed below) are comprised of gravels with a distinct petrographic Rio Hondo signature. While limestone, sandstone, and chert, could've originated anywhere within the Sacramento Mountains and along its eastern flanks, the porphyritic igneous, mafic igneous, and rhyolitic gravels common throughout these deposits could only have originated from Sierra Blanca, the headwaters of the Rio Hondo. A gravel clast count clearly documents this provenance (see Figures 3 and 4).



Figure 3. View of western gravel pit wall developed in an old Rio Hondo fan channel (*Qahc₁*) developed in the oldest fan unit (*Qahf₁*). Paleoflow directions, based upon clast imbrication varies from 118° to 128° (roughly represented by the observer’s face). The clast count depicted in Figure 4 came from this locality.

The Rio Hondo alluvial fan complex contains numerous alluvial channel deposits, ranging from old, abandoned channels to historic ephemeral streams (formerly perennial – artesian spring-fed). The oldest (*Qahc₁*—which flowed eastward off of the oldest *Qahf* lobes) were often mapped primarily by soil moisture increases noted on aerial photography, relative to adjacent lobe deposits, as eolian input from these adjacent lobes often mantles the “v-shaped” contours associated with stream channels. Many of both *Qahc₁* and *Qahc₂* channels are also mapped in this matter due to the fact that their deposits have been “blurred” by plowing and dairy farm agriculture.

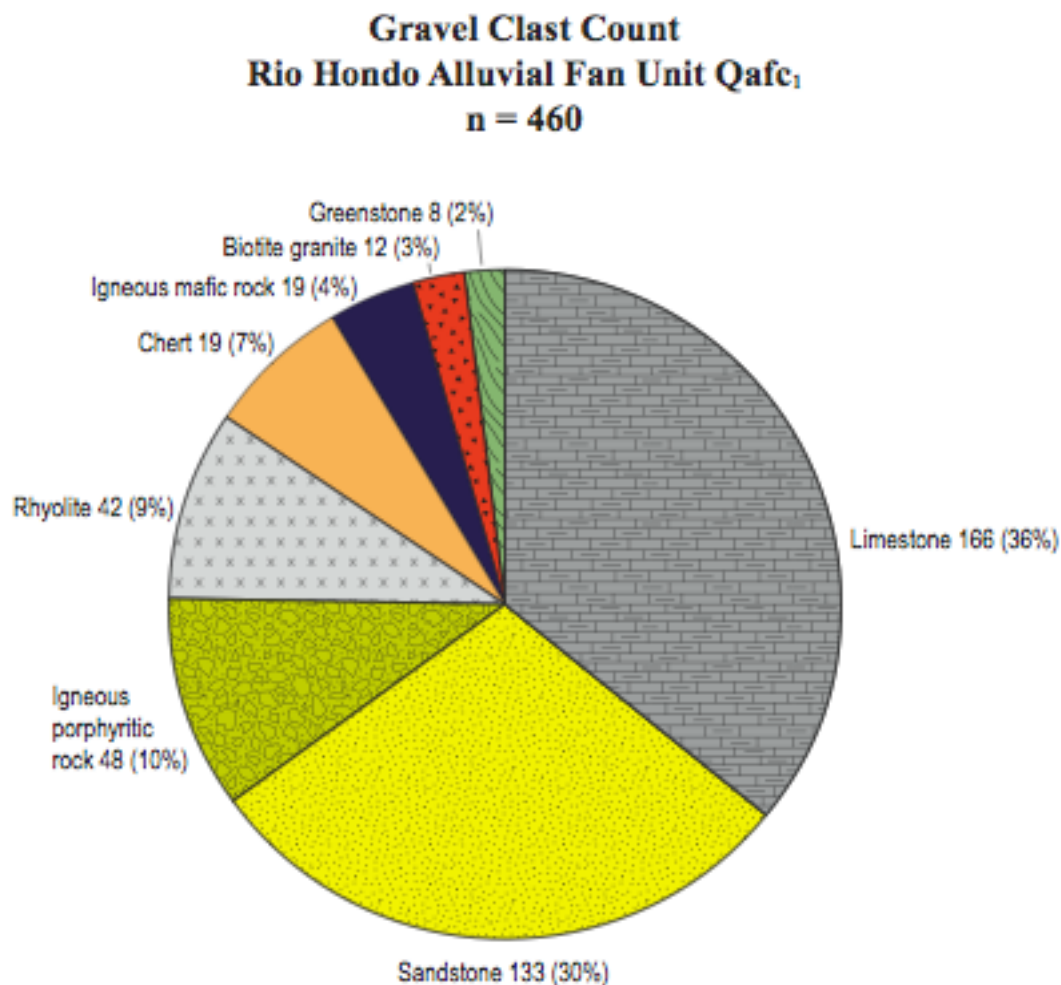


Figure 4. Gravel clast count derived from western wall of an active gravel pit developed in an old Rio Hondo fan channel ($Qahc_1$).

In Figure 5, which was constructed from a section measured in a trench wall, young distal fan deposits ($Qahf_4$) are seen burying a Pecos River Orchard Park terrace deposit ($Qoae$). Both units have stage II to III pedogenic carbonate developed into their tops, documenting their relative antiquity.

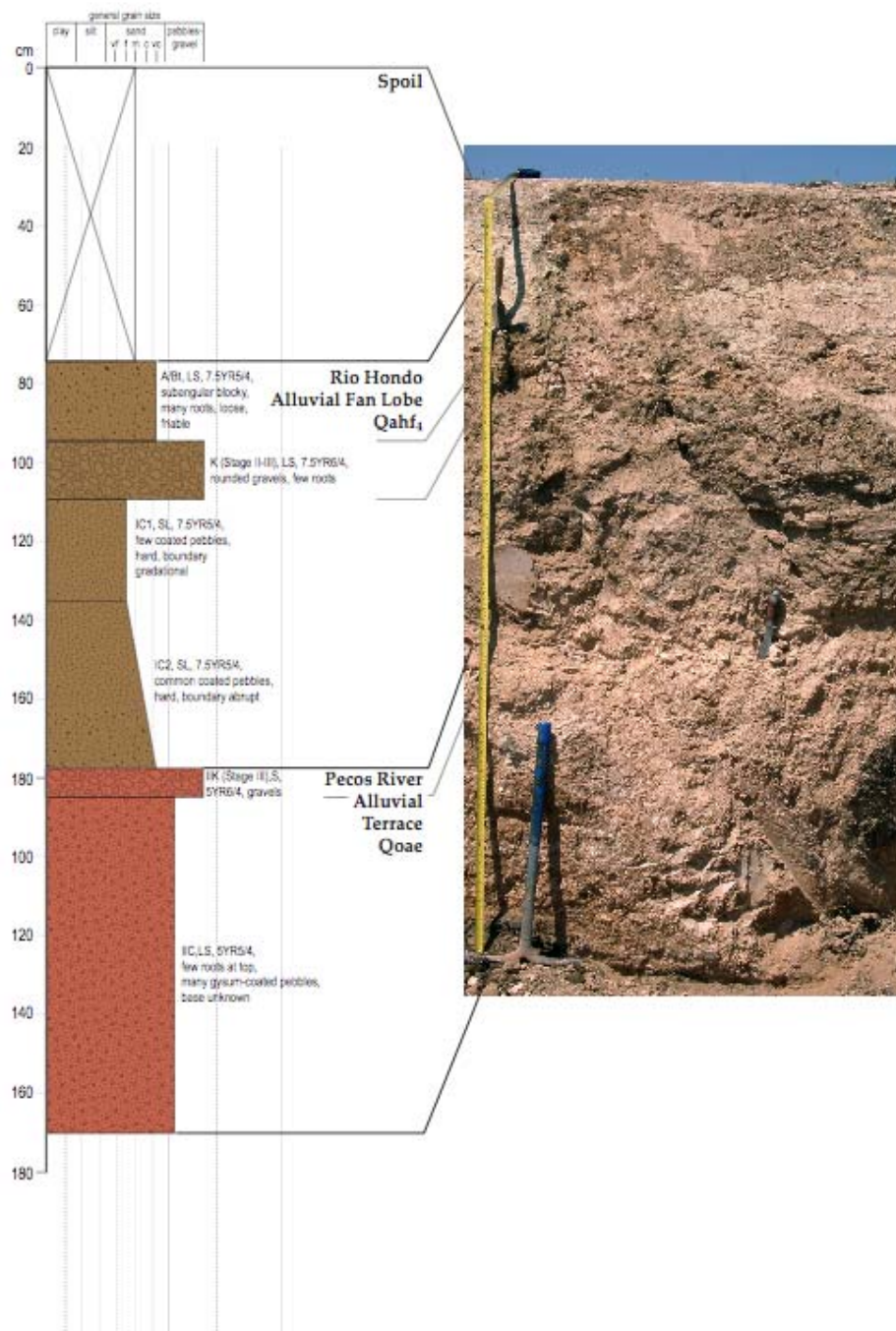


Figure 5. Description of trench wall near the distal edge of the Rio Hondo alluvial fan, showing fan sediments *Qahf₄* overlying Pecos River Orchard Park alluvial terrace (*Qoae*) sediments.

STRUCTURE

Named by Merritt (1920) and recognized through this area by Nye (Fielder and Nye, 1933), the Y-O Buckle, along with several other semi-parallel buckles crossing the Pecos slope, were best described by Kelley (1971). He mapped the Y-O Buckle as a right-lateral strike-slip fault west of Artesia to the south, but indicates its movement is normal and down to the west where it comes out of the Pecos alluvial valley, east of Bitter Lake. It was primarily active during the Pennsylvanian and likely reactivated during the Laramide. After examination of both surface exposure on the Comanche Springs 7.5-minute quadrangle and well records in the Bitter Lake area, which recorded no vertical offset of strata, McCraw *et al.*, (2007) concluded that the structure showed minor normal movement and primarily remains a right lateral strike-slip fault here. They suggested a minimum of 25- to 30-m of right-lateral offset based upon the apparent right lateral offset of convoluted, monoclinical beds exposed in the eastern Permian uplands. Where it cuts through the northwest corner of the South Spring quad, the Y-O Buckle remains buried beneath Rio Hondo fan alluvium and Pecos River terrace alluvium.

HYDROLOGY

The South Spring quadrangle lies in the northeast sector of the Roswell Artesian Basin, an intensively farmed area in the lower Pecos Valley of southeastern New Mexico. Agricultural activity in this arid region (mean precipitation = ~25 cm/yr) is sustained by irrigation using groundwater from a karstic limestone aquifer comprised for the most part of the middle Permian San Andres limestone, as well as a shallow water table aquifer made up of sand and gravel in the Pecos River terrace deposits. The two aquifers are

separated by redbeds and gypsum of the Seven Rivers formation, which serves as a leaky confining unit for the artesian aquifer (Land and Newton, 2008).

Recharge to the artesian aquifer occurs on the Pecos Slope, west of Roswell, where the San Andres limestone is exposed in outcrop. Some recharge occurs directly via precipitation, but most recharge is derived from underflow and from losing streams such as the Rio Hondo flowing eastward across the Pecos Slope. Groundwater flows eastward (downgradient) through the San Andres and passes beneath the Seven Rivers Formation a few miles west of Roswell, where the San Andres becomes a confined aquifer. Artesian head causes upward flow of groundwater from the artesian aquifer into the shallow alluvial aquifer. A significant amount of recharge to the shallow aquifer is derived from this upward leakage rather than from precipitation (Welder, 1983; Land and Newton, 2008).

Prior to historic agricultural development, natural artesian discharge occurred from numerous, large springs throughout the Roswell area, including South Spring. Early settlement patterns in the area during the late 1800s were greatly influenced by freshwater resources from these springs, since water from the Pecos River farther east was too brackish for human consumption (Fiedler and Nye, 1933). Since the inception of irrigated agriculture in the Roswell area in the early 20th century, all the major springs, including South Spring, have dried up, becoming extinct, and their tributaries, including South Spring Creek, North Spring Creek, and Berrendo Creek, have ceased to flow.

A freshwater-saltwater interface is present in the artesian aquifer, extending roughly north-south along the eastern margin of the South Spring quadrangle. Chloride concentrations west of the interface are less than 100 ppm (for comparison, EPA

secondary standards for chloride concentrations in drinking water are no more than 250 ppm). Along the east side of the mapped area, near the Hagerman Canal, however, chloride concentrations have been measured approaching 1,000 ppm.

DESCRIPTION OF MAP UNITS

NEOGENE

Alluvium and anthropogenic deposits

- daf** **Disturbed land and/or artificial fill** — Dumped fill and areas affected by human disturbances, mapped where deposits or extractions are areally extensive. Includes the Hagerman Canal, the channelized Rio Hondo, gravel (“caliche”) pits, and numerous settling ponds associated with the widespread dairy industry.
- Qa** **Quaternary tributary alluvium and valley-fill alluvium, undifferentiated (Historic to upper Pleistocene)** — Brown (7.5YR4/2) to pinkish gray (7.5YR6/2) (*tributaries*) to light reddish-brown (5YR 6/4) to reddish brown (2.5YR4/6) (*Pecos floodplain valley-fill*), unconsolidated, moderately sorted, pebbly sand, silt, and clay, often gypsiferous in Orchard Park terrace and Pecos floodplain areas. Varies considerably in thickness from <1 to 3 m in tributaries and up to 10-12 m in the floodplain.
- Qvf** **Quaternary valley-fill alluvium, undifferentiated (Holocene to upper Pleistocene)** — Brown (7.5YR4/2) to reddish brown (2.5YR4/6), unconsolidated, moderately sorted, pebbly sand, silt, and clay. Often contains Qa bottomland within deposits. Primarily alluvium, occasionally reworked by sheetwash and colluvial processes. Varies considerably in thickness from <1 to 5 (?) m.

Pecos River alluvial valley floor

Pecos River meanderbelt alluvial deposits (Historic to lower (?) Holocene) — During the Holocene, the Pecos River built four distinguishable meanderbelts on top of an upper Pleistocene Pecos River braided alluvial valley-fill deposit (*Qabp*), which is the basal unit of the floodplain. Meanderbelts consist of channel, channel bar, point bar, and natural levee deposits, undivided. McCraw, *et al.* (2007) differentiated these meanderbelts on the Bitter Lake quad, immediately north of South Spring, based upon field observation of cross-cutting relationships and aerial photographic work. They mapped two older Holocene units and two Historic units. Only the youngest of the two older Holocene meanderbelts (*Hmp₂*) is found on the South Spring quad.

The modern meanderbelt (*hmp₄*) was mapped from both 2005 digital 1-m resolution, color orthophotography and 1981 color aerial photography, and a 1939-1940 meanderbelt (*hmp₃*) was mapped using vintage U.S.D.A. – Soil Conservation Service black and white aerial photography. All aerial photography was georeferenced and plotted onto the 2005 orthophotography using ArcGIS, to produce a derivative Pecos River channel historical map

showing channel migratory change patterns (not included in the open-file report). The historic units are differentiated from the Holocene units by using a lower case “h” on the unit labels.

- hmp₄** **Modern meanderbelt deposits (Historic)** — Very pale brown (10YR7/4) to reddish brown (2.5YR4/6), unconsolidated, moderately to well-sorted, occasionally pebbly, coarse- to fine-grained sand in the modern channel and adjacent bar crests, grading to silty sand and sandy clay with distance from the channel. Thickness generally <1 m, but reaches ~1.5 m in a few places.
- hmp₃** **1939-1940 meanderbelt deposits (Historic)** — Very pale brown (10YR7/4) to reddish brown (2.5YR4/6), unconsolidated, moderately to well sorted, coarse- to fine-grained sand in the Historic channel and adjacent bar crests, grading to silty sand and sandy clay with distance from these older channels. Throughout the upper Holocene, extensive point bar development, with some minor channel bar development has taken place. This has resulted in a series of sweeping meanders, with meander amplitudes >1 km in width common, the largest reaching about 1.8 km in width on the Bitter Lake quad. The largest *hmp₃* meander on South Spring has an amplitude of 0.9 km. Thickness 2-4 m.
- Hmp₂** **Younger Holocene meander belt deposits (Historic to upper Holocene)** — Very pale brown (10YR7/4) to reddish brown (2.5YR4/6), unconsolidated, moderately to well sorted, occasionally pebbly, coarse- to fine-grained sand, silty sand, and sandy clay. Meander geometries are similar to *hmp₃*, and while much of this is obscured by more recent meander belt deposition and/or agriculture, amplitudes are estimated to average about 1 km in width. Thickness 3-10 m.
- Qabp** **Pecos River braided alluvial deposits (lower Holocene to upper Pleistocene)** — Light reddish-brown (5YR6/4) to reddish brown (2.5YR4/6), unconsolidated, poorly to moderately sorted, pebbly coarse- to fine-grained sand, silty sand, sandy clay, and clay. Braided channels and bars typify the surface of *Qabp*. Thickness 10 - 20 m.

Rio Hondo alluvial deposits within the Pecos River floodplain: meanderbelts (Historic to lower (?) Holocene) and braided alluvium (upper Pleistocene) — Gravels of limestone, sandstone, and igneous rocks in brown (10YR5/3) to dark yellowish brown (10YR3/4), unconsolidated, moderately sorted, coarse- to fine- grained sand, silty sand, silt (largely calcareous), and sandy clay. The southernmost (and oldest) deposits of a large, braided, fluviodeltaic fan that the Rio Hondo built out into the Pecos River floodplain during the upper Pleistocene extend into the South Spring quad (*Qabh₁*). At the onset of the Holocene, both the Pecos River and the Rio Hondo began meandering, building meanderbelts. The earliest two Rio Hondo meanderbelts built across the entire Pecos River floodplain (*Qabh* and *Qabp* deposits) during the early to middle Holocene, due to the fact that the Pecos River occupied collapsed karstic depressions along the eastern margin at this time (McCraw, *et al.*, 2007). Responding to an avulsion of the Pecos River in the middle Holocene on the Bitter

Lake quad, the Rio Hondo abandoned these meanderbelts and was forced to turn south along the western edge of the floodplain, building a third meanderbelt over *Qabh₁*. While meander geometries are essentially identical between all three Hondo meanderbelts, *Hmh₁* certainly exhibited the widest lateral migration (although not necessarily widest meander amplitude).

- Hmh₃ Modern (pre-channelization) meanderbelt deposits (Historic to upper Holocene)** — Deposition was abandoned in the early to middle 20th Century due to the construction of the Hagerman Canal and the channelized Rio Hondo. Thickness 1-3 m.
- Hmh₂ Young meanderbelt deposits (middle Holocene)** — This meanderbelt primarily built upon the top of the oldest meanderbelt (*Hmh₁*). Thickness 1-3 m.
- Hmh₁ Older Holocene meanderbelt deposits (middle Holocene to lower (?) Holocene)** — Deposition was clearly influenced by the youngest upper Pleistocene channels within *Qabh₅* on the Bitter Lake quad. Thickness 1-3 m.
- Qabh₁ Oldest braided valley-mouth alluvial-fan deposits (upper to middle (?) Pleistocene)** — Lowest-lying, yet most extensive braided alluvial-fan deposit. Greatly modified by agriculture on its eastern margin adjacent to and within the Pecos floodplain. Only an occasional channel remnant remains. Overridden by *Hmp₃*. Thickness ~2 to 30 m.

Alluvial terrace deposits

Lakewood terrace alluvial deposits (upper to middle Pleistocene) — Alluvial terraces of the Pecos River and its tributaries were first described in the classic study of Fiedler and Nye (1933). They recognized 3 terraces: (from lowest to highest) the Lakewood, the Orchard Park, and the Blackdom. The Lakewood terrace, with an elevation of 6 to 9 m above the floodplain, flanked the inset Pecos floodplain and extended up many of its western tributaries. Following McCraw, *et al.* (2007), three distinct, low-lying (upper to uppermost middle(?) Pleistocene) “Lakewood terraces” are recognized. The highest and oldest of which (*Qlt₁*) would be Fiedler and Nye’s original. Surface tread elevations above the floodplain for these three are: <1-1.2 m, 1.2-6 m, and 6-9 m, respectively. They are comprised of occasional gravels and pebbles, brown (10YR5/3) to dark yellowish brown (10YR3/4), unconsolidated, moderately sorted, coarse- to fine- grained sand, silty sand, silt and sandy clay. Pedogenic carbonate increases from stage I to stage II+ (occasionally III) from *Qlt₃* to *Qlt₁*. Mostly non-gypsiferous.

- Qlt₃ Youngest Lakewood terrace alluvial deposits (upper Pleistocene)** — Thickness <1 to 1 m.
- Qlt₂ Young Lakewood terrace alluvial deposits (upper Pleistocene)** — Thickness 1.5 to 5 m.

Qlt₁ Older Lakewood terrace alluvial deposits (upper to middle Pleistocene) —
Thickness ~2 to 9 m.

Orchard Park terrace alluvial deposits (upper to middle Pleistocene) — According to Fiedler and Nye (1933), the Orchard Park terrace rises 1.5-3 m above the Lakewood terrace and 6-10.5 m above the Pecos floodplain. It consists of interbedded alluvial and eolian deposits and is mapped as an alluvial-eolian complex (*Qoae*). On the South Spring quad, the Orchard Park terrace is largely buried by the Rio Hondo alluvial fan complex, and is only exposed in the northeast corner. Unlike the majority of *Qoae* deposits on the Bitter Lake quad, these deposits lie primarily west of gypsiferous soils and saline ground-waters, and thus support extensive agriculture. Only along the bluffs, where *Qoae* is so choked with gypsum it forms gypsite, an indurated hyper-concentration of gypsum in the soil (Watson, 1983), is agriculture limited.

Qoae is comprised of very pale brown (10YR7/4) to reddish brown (5YR4/4), unconsolidated, moderately sorted, coarse- to fine- grained sand, silty sand, silt, and sandy clay. Stage III to III+ pedogenic carbonate. Where gypsiferous, it is white (2.5Y8/1) to light gray (2.5Y7/1) to very pale brown (10YR 7/4), unconsolidated, well sorted, fine-grained, gypsiferous sand, silty sand, and sandy clay.

Qoae Orchard Park terrace alluvial and eolian deposits, undivided (upper to middle Pleistocene) — Thickness 15 to 45 m.

Rio Hondo alluvial fan complex deposits

Rio Hondo alluvial fan lobe deposits (Historic to lower Pleistocene) — During most of the Pleistocene, the Rio Hondo debouched from the western uplands into the Pecos valley south of its current location. It flowed from approximately latitude 33° 17' 30" N, roughly due east through what is now known as Rocky Arroyo onto the valley floor, two quads west of the South Spring quad. From here, it built a very large alluvial fan complex out over Pleistocene Pecos River terraces. It prograded east until a stream capture occurred within the western uplands, sometime in the upper Pleistocene. This capture, located at the current site of the dry Twin Rivers reservoir, on the Hondo Reservoir 7.5-minute quadrangle, turned the Rio Hondo northeast into its present channel and cut off fluvial and sediment input to the distal reaches of its fan complex in the South Spring quad.

On the South Spring quad, four distinct fan lobes are mapped, prograding east to northeast (*Qahf₁₋₄*). These are comprised of gravels with a distinct petrographic Rio Hondo signature. While limestone, sandstone, and chert, could've originated anywhere within the Sacramento Mountains and along its eastern flanks, the porphyritic igneous, mafic igneous, and rhyolitic gravels common throughout these deposits could only have originated from Sierra Blanca, the headwaters of the Rio Hondo. These gravels are supported by a matrix of brown (10YR5/3) to dark yellowish brown (10YR3/4), unconsolidated, moderately sorted, coarse- to fine- grained sand, silty sand, silt (largely calcareous), and sandy clay. Pedogenic carbonate varies from stage III+ to II, west to east and northeast.

Qahf₄ **Youngest Quaternary alluvial fan lobe (upper Pleistocene)** — Thickness 1 to 3 m.

Qahf₃ **Younger Quaternary alluvial fan lobe (upper Pleistocene)** — Thickness 2 to 4 m.

Qahf₂ **Older Quaternary alluvial fan lobe (upper to middle Pleistocene)** — Thickness 2 to 4 m.

Qahf₁ **Oldest Quaternary alluvial fan lobe (lower to middle Pleistocene)** — Thickness 2 to 4 m.

Rio Hondo alluvial fan channel deposits (Historic to lower Pleistocene) — The Rio Hondo alluvial fan complex contains numerous alluvial channel deposits, ranging from old, abandoned channels to historic ephemeral streams (formerly perennial – artesian spring-fed). The oldest (*Qahc₁*—which flowed eastward off of the oldest *Qahf* lobes) were often mapped primarily by soil moisture increases noted on photography, relative to adjacent lobe deposits, as eolian input from these adjacent lobes often mantles the “v-shaped” contours associated with stream channels. Many of both *Qahc₁* and *Qahc₂* channels are also mapped in this matter due to the fact that their deposits have been “blurred” by plowing and dairy farm agriculture. Channel sediments are usually comprised of gravels of limestone, sandstone, and igneous rocks in brown (10YR5/3) to dark yellowish brown (10YR3/4), unconsolidated, moderately sorted, coarse- to fine- grained sand, often containing clay drapes

Qahc₂ **Younger Quaternary alluvial fan channels (Holocene to upper Pleistocene)** — Thickness <1 to 3 m.

Qahc₁ **Older Quaternary alluvial fan channels (upper to middle Pleistocene)** — Thickness 1 to 3 m.

Depressions and sinkhole deposits

Qd **Quaternary depression fill, primarily caused by subsidence (Historic to middle Pleistocene)** — Unconsolidated, well-sorted, fine-grained (fine sands to clay) complexes of alluvial, colluvial, eolian, and occasional lacustrine deposits within closed depressions created by either gradual subsidence or sudden collapse followed by gradual subsidence of underlying gypsiferous carbonate terrane. These complexes are often significantly modified by stream erosion and deposition, playa deposition, deflation, and mass wasting. Depression fills have been active since the middle Pleistocene and are usually 1-3 m thick.

Qds **Quaternary sinkhole deposits, primarily caused by collapse (Historic to middle Pleistocene)** — occasional pebbles in a fine-grained sandy clay matrix. Thickness <1 to 3 m.

PALEOZOIC

Permian Artesia Group

Psr **Seven Rivers Formation (Guadelupian - upper Permian)** – White to pale gray gypsum, brick red, pale red, to orange very fine sandstone, siltstone, and mudstone, and minor limestone. Near surface in eastern part of quadrangle. Top not exposed; at least 75 m based on cross-section.

Pqg **Queen and Grayburg Formations, undivided (Guadelupian - upper Permian)** – cross section only.

Psa **San Andres Formation (middle to upper Permian)** – cross section only.

Pya **Yeso and Abo Formations (lower to middle Permian)** – cross section only.

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