Geologic Map of the Organ Peak NW 7.5-Minute Quadrangle, Doña Ana County, New Mexico

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Open-file Digital Geologic Map OF-GM 289

Scale 1:24,000

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Introduction

The Organ Peak NW 7.5-minute quadrangle is located in south-central New Mexico and includes the northeastern portion of the city of Las Cruces and several subdivisions (or colonias). Most of the quadrangle lies in the Isaack Lake subbasin portion of the southern Jornada del Muerto Basin, which is bound on the west by the foothills of the Doña Ana Mountains and on the east by the foothills of the San Andres Mountains, San Agustin Peak, and the Organ Mountains. The Doña Ana Mountains preserve the 33–36 Ma Doña Ana caldera and older andesite lavas and breccias on a horst block that separates the Jornada del Muerto Basin to the east from the Mesilla Basin to the west. West-dipping Pennsylvanian to Permian carbonates and clastic rocks are exposed on the western flank of the San Andres Mountains and 34–36 Ma monzonite intrusions and intermediate to silicic volcanic rocks associated with the Organ caldera are exposed in the San Agustin-Organ Mountains highlands (Dunham, 1935; Seager, 1981; Zimmererand McIntosh, 2013; Rioux et al., 2016). The basin fill exposed at the surface in this internally drained subbasin is comprised primarily of younger Holocene to Late Pleistocene piedmont slope and basin floor facies. Arroyo de Alameda, which is located along the southern boundary of the quadrangle in the Talavera subbasin of the southern Jornada del Muerto, lies south of southern drainage and groundwater divide of the Isaack Lake subbasin in the vicinity of U.S. Highway 70; this arroyo drains into the Rio Grande. Older Plio-Pleistocene Camp Rice Formation fluvial (Ancestral Rio Grande), transitional, and piedmont deposits are exposed in Arroyo de Alameda and Camp Rice Formation fluvial/piedmont facies have been revealed in currently active construction sites near Sonoma Ranch Road in the southeast corner of the quadrangle.

This area was first mapped as part of the well-known Desert Soil-Geomorphology Project by the U.S. Soil Conservation Service (Gile et al., 1981). The 1:125,000-scale deposit (Sheet 1) and geomorphic surface (Sheet 2) maps that accompany that report, as well as vintage orthophotos (taken before the city of Las Cruces expanded into this area) and the map of Seager et al. (1987) helped guide the mapping.

Researchers associated with the Desert Soil-Geomorphology Project used the amount of carbonate that accumulates in the C horizon of soil in this arid environment to estimate the age of surficial deposits. These scientists examined buried soils in arroyo exposures or long trench excavations at several sites in the area. The ages of the deposits were determined using radiocarbon dating of charcoal or soil carbon, fossils, and pollen, and the amount of carbonate that had accumulated at each site was measured. Older deposits have more carbonate in their soil profiles, so the relative ages of soils can be estimated. For example, soils with partial to complete coats of carbonate on gravel clasts (Stage I) are younger that those with a thick, hard layer of pedogenic carbonate (Stage III). Sixteen of the sites used to calibrate the relative ages of the buried soils, called pedons, are located within the quadrangle. These sites were described in great detail between 1959 and 1970 and the location of the sites were marked on 1935 aerial photographs published in Gile and Grossman (1979). During the last 50 to 60 years, Las Cruces has grown significantly and some of the sites are now in neighborhoods. The location of each site was determined by geo-rectifying a scan of the 1935 orthophoto in ArcGIS, estimating the position of the site using the photos in Gile and Grossman (1979), and then superimposing the point on modern imagery. Some sites, especially arroyo exposures, are still visible, but more than half are either filled in, are in backyards, or are about to be under concrete. The pedon locations are presented on the map and ^{14}C dates on charcoal from five pedons are presented in the unit descriptions.

Geologic History

The oldest unit in the study area, the Middle Eocene Palm Park Formation, forms a small hill on the west side of the quadrangle. The andesite flows and breccia were erupted from a source in the central part of the Doña Ana Mountains between 41.3±0.7 and 43.05±0.28 Ma. (Creitz et al., 2018; Ramos and Heizler, 2018).

Late Oligocene to Miocene Rio Grande rift extension disrupted the regional-scale Eocene and Oligocene volcanic landscape. The southern Jornada del Muerto basin was down-dropped along two major, mostly buried, fault zones, the Jornada fault zone to the west and the East Jornada fault zone along the west flank of the San Andres-San Augustin-Organ mountain chain, creating a west-dipping half-graben. The faults have not offset Holocene deposits, but Pleistocene piedmont slope deposits have been deformed by both fault zones. The location of the deformed deposits will be described in more detail later in this report.

The 5.0 to 0.8 Ma Camp Rice Formation was deposited broadly across south-central New Mexico (Gile et al., 1981; Mack et al., 1998, 2006). This unit is comprised of both axial-fluvial deposits of the ancestral Rio Grande that formed widespread distributary channels as the river left a narrow bedrock constriction in the vicinity of Rincon, and gravelly alluvial fan deposits shed from the rift-flank uplifts that grade near the basin floor into fine-grained distal piedmont deposits, which in turn, interfinger with and bury the fluvial deposits. These sediments were deposited during a time of rising base level (Gile et al., 1981). Both the basal, well-indurated and the younger, generally poorly cemented piedmont slope deposits of the Camp Rice Formation are buried by younger deposits; the top of the younger Camp Rice piedmont-slope deposit on the east side of the basin does have a strongly developed Stage III to IV pedogenic carbonate soil horizon that corresponds to the Jornada I geomorphic surface of Gile et al. (1981). In places, the top of the Camp Rice piedmont is exposed in 2–3 m-deep arroyos.

Gile (2002) proposed that a large lake may have covered the basin floor of the southern Jornada del Muerto between ~1.04 Ma and ~325 ka. The lake formed in response to ~24 m of Pleistocene offset along the Jornada fault. An earlier lake was present during the waning stages of Camp Rice Formation deposition and before the incision of the Rio Grande at 780 ka. He notes that gypsum that was revealed during the trenching of pedon 66-6 on the Organ Peak NW quadrangle overlies the Camp Rice Formation at depths of 4.4 to 5.2 m below that current land surface. The gypsum was likely derived from the Permian Yeso Formation exposed in the San Andres Mountains many miles to the northwest. He also proposes the existence of a smaller younger lake to account for a silt horizon at depths of 2–3 m exposed in pedons 66-6 and nearby 70-7. The lake may have been 14 m deep in the vicinity of current Issack Lake. Lacustrine deposits are not preserved because the fine-grained sediment has been removed by the wind. The lake dried up once incision of the Rio Grande occurred after 780 ka, and the water table in the southern Jornada del Muerto basin dropped. Modern Isaack Lake rarely contains water; Gile et al. (1981) report that the lake flooded only six times between 1957 and 1979.

Post-Camp Rice piedmont slope deposits filled in low drainages between the Camp Rice fans, which were as much as 9.5 km wide (Gile et al., 1981). Older, post-Camp Rice piedmont slope deposits that are on the Jornada I surface commonly are capped by Bt, Bk, and Stage III pedogenic carbonate horizons, indicating post-depositing landscape stability during glacial pluvial cycles. This soil is associated with the Jornada II surface of Gile et al. (1981). The Jornada II deposits are gravelly near the mountains and become finer grained toward the basin center, transitioning into the fine-grained alluvial flat deposits associated with the Petts Tank surface north of Isaack Lake that are laminated and contain gypsum. The younger deposits related to the Isaack's Ranch surface fill in low areas incised into the older fans. This unit is characterized by Stage II pedogenic carbonate development. Following a period of landscape stability leading to soil formation on the Isaack's Ranch surface, Organ deposition began < 7000 years ago; these channel and debris flow sediments are inset into or cover older units. A Stage I pedogenic carbonate horizon developed on Organ deposits.

Aquifers

In the northern two-thirds of the quadrangle, the thin (<4-5 m) Holocene to Late Pleistocene surficial piedmont slope and basin floor deposits are underlain by much thicker coarse-, medium- and fine-grained medial to distal Pliocene to Miocene Santa Fe Group piedmont slope deposits. The older Santa Fe Group basin fill in this area is 450–900 m thick, and the water table is 90–120 m deep (Hawley et al, in review). Water table maps show flow of fresh to brackish groundwater to the north into the Experimental Range subbasin of the southern Jornada del Muerto (Hawley et al., in review). Groundwater in the southern third of the basin is derived from Camp Rice Formation fluvial and piedmont slope facies. City of Las Cruces wells located south of Highway 70 produce fresh water from depths of 60 to 215 m.

Observations from this Investigation

Deformed Pleistocene Deposits

Two strands of the Jornada fault that appear to dip steeply (70°) in opposite directions (east and west) are exposed in Arroyo De Alameda (UTM 340282N 3583601E and 340258N 3583597E, NAD83; Figure 1). Figure 1 shows the west-dipping strata associated with the western strand. Tilted stone lines along the East Jornada fault in the vicinity of Brahman dam along the eastern edge of the quadrangle were noted at 346829N 3589134E and 347224N 3588936E. A large outcrop of a west-dipping Bk horizon with carbonate nodules and root casts and an underlying west-dipping C horizon along the East Jornada fault is located at 345245E 3584822N (Figure 2). At this locality the overlying Qpy deposit is characterized by well-cemented tabular benches that may have formed as water moved up the fault and flowed laterally through the younger, generally unconsolidated sediment.

Figure 1. West-dipping Camp Rice Formation transitional facies in Arroyo del Alameda along the Jornada fault. Clipboard is 0.3 m tall.

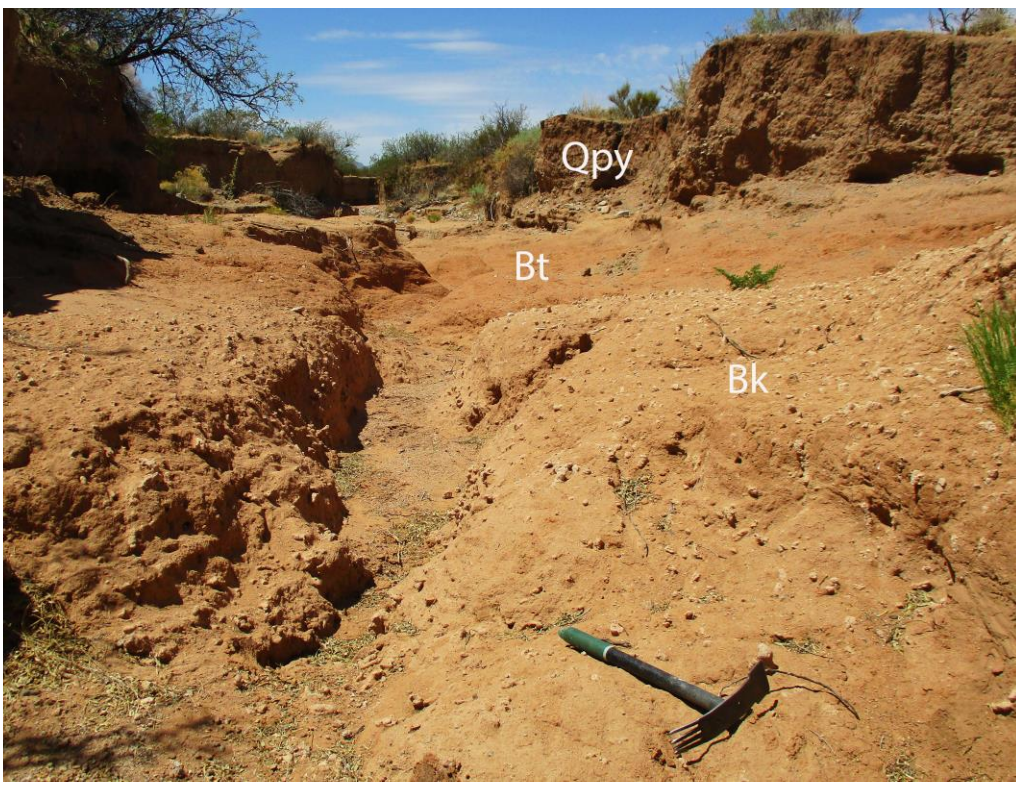

Figure 2. Looking west across the East Jornada fault zone. The Bk horizon in Qpo in the foreground is dipping west below the Bt in Qpo in the middle ground. Note the well-cemented ledges below the Qpy label. The digging tool is 0.4 m long.

Charcoal Dates

Scattered pieces of charcoal about 3 to 5 mm across were found in Organ alluvium (Qpy) northwest of Washington Tank at 346237E 3591721N. The charcoal is in two layers of brown silty clay interbedded yellowish brown clayey silt in the bottom 0.25 m of the arroyo bank (Figure 3). The presence of clay in this proximal position on the piedmont slope is unusual, and may suggest deposition following a wildfire event. Two samples were submitted to Beta Analytical for ^{14}C dating. The dates are 1770 +/- 30 BP and 1780 +/- 30 BP and $\delta^{13}C$ values of -23.3 o/oo for both samples were measured. These dates are well within the <7000 years accepted age of Organ alluvium.

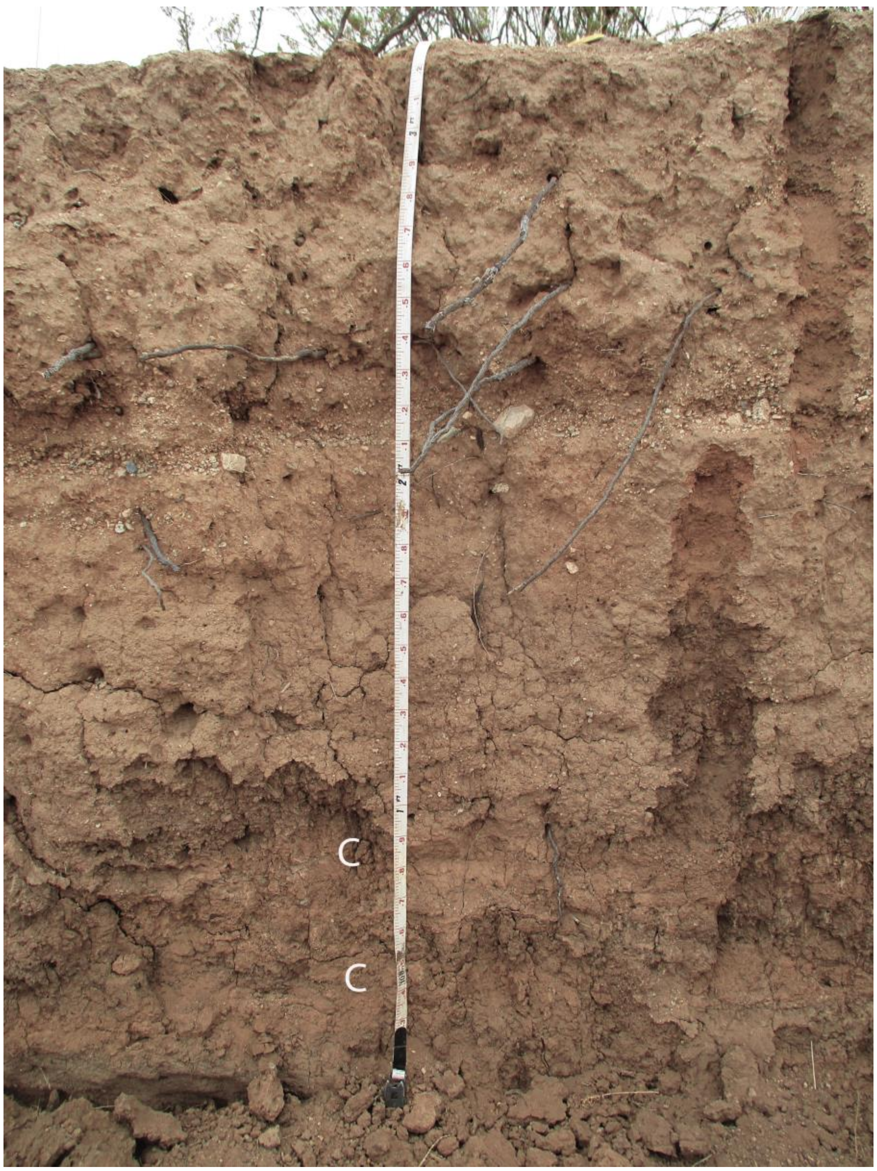

Figure 3. Photograph of the charcoal locality. The letter "C" denotes the two charcoal-bearing horizons. The tape measure units are in tenth of feet.

XRD Results

Seven clay rich samples were collected as part of this investigation. Two samples were collected in Arroyo del Alameda from the reddish brown Camp Rice Formation transitional facies and from the brown overlying younger valley alluvium to see if the units had different compositions. OPNW01 (344925E 3583622N) is from the younger unit and OPNW02 (343099E 3583564N) is from the older paleosol in clayey fine-grained sand in the Camp Rice Formation. Both samples have similar mineralogy, dominantly quartz, lesser feldspars, and trace smectite. The big difference is that OPNW01 contains calcite.

Two samples were collected from Whitebottom clayey silt (Qps):

21OPNW10 (341251E 3593785N): Calcite, quartz, blodite, illite (muscovite is used as a proxy), kaolinite, montmorillonite (quartz & calcite occur ~50:50 ratio)

21OPNW11 (340582E 3593907N): Roughly the same mineralogy and calcite: quartz ratio as sample 10. Albite and augite are also present as a few percent.

One sample was collected from a clayey silt covering a Qpy deposit.

21OPNW12 (341928E 3591559N): Mostly quartz, with lesser feldspars, illite (muscovite as proxy), kaolinite, and **hotsonite (an aluminum phosphate mineral).** No calcite present, no blodite either.

Two samples were collected from a deposit that is visible on photogrammetry imagery from 2009. This deposit can still be observed in the field as of 2021 and is the remnants of a muddy flood that overtopped the banks of shallow arroyos in an area south of Rabbit Run Road and east of Holman Avenue. The muddy flood covered cryptogrammic soil (Figure 4), but in one place a new colony is forming on the thin silty clay (Figure 5).

21OPNW13 (342158E 3592083N): Mostly quartz, with calcite, feldspars, illite, montmorillonite, kaolinite, richterite (or some similar amphibole); quartz: calcite ~ 85:15

21OPNW14 (342246E 3592182N): Similar to sample 13; quartz: calcite is ~90:10

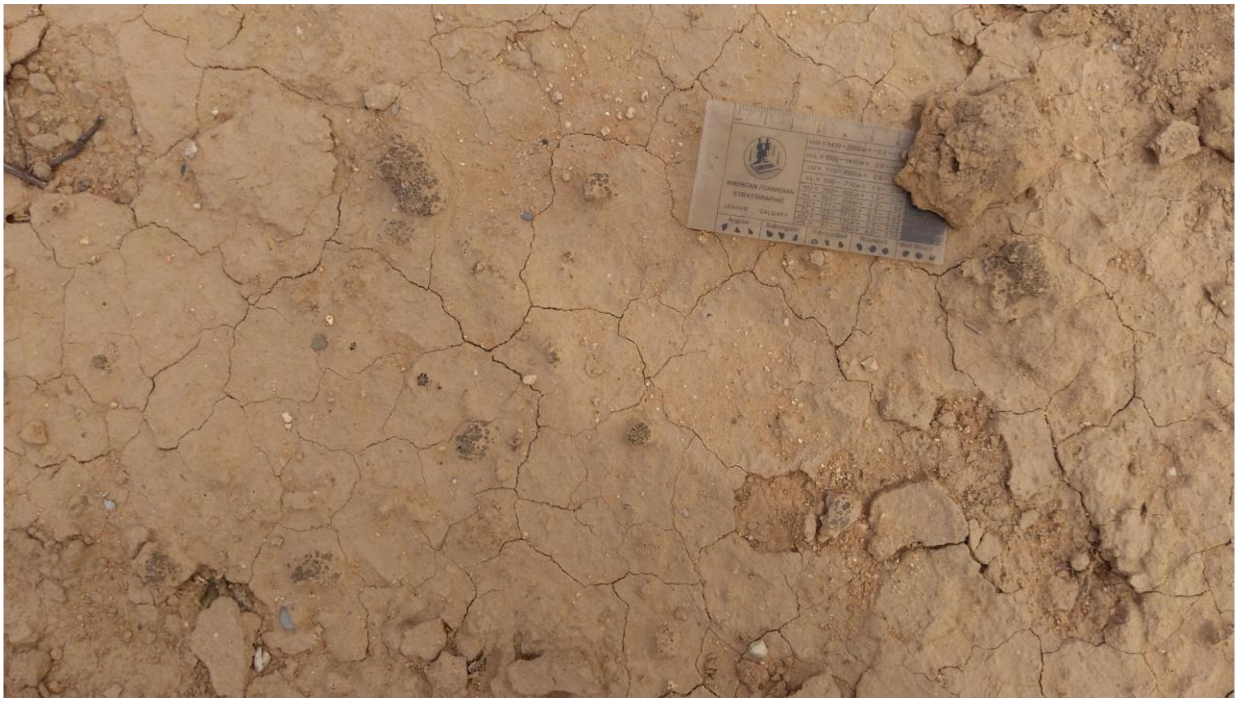

Figure 4. Muddy flood deposit covering cryptogrammic colonies

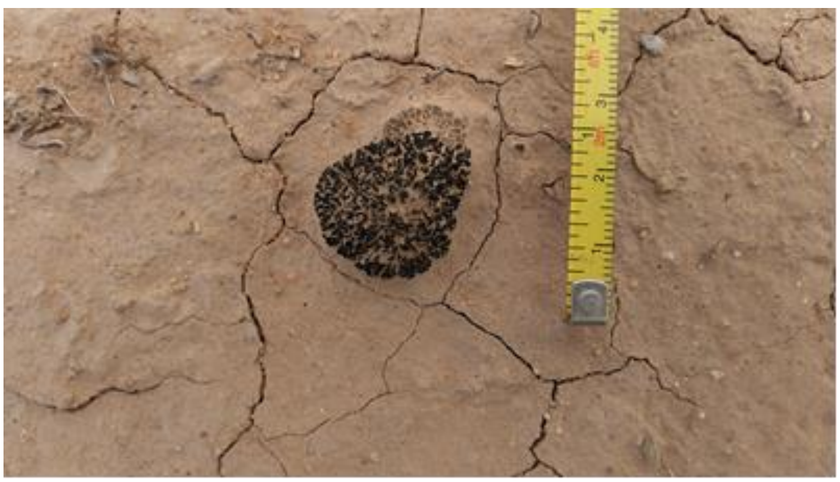

Figure 5. New colony growing on the clay deposit.

Unusually Thick Organ Alluvium Exposure

A remarkable exposure of the Organ Alluvium is exposed in a 3–4 m deep arroyo in the northeastern part of the quadrangle on BLM land (Figure 6). The buttress unconformity between this younger, thick deposit with Stage I pedogenic carbonate horizon and older fan deposits with Stage III carbonate development is exposed at 346294E 3595285N (Figure 7). This locality nicely illustrates the fact that the younger fans filled in low spots between older fans, as described by Gile et al. (1981).

Figure 6. Thick Organ Alluvium (Qpy) exposed in a deep arroyo. Digging tool is 0.4 m long.

Figure 7. Buttress unconformity between brown Qpy on the left and older Stage III carbonate-cemented piedmont slope gravel on the right.

Unit descriptions

QUATERNARY

Anthropogenic Unit

daf Disturbed Land and Anthropogenic Fill (Modern to ~60 years old) – Dumped fill consisting of thick accumulations of sand, gravel, and clayey-silty sand. Mapped for thick road fill along Highway 70, flood retention dams, and other areas affected by aggregate mining or urban development. Fill thickness is 1–10 m.

Eolian Units

Qes Eolian Sand and Sheetwash, undivided (Historical) – Loose silt to mostly fine-grained sand forming sheets or coppice dunes with evidence of fluvial reworking between the dunes. Colors range from reddish-brown to brown (5-10YR); redder hues result from the presence of argillic (Bt) horizons; C horizons have developed beneath some of the taller (2–3 m) dunes. Coppice dunes are vegetated by mesquite (*Prosopis juliflora*) and largely formed 1885–1920 CE (Gile, 1966). Thickness is <0.5–3 m.

Short Loose silt to mostly fine-grained sand forming sheets or coppice dunes with evidence of fluvial reworking between the dunes. Coppice dunes are vegetated by mesquite and largely formed 1885–1920 CE (Gile, 1966). Thickness is <0.5–3 m.

Qse Sheetwash and Eolian Sand, undivided (Historical) – This unit is similar to Qes, but the dunes are farther apart and are less than 1 m high. Small shallow sandy drainage ways between the dunes are more common. Thickness is < 1–2 m.

Qe Eolian Sand (Historical) – Loose fine-grained sand and silt that forms continuous ridges of merged coppice dunes. Many of these features formed on the Camp Rice fluvial facies on the basin floor north of Isaacks Lake. Dunes are 1–2 m tall.

Colluvial Unit

Qc Colluvium (Holocene) – Loose angular boulders and blocks up to 1 m across on the eastern lower slopes of a hill composed of Paleogene Palm Park andesite and andesite breccia. Thickness is 1–2 m.

Arroyo Deposits in the Internally Drained Jornada del Muerto

Qam Modern Alluvium (Modern to ~50 years old) – Loose sand and gravel filling channels and forming longitudinal bars in ephemeral stream courses. Sand is reddish brown to light tan to gray and is horizontal-planar or low-angle cross-laminated. Gravels occur predominantly in bars and are clast-supported. Deposit features bar-and-swale topographic relief of 0.3–0.5 m. Thickness is <2–4.5 m (Gile et al., 1981).

Short Loose sand and gravel filling channels and forming longitudinal bars in ephemeral stream courses. Thickness is <2–4.5 m (Gile et al., 1981).

Qah Historical Alluvium (~50 to ~150 years old) – Loose, sandy pebble to boulder gravel forming low ridges along arroyo courses. Deposit lacks significant soil development. Surface features subdued bar-and-swale topographic relief of up to 0.25– 0.3 m. Tread height is 0.2–0.8 m above modern grade. Thickness is 0.5–4.5 m.

Qay Arroyo Alluvium, undivided (Holocene to Uppermost Pleistocene) – Varying proportions of modern (**Qam**), historical (**Qah**), and young alluvium filling arroyo bottoms and underlying modern channels. See detailed descriptions of each unit.

Deposits in Arroyos Draining into the Rio Grande

Qvm Modern Valley Alluvium (Modern to ~50 years old) – Loose sand and gravel filling channels and forming longitudinal bars in ephemeral stream courses. Sand is yellowish to light-yellowish-brown (10YR) and horizontal-planar or low-angle cross-laminated. Gravels occur predominantly in bars and are clast-supported. Deposit features bar-and-swale topographic relief of 0.3–0.5 m. Thickness is <2–4.5 m (Gile et al., 1981).

Short Loose sand and gravel filling channels and forming longitudinal bars in ephemeral stream courses. Deposit features bar-and-swale topographic relief of 0.3–0.5 m. Thickness is <2–4.5 m (Gile et al., 1981).

Qvh Historic Valley Alluvium (~50 to ~150 years old) – Loose, sandy pebble to boulder gravel forming low ridges along arroyo courses that drain into the Rio Grande. Deposit lacks significant soil development. Surface features subdued bar-and-swale topographic relief of up to 0.25– 0.3 m. Tread height is 0.2–0.8 m above modern grade. Thickness is 0.5–4.5 m.

Qvy Younger Valley Alluvium (Holocene to Uppermost Pleistocene) – *Includes Fort Selden (Fillmore+Leasburg landforms).*

Loose to weakly consolidated, pebbly sand or sandy pebble gravel. Surface soils feature cambic to weak calcic horizons featuring stage I carbonate accumulation; the Bt horizons commonly have reddish-brown hues (5-7.5YR). Bedding is variably fining-upward, laminar to cross-bedded channel deposits or poorly sorted, matrix-supported sand and gravel debris flow deposits. Charcoal and shell ^{14}C ages span an interval from ~9,400 to 1,100 cal yr BP, with soil development indicating a stable period ~7,000 ka (Gile and Hawley, 1968; Metcalf, 1969; Gile et al., 1981). This unit is correlative to the Fort Selden (Fillmore + Leasburg), Gile et al. (1981). Thickness ranges from 2–3 m on the piedmont slope.

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Qva Valley-floor Alluvium, undivided (Holocene to Uppermost Pleistocene) – This unit contains varying proportions of modern **(Qvm)**, historical (**Qvh**), and younger (**Qvy**) alluvium filling valley-floors and underlying modern channels. See detailed descriptions of each unit.

Qvop Picacho Valley Alluvium (Upper Pleistocene) – Sandy pebble to pebble-cobble gravel; clasts consist of monzonite, volcanic rocks, and limestone derived from the Organ Mountains. The deposit is poorly exposed in Arroyo de Alameda just south and east of Oñate High School and the unit appears to be capped by a stage III calcic horizon. Estimated to be 25–75 ka (Gile et al., 1981). The top of the deposit is inset <5 m below the La Mesa surface and the thickness is estimated to be <10 m.

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Basin-floor Units

Ql Playa Lake Deposits (Modern to Holocene) – Moderate brown to grayish brown to reddish-brown calcareous clay and silt deposited in modern Isaack Lake. Well-rounded volcanic (mostly rhyolite and andesite) pebbles are scattered across the surface. Gile and Grossman (1979) dug a pit into the basin floor and found that the soil is well mixed by repeated wet and dry cycles. These authors also note that soluble salts are not present because of deep percolation of precipitation during summer rainstorms. The playa deposit is up to 4 m thick.

Short Moderate brown to grayish brown to reddish-brown calcareous clay and silt deposited in modern Isaack Lake. Well-rounded volcanic (mostly rhyolite and andesite) pebbles are scattered across the surface. The playa deposit is up to 4 m thick.

Qbfs Sandy Fine-Grained Basin Floor Deposits (Holocene to Upper Pleistocene) – Reddish brown sandy clayey silt deposits that grade downward into Camp Rice fluvial deposits; angular volcanic clasts from the Doña Ana Mountains to the west (~60%), exotic mixed rounded pebbles from the Camp Rice fluvial facies (e.g., chert, quartz, granite; ~30%), and sedimentary clasts (~10%) are commonly scattered on the floor of the basin. The unit is up to 2 m thick.

Qbf Fine-Grained Basin Floor Deposits (Holocene to Upper Pleistocene) – Brown to grayish brown clay, silty clay, and clayey silt that grades down into sandy to gravelly distal piedmont or Camp Rice fluvial deposits. 0.5–1.5 m thick.

Qbfp Petts Tank Fine-Grained Basin Floor Deposits (Upper to Middle Pleistocene) – Brown to moderate brown mudcracked carbonaceous clayey silt and minor gravel deposits associated with the Petts Tank geomorphic surface; the unit was derived from Paleozoic carbonates in the San Andres Mountains to the east (Gile et al., 1981). This deposits is the distal facies of **Qpo,** and the Petts Tank surface is the basin-center equivalent of the Jornada II piedmont-slope surface. Pebbles are sparse (< 3%) and sand is absent. The upper deposits grade laterally into **Qbfs**. The age is estimated to be 25–75 ka (Gile et al., 1981). Unit is up to 2 m thick.

Short Brown to moderate brown mudcracked carbonaceous clayey silt and minor gravel deposits associated with the Petts Tank geomorphic surface; the unit was derived from Paleozoic carbonates in the San Andres Mountains to the east (Gile et al., 1981). Pebbles are sparse (< 3%) and sand is absent. Unit is up to 2 m thick.

Alluvial Fan and Piedmont Slope Units

Qhs Historic clayey silt deposit (<50 years?) –Thin reddish brown clayey silt deposit with monzonite granules that is visible on photogrammetry imagery from 2009. This deposit can still be observed in the field as of 2021 and is the remnants of a muddy flood that overtopped the banks of shallow arroyos in an area south of Rabbit Run Road and east of Holman Avenue. The deposit is mostly quartz, with calcite, feldspars, illite, montmorillonite, kaolinite, richterite (or some similar amphibole); the quartz:calcite ratio ~ 85:15 to 90:10, based on XRD analysis. The muddy flood covered cryptogrammic soil, but in one place a new colony is forming. The deposit is 0.5–2 mm thick.

Short Thin reddish brown clayey silt deposit with monzonite granules that is visible on photogrammetry imagery from 2009. This deposit can still be observed in the field as of 2021 and is the remnants of a muddy flood that overtopped the banks of shallow arroyos in an area south of Rabbit Run Road and east of Holman Avenue. The deposit is 0.5–2 mm thick.

Qpf Fine-grained silty clay deposits (Historical to Holocene) – Moderate to light brown clayey silt, silty clay, and clayey sandy silt deposits with little (<1–2 % volcanic clasts) to no gravel that fill in low spots on piedmont slopes both east and west of the basin floor. The elevation of these topographic lows is 10 m above the elevation of the Isaack Lake basin floor. The unit is estimated to be <7000 years old. The unit generally less than 0.5 m thick.

Qps Piedmont slope deposits composed of clayey silt (Historical to Holocene) – White to tan clayey silt derived from the erosion of Paleozoic carbonate exposed on the western flanks of the San Andres Mountains. Near the mountain front, the silt is commonly interbedded with lenses of gravel containing clasts of limestone, laminated sandstone, shale, and chert. Toward the center of the basin the silt overlies older fan-piedmont alluvium (Jornada II surface or Organ surface). The basin-center exposures correspond with the Whitebottom surface of Ruhe (1964, 1967), where erosion has exhumed the underlying gravels and the silt forms erosional scarps (Figure 8). The unit includes the exhumed older gravels. The deposit is < 3 m thick.

Short White to tan clayey silt derived from the erosion of Paleozoic carbonate exposed on the western flanks of the San Andres Mountains. The basin-center exposures correspond with the Whitebottom surface of Ruhe (1964, 1967), where erosion has exhumed the underlying gravels and the silt forms erosional scarps. The unit includes the exhumed older gravels. The deposit is < 3 m thick.

Figure 8. Photograph of the clayey silt and erosional scarps associated with the Whitebottom surface. Organ Mountains in the background. Digging tool is 0.4 m long.

Qpy Younger Fan-Piedmont Alluvium (Holocene) –Deposits on fans, sheets, and lobes that are equivalent to the Organ morphostratigraphic unit. Unit is common on the lower piedmont slope. Bedding in the gravelly sand to sandy gravel ranges from tabular, graded, or cross-bedded (channels) to massive and poorly sorted (debris flows). A red-brown Bt and/or Bk can be preserved and the calcic soil development is Stage I. This undivided unit contains subequal amounts of monzonitic, volcanic, and sedimentary clasts. Gile and Grossman (1979) report charcoal at pedon sites 67-1, 67-3, 60-15, 59-6, and 59-7; a ^{14}C date on charcoal from 67-1 is 4035±115 years and on carbonate is 4430±135 years. A ^{14}C date on carbonate from 60-15 is 10,580 Years. Charcoal found in pale brown silty clay in a Qpy deposit at UTM 346237E 3591721N (NAD83) during this investigation yielded ^{14}C dates of 1770 +/- 30 BP and 1780 +/- 30 BP. Gile et al. (1981) generally consider the Organ alluvium to be < 7000 years old. Thickness is <2–3 m (Gile et al., 1981).

Short Deposits on fans, sheets, and lobes that are equivalent to the Organ morphostratigraphic unit. Unit is common on the lower piedmont slope. Bedding in the gravelly sand to sandy gravel ranges from tabular, graded, or cross-bedded (channels) to massive and poorly sorted (debris flows). Thickness is <2–3 m (Gile et al., 1981).

Qpym Younger Fan-Piedmont Alluvium with Monzonitic Clasts–Piedmont slope deposits predominantly containing monzonite granules and clasts and volcanic clasts derived from the Organ Mountains and San Agustin Peak.

Qpyl Younger Fan-Piedmont Alluvium with Limestone and Sedimentary Clasts– Piedmont slope deposits predominantly containing limestone, sandstone, shale, and chert derived from the San Andres Mountains.

Qpyv Younger Fan-Piedmont Alluvium with Volcanic Clasts–Piedmont slope deposits predominantly containing andesite and other volcanic clasts derived from the Doña Ana Mountains.

Qpi Intermediate Fan-Piedmont Alluvium, Isaacks' Ranch Morphostratigraphic Unit (Holocene to Uppermost Pleistocene) – Similar to units **Qpy** but occurring in mostly undissected fans, sheets, and lobes correlated with the intermediate elevation Issacks' Ranch geomorphic surface of Ruhe (1964, 1967) and morphostratigraphic unit of Gile et al. (1981). A red-brown Bt and/or Bk can be preserved and the calcic soil development is Stage II. This undivided unit contains subequal amounts of monzonitic, volcanic, and sedimentary clasts. This unit may include Qpy. ^{14}C dates on carbonate in the unit at pedons 59-6 and 59-7 are 11,700±170 years and 7890±150 years, respectively (Gile and Grossman, 1979). The age range of Qpi is 8–15 ka (Gile et al., 1981). Thickness is 2–3 m.

Short Similar to units Qpy but occurring in mostly undissected fans, sheets, and lobes correlated with the intermediate elevation Issacks' Ranch geomorphic surface of Ruhe (1964, 1967) and morphostratigraphic unit of Gile et al. (1981). A red-brown Bt and/or Bk can be preserved and the calcic soil development is Stage II. Thickness is 2–3 m.

Qpil Intermediate Fan-Piedmont Alluvium with Limestone and Sedimentary Clasts–Piedmont slope deposits predominantly containing limestone, sandstone, shale, and chert derived from the San Andres Mountains.

Qpiv Intermediate Fan-Piedmont Alluvium with Volcanic Clasts–Piedmont slope deposits predominantly containing andesite and other volcanic clasts derived from the Doña Ana Mountains.

Qpsl Gravelly clayey silt piedmont slope deposit (Holocene to Uppermost Pleistocene) – This deposit occupies a large area near the center of the quadrangle that is composed of gravelly silt reworked from the older deposits **Qpo** and **Qpu.** The clasts are predominantly limestone and other sedimentary clasts derived from the San Andres Mountains. The unit is <2–3 m thick.

Qpo Older Fan-Piedmont Alluvium (Upper to Middle Pleistocene) –Moderately consolidated gravel that is massive to imbricated. Matrix sand is reddish-brown or pale- to yellowish-brown. This undivided unit contains subequal amounts of monzonitic and sedimentary clasts. Deposit is commonly buried and can only be observed in arroyos; a red-brown Bt and/or Bk can be preserved and calcic soil development is stage II+–III. Likely correlative to the Jornada II surface (Ruhe, 1967; Gile et al., 1981). Radiocarbon dates on carbonate at 59-7 are 25, 500 (+800,-700), 29,000 (+2700, -2100), and 26,950 ±1,050 years (Gile and Grossman, 1979). The age range is estimated to be 25–75 ka (Gile et al., 1981). Thickness is 2–10 m.

Short Moderately consolidated gravel that is massive to imbricated. Matrix sand is reddish-brown or pale- to yellowish-brown. Deposit is commonly buried and can only be observed in arroyos; a red-brown Bt and/or Bk can be preserved and calcic soil development is stage II+–III. Likely correlative to the Jornada II surface (Ruhe, 1967; Gile et al., 1981).

Qpol Older Fan-Piedmont Alluvium with Limestone and Sedimentary Clasts– Piedmont slope deposits predominantly containing limestone, sandstone, shale, and chert derived from the San Andres Mountains.

Qpov Older Fan-Piedmont Alluvium with Volcanic Clasts–Piedmont slope deposits predominantly containing andesite and other volcanic clasts derived from the Doña Ana Mountains.

Qpa Fan-Piedmont Alluvium (Historical to Middle Pleistocene) – This undivided unit includes varying proportions of younger (**Qpy, Qpi**) and older (**Qpo**) fan-piedmont alluvium. See the detailed descriptions of each unit.

Qpu Old Fan-Piedmont Alluvium, undivided (Pleistocene) – High ridges on the east side of the quadrangle near the San Andres Mountains with varying proportions older (**Qpo**) fan-piedmont alluvium and Camp Rice piedmont-slope facies (**Qcp**). These fans are derived from calcareous-sedimentary-rock-bearing units in the San Andres Mountains to the east of the quadrangle. See detailed descriptions of each unit.

QUATERNARY-NEOGENE

Basin-Fill Units

Qcp Younger Piedmont Facies of the Camp Rice Formation (Lower Pleistocene) – Weakly consolidated to carbonate-cemented, pebble-cobble to pebble-cobble-boulder gravel that is massive or in medium to thick (25–80 cm), tabular beds. Gravel clasts are generally matrix-supported (less commonly clast-supported). Clasts consist of angular to subrounded pebbles, cobbles, and boulders of monzonite and volcanic rocks eroded from the Organ Mountains. Unit may grade to loam or silt with gravel interbeds at distal piedmont positions (**Qct**), may contain buried soils, and is frequently capped by a laminar, petrocalcic (stage IV) horizon (Gile et al., 1981). Maximum thickness is 30–40 m.

Short Weakly consolidated to carbonate-cemented, pebble-cobble to pebble-cobble-boulder gravel that is massive or in medium to thick (25–80 cm), tabular beds. Clasts consist of angular to subrounded pebbles, cobbles, and boulders of monzonite and volcanic rocks eroded from the Organ Mountains. Maximum thickness is 30–40 m.

Qct Transitional Facies of the Camp Rice Formation (Lower Pleistocene) –

Weakly consolidated, massive, poorly sorted sand and gravel to tabular-bedded, imbricated gravel and sand channel deposits. Sand is commonly fine grained. Gravel is subround to subangular and consists primarily of monzonite granules to boulders or volcanic rocks derived from the Organ Mountains. Deposit is light-brown to reddish-orange brown. Unit contains one or two buried cambic (Bw) to argillic or calcic (Bt, Btk/stage I to stage III) soil horizons; locally, Bw or Bt and C horizons are eroded. Paleosol packages are typically 1–1.5 m thick. Maximum exposed thickness in Arroyo de Alameda along the southern boundary of the quadrangle is about 10 m.

Short Weakly consolidated, massive, poorly sorted sand and gravel to tabular-bedded, imbricated gravel and sand channel deposits. Sand is commonly fine grained. Gravel is subround to subangular and consists primarily of monzonite granules to boulders or volcanic rocks derived from the Organ Mountains. Deposit is light-brown to reddish-orange brown. Maximum exposed thickness in Arroyo de Alameda along the southern boundary of the quadrangle is about 10 m.

QNcf Axial-fluvial Facies of the Camp Rice Formation (Lower Pleistocene to Pliocene) – Weakly to moderately consolidated and calcite-cemented, pebble gravel and sand. Gravels are well-imbricated to cross-stratified and contain common exotic clasts (quartzite, granite, and chert). These deposits underlie internally massive to planar cross-stratified sand that is brownish (10YR) in color. Soils are generally not observed. The Camp Rice fluvial facies was deposited between 5 and ~0.8 Ma (Mack et al., 1998). Maximum thickness is 215 m.

Short Weakly to moderately consolidated and calcite-cemented, pebble gravel and sand. Gravels are well-imbricated to cross-stratified and contain common exotic clasts (quartzite, granite, and chert). These deposits underlie internally massive to planar cross-stratified sand that is brownish (10YR) in color. Maximum thickness is 215 m.

QNcpf Piedmont and Fluvial Facies of the Camp Rice Formation (Lowermost Pleistocene? to Pliocene) – Weakly consolidated to carbonate-cemented piedmont and fanglomerate gravel/conglomerate derived from porphyritic volcanic rocks in the Doña Ana Mountains and fluvial facies sand with <1-3% exotic clasts of chert and quartz (Figure 9). Matrix sand is tan and is mostly fine grained, with medium- to coarse-grained intervals. Unit contains 10–15% thin beds of pebbly sand. Stage III-IV calcic horizons observed in upper 2 m in excavations and in the escarpment near Red Hawk Golf Course that correlate to the La Mesa surface. Exposed thickness is <10 m.

Short Weakly consolidated to carbonate-cemented piedmont and fanglomerate gravel/conglomerate derived from porphyritic volcanic rocks in the Doña Ana Mountains and fluvial facies sand with <1-3% exotic clasts of chert and quartz. Matrix sand is tan and is mostly fine grained, with medium- to coarse-grained intervals. Exposed thickness is <10 m.

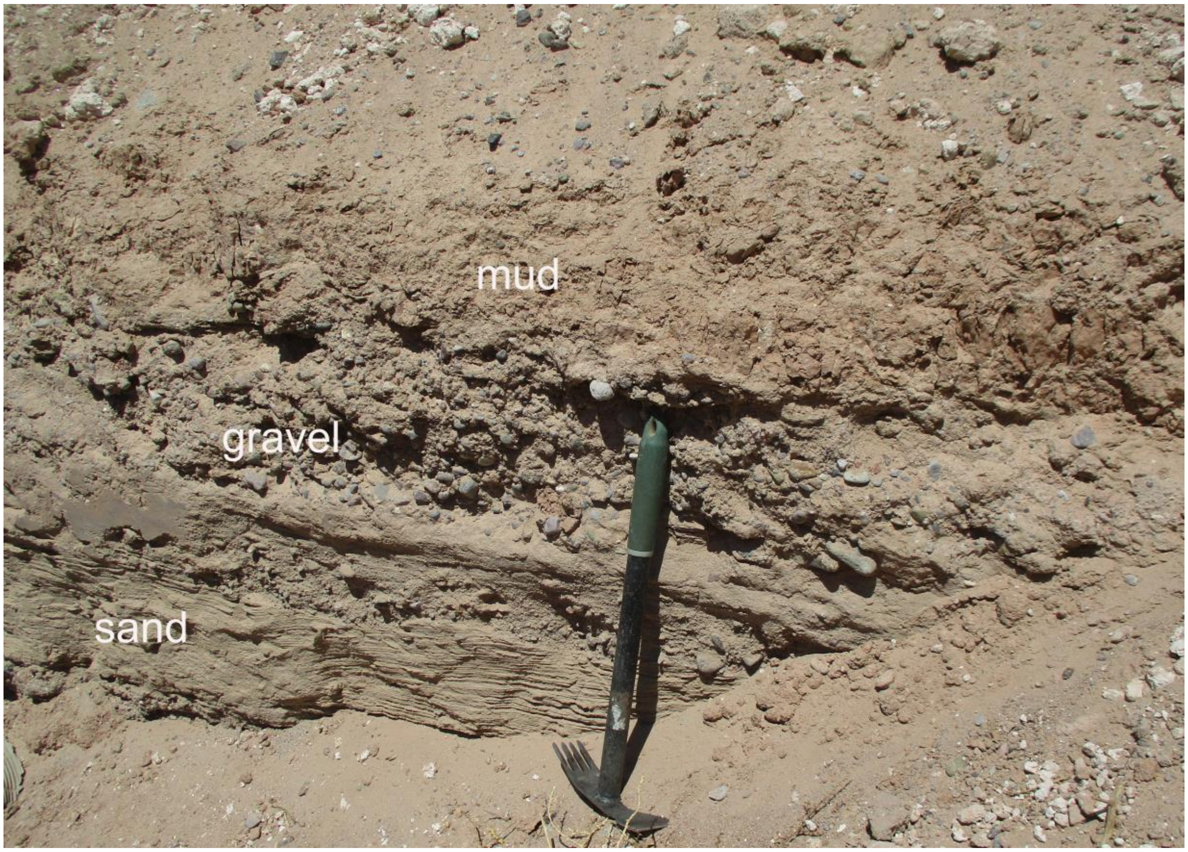

Figure 9. Camp Rice fluvial deposit containing clasts from the nearby Doña Ana Mountains.

Nmsfp Middle Santa Fe Group Proximal Piedmont-Slope Deposits (Pliocene–Miocene) – Indurated sandy gravel deposited on a proximal to medial piedmont slope. *Not exposed. On cross-sections only.*

Nmsfd Middle Santa Fe Group Distal Piedmont-Slope Deposits (Pliocene–Miocene) – Partially indurated gravelly sand and clayey silt deposited on a medial to distal piedmont slope. *Not exposed. On cross-sections only.*

Nlsfp Lower Santa Fe Group Proximal Piedmont-Slope Deposits (Miocene) – Indurated sandy gravel deposited on a proximal to medial piedmont slope. *Not exposed. On cross-sections only.*

Nlsfd Lower Santa Fe Group Distal Piedmont-Slope Deposits (Miocene) – Partially indurated gravelly sand and clayey silt deposited on a medial to distal piedmont slope. *Not exposed. On cross-sections only.*

PALEOGENE

PEmrs Silicic pyroclastic and volcaniclastic rocks (Oligocene) – mainly rhyolite and dacitic ash-flow tuffs and tuffaceous sandstones primarily derived from the Organ caldera, with some capping basaltic-andesite flows. *Not exposed. On cross-sections only.*

PEpp Palm Park Formation (Middle Eocene) – Gray to greenish gray dacitic porphyry with 5–20% hornblende and plagioclase phenocrysts. The plagioclase is 2–3 mm long and the hornblende is 2–5 mm long; xenoliths of that are 1–2 cm across comprised of equigranular to porphyritic rocks are common; the equigranular xenoliths are composed of hornblende, and white and gray plagioclase and the porphyritic xenoliths have ~2% hornblende and plagioclase. Fractures at the top of the knob are coated with epidote. Recent U-Pb and $^{40}Ar/^{39}Ar$ studies of the Palm Park Formation in the central part of the Doña Ana Mountains yielded dates of 41.3±0.7–41.6±0.7 Ma and 43.05±0.28 Ma, respectively (Creitz et al., 2018; Ramos and Heizler, 2018). These dates are from the lower part of the formation. Reported $^{40}Ar/^{39}Ar$ of ~36 Ma on the Doña Ana Rhyolite, which intrudes the Palm Park Formation, place an upper limit on the age of the andesite in this area (Ramos and Heizler, 2018). Approximately 30 m of this unit is exposed on a knob on the east flank of the Doña Ana Mountains.

Short
Gray to greenish gray dacitic porphyry with 5–20% hornblende and plagioclase phenocrysts; xenoliths of that are 1–2 cm across comprised of equigranular to porphyritic rocks are common. U-Pb and $^{40}Ar/^{39}Ar$ dates on andesite and rhyolite in the Doña Ana Mountains to the east constrain the age of the Palm Park Formation in this area to be 36–43 Ma (Creitz et al., 2018; Ramos and Heizler, 2018).

PEls Love Ranch Formation (Early Eocene to Paleocene) –Mostly red to reddish-brown sedimentary rocks, including sandstones, mudstones and conglomerates with few or no volcanic constituents eroded from Laramide highlands. *Not exposed. On cross-sections only.*

PALEOZOIC

Pzu Upper Paleozoic sedimentary rocks, undivided (Pennsylvanian and Permian)– Primarily limestone and redbed mudstones, with shale, sandstone, and some gypsum (marine and nonmarine). *Not exposed. On cross-sections only.*

Pzl Lower Paleozoic sedimentary rocks, undivided (Ordovician to Mississippian) – Primarily limestone, with shale and sandstone (mostly marine). *Not exposed. On cross-sections only.*

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