GEOLOGIC MAP OF THE THREE RIVERS 7.5-MINUTE QUADRANGLE, OTERO COUNTY, NEW MEXICO

BY

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INTRODUCTION

Below are descriptions for geologic map units depicted in the Three Rivers 7.5-minute quadrangle, New Mexico. The topography in the eastern part of this quadrangle generally consists of gentle slopes, with isolated hills and mesas. Quaternary alluvium and slopewash occupy most of the surface area here, but sufficient outcrops of bedrock units exist to map Permian, Triassic, and Cretaceous formations, as well as the structures that deform them. The north- to northwest-striking Alamogordo fault passes near the center of the quadrangle. Relatively recent movement along this fault has created fault scarps in the Quaternary alluvium. To the west of the fault are west-sloping alluvial fan deposits. Alluvial fan sediment consists primarily of interbedded clayey-silty sand and sand-gravel beds, with common gravel near the mountain-front and clay becoming abundant in the west. The Phillips Hills extend into the northwestern corner of the map, and are underlain primarily by limestone, dolomite, and gypsum.

DESCRIPTION OF MAP UNITS

Most of the map units on the Three Rivers quadrangle are Quaternary or Pliocene in age. Locally, sediment of the Santa Fe Group was observed (map unit **Tsf**), probably Miocene in age. A variety of intrusive sills, laccoliths, and dikes intrude older Mesozoic and Permian strata. The Quaternary units on this quadrangle are grouped into the following six categories: Modern alluvium, artifical fill and excavations, eolian and slopewash deposits, terraces and terrace deposits, alluvial fan deposits west of the Alamogordo fault, and alluvial slope deposits east of the Alamogordo fault. The latter two categories are further discussed in the report.

These units were mapped by field traverses and aerial photography (White Sands Missile Range project, December and November of 1985). Initial work consisted of mapping representative parts of the alluvial fan and basin-floor sediment with a hand-held GPS unit and using the 20-ft contours on the published topographic map. This preliminary map was then utilized in identifying and mapping units using aerial photography. Mapping from aerial photographs using the PG-2 plotter at the U.S. Geological Survey in Denver produces relatively precise lines (contacts) separating the map units. Line work from the aerial photograph-based mapping was then field-checked during subsequent field visits to the quadrangle. Emphasis was placed on field-mapping of bedrock units east of the Alamogordo fault. Note that access restrictions prohibited field-checking in the White Sands Missile Range (the 2.5 km-wide strip along the western border). In the areas I did field-check, we found that there was an approximate 10-15% error in map unit identification of Quaternary units using the aerial photographs. Consequently, the user should assume that there is a potential 10-15% error in the identification of the Quaternary map units. Some areas of the alluvial fan have two or more units that cannot be practically differentiated at a scale of 1:24000. In such cases, we use nomenclature reflecting a combination of units. This nomenclature involves listing both units separated by a hypen (e.g., **Qfy2-Qam**), where the first unit predominates. Otherwise, I interpret ≤10% of other units

present within a single-named unit. For example, in a map unit labeled "**Qfo**" I interpret ≤10% of other map units, such as **Qfy** or **Qam**, within that mapped polygon.

Grain sizes follow the Udden-Wentworth scale for clastic sediments (Udden, 1914; Wentworth, 1922) and are based on field estimates. Pebbles are subdivided as shown in Compton (1985). The term "clast(s)" refers to the grain size fraction greater than 2 mm in diameter. Descriptions of bedding thickness follow Ingram (1954). Colors of sediment are based on visual comparison of dry samples to the Munsell Soil Color Charts (Munsell Color, 1994). Soil horizon designations and descriptive terms follow those of the Soil Survey Staff (1992), Birkeland et al. (1991), and Birkeland (1999). Stages of pedogenic calcium carbonate morphology follow those of Gile et al. (1966) and Birkeland (1999). Because both calcic and gypsum often accumulate together in a given soil horizon on this quadrangle, we may use the term "apparent carbonate morphology" to indicate that gypsum accumulation is influencing the determination of the carbonate stage. Discussion of a unit's age control is presented in the accompanying report. The report also presents interpretations regarding structure and geologic history.

MODERN AND HISTORICAL ALLUVIUM

Qam **Modern alluvium (less than 50 years old) –** Gravelly sand and sand deposited by recent discharge events in topographically low, but relatively wide, areas or as lobes at the mouths of incised arroyos. Unit overlies units **Qfy** or **Qay**. Bedding is very thin to medium and planar-horizontal, with internal planar-laminations(minor wavy laminations) and local cross-stratification. Gravel include pebbles and cobbles that are subrounded (minor subangular) and poorly sorted. Clasts consist of varying proportions of Mesozoic sandstone, Paleozoic limestone and siltstone, and Tertiary intrusive and volcanic clasts, depending on the source area of a given drainage. Colors of sand range from brown to pale brown (10YR 5-6/3) and grayish brown to light brownish gray (10YR 5-6/2). Sand is very fine- to very coarse-grained, subangular to subrounded, moderately to poorly sorted, and composed of plagioclase and quartz with minor potassium feldspar and lithic grains. Surface has fresh bar- and swale topography up to ~50 cm. No soil development. Loose. This unit includes subordinate amounts of the **Qamf** and **Qamg** units. Generally 1-2 m-thick.

Qamhf **Fine-grained modern to historic alluvium (less than 50 years old) –** Silt, very fine- to fine-grained sand, and subordinate clay deposited on top of **Qay** or **Qfy** by baffling of sheetflooding due to dense grass and other vegetation. Incised channels are few, discontinuous, and relatively shallow (less than 50 cm). Colors of sediment ranges from pale brown to brown (10YR 5-6/3) or light gray to light brownish gray (10YR 6-7/2). Deposit is massive, probably because of bioturbation, relatively thin (1 m-thick or less), well-sorted, and loose.

Qamg **Modern alluvium deposited in gullies or arroyos (less than 50 years old) –** Gravelly sand, sandy gravel, and sand deposited by recent discharge events at the bottoms of incised gullies or arroyos. Unit typically incised below the top of units **Qfy** or **Qay**.

There may be up to 1.5 m of erosional (gullied) relief on the surface of this unit; typical bar and swale topography is generally 30-60 cm-tall. Bedding is very thin to medium and planar-horizontal, with internal planar-laminations (minor wavy laminations) and local cross-stratification. Gravel consist of poorly to very poorly sorted pebbles, cobbles, and boulders that are mostly subrounded. Clasts are composed of varying proportions of Mesozoic sandstone, Paleozoic limestone and siltstone, and Tertiary and volcanic clasts, depending on the source area of a given drainage. Colors of sand range from brown to pale brown (10YR 5-6/3) and grayish brown to light brownish gray (10YR 5-6/2). Sand is very fine- to very coarse-grained (mostly medium- to very coarse-grained), subangular to subrounded, moderately to poorly sorted, and commonly dominated by lithic, plagioclase, and quartz grains. No soil development. 1-3 m-thick.

Qamh Modern alluvium with subordinate historical alluvium (0 to approximately 200 years ago) -- See descriptions for **Qam** (above) and **Qah** (below).

Qah **Historical alluvium (approximately 50-200 yrs ago) --** Well-stratified sand and subordinate gravel, locally internally massive. Unconformably overlies older **Qfy** sediment; basal contact is sharp and horizontal-planar. Colors range from light brown to brown (7.5YR 6/3-4 and5/4) to light brownish gray (10YR 6/2). Stratification is mostly laminated to very thin, horizontal-planar to wavy to cross-stratified (very minor ripple-marks). In the proximal fans, there is up to 20% pebbly channel-fills (lenticular to U-shaped); these are up to 50 cm thick and internally laminated to very thin bedded (horizontal-planar to low-angle cross-stratified, or in lenticular beds). Local hummocky cross-lamination indicates a minor component of eolian facies, where sand was blown in from adjacent, relatively wide, exposed channel floors. Sand is very fine- to very coarse-grained (mostly very fine- to medium-grained), subrounded to subangular, well to poorly sorted, and composed of quartz, 20-25% feldspar, and 10-30% volcanic lithic + mafic grains. Very fine sand and silt dominate in the distal fans near the western quadrangle boundary. No soil development. Surface is relatively fresh, with bar and swale topography up to about 50 cm-tall. No desert pavement development or clast varnish, but an erosional gravel lag may be present. Unit correlates to the **Qah** unit in the Tularosa NE quadrangle to the south. Historic age assignment is based on the presence of post-Native American artifacts, such as tires and railroad-related coal. Parts of the unit may possibly be as much as 500 years old. The **Qah** deposit is difficult to distinguish from sediment of the younger subunit of younger alluvium (**Qfy3**). But in aerial imagery the **Qah** surface exhibits much better defined bar-and-swale topography than surfaces associated with unit **Qfy3. L**oose to weakly consolidated. Generally less than 1 m thick.

Qahm Historical alluvium with subordinate moderna alluvium (0 to approximately 200 years ago) -- See descriptions for **Qah** and **Qam** above.

Qahg Historical alluvium capping strath terraces of modern arroyos (approximately 50-100 years old) -- Historical alluvium (**Qah**) is very thin and may locally be absent, in which case there is an erosional surface underlain by unit **Qfy**.

Qahmy3 A combination of historical alluvium, modern, alluvium, and older upper Holocene sediment (upper Holocene) -- See descriptions of units **Qah** and **Qam** above, and unit **Qfy3** below.

Qahy3 Historical alluvium with subordinate older upper Holocene sediment (upper Holocene) -- See descriptions of units **Qah** above and **Qfy3** below.

ARTIFICIAL FILL AND EXCAVATIONS

ae **Artificial excavation (modern) –** Pit, quarry, or reservoir; the base of these excavations have generally been filled by >10 cm-thick deposits of clay, silt, sand, and gravel carried into the pit by mass-wasting or slopewash processes.

af **Artificial fill (modern) –** Compacted silt, clay, and sand (minor pebbles) under highways and railroads; also found in berms surrounding pits, quarries, or reservoirs. In the case of railroads, coarse to very coarse pebbles and fine cobbles drape compacted fill.

SHEETFLOOD. SLOPEWASH, COLLUVIAL, LANDSLIDE, AND EOLIAN DEPOSITS

Note: These two deposits are grouped together because most eolian sheet deposits have been affected to some degree by sheetflooding

Qse **Sheetflood and slopewash deposits reworked from eolian sand sheets (middle Holocene to present) --**Very fine- to medium-lower sand and clayey-silty fine sand. Within this fine sand is minor, scattered coarser-grained sand, 1-5% very fine to coarse, scattered pebbles, and very minor, very thin to thin, sandy pebble lenses. Unit commonly covers high-level surfaces and mantles slopes at the headwaters of small drainages, where the deposit commonly grades laterally into younger alluvium (**Qay**). Unit exhibits a wide range of colors: most commonly pale brown (10YR 6/3) and light brown to brown (7.5YR 5-6/3-4); less common colors include pink (7.5YR 7/3), light gray (10YR 7/2), and strong brown to reddish yellow (7.5YR 5-6/6). Internally massive, with weak soil development characterized by ped development and minor gypsum + calcium carbonate accumulation, generally as filaments (comparable to a stage I carbonate morphology). Sand is subangular to subrounded, moderately to well sorted, and an arkose to litharenite. Composition varies with the local source area. Generally less than 25% fines, but locally as much as 50%. A very thin pebble bed may be present at base of the deposit. <8% coppice dunes on the surface. Surface is sandy, commonly has a sparse lag gravel, and exhibits weak to no desert pavement development. Loose to moderate consolidated. Generally less than 1 m thick.

Unit Qse commonly is mapped as overlying other units:

Qse/Qai **Sheetflood and slopewash deposits reworked from eolian sand sheets, overlying intermediate alluvial fan deposits --** See descriptions of units **Qse** above and **Qai** below**.**

Qse/Qfo **Sheetflood and slopewash deposits reworked from eolian sand sheets, overlying older alluvial fan deposits --** Only differentiated where **Qse** is inferred to be >30 cm thick. The **Qse** unit consists of light brown (7.5YR 6/4), clean, vfL-mL sand, with <3% m-vc sand and <15% vf-vc pebbles (mostly 10% such pebbles). Sand is subrounded to subangular, well-sorted, and composed of quartz, minor feldspar, and 5-15% mafic + lithic grains.

Qse/Qao2 -- Sheetflood and slopewash deposits from locally reworked eolian sand sheets that overlie the middle subunit of older alluvium -- See descriptions of units **Qse** above and **Qao2** below**.**

Qse/Psaf **Sheetflood and slopewash deposits reworked from eolian sand sheets, overlying the Fourmile Draw Member of the San Andres Formation --** See descriptions of units **Qse** above and **Psa** below**.**

Qsec **Sheetflood and slopewash deposits from reworked from eolian sand sheets, with coppice dunes on the surface (middle to upper Holocene) --** Similar to unit **Qse**, but with 7-10% or greater surface coverage by coppice dunes (coppice dunes described in unit **Qec** below).

Unit Qsec commonly is mapped as overlying other units:

Qsec/Qfy **Sheetflood and slopewash deposits reworked from eolian sand sheets (with coppice dunes) that overlie younger alluvial fan deposits --** See descriptions of units **Qsec** above and **Qfy** below**.**

Qsec/Qfy2 **Sheetflood and slopewash deposits reworked from eolian sand sheets (with coppice dunes) that overlie the middle subunit of younger alluvial fan deposits --** See descriptions of units **Qsec** above and **Qfy** below**.**

Qsec/Qai **Sheetflood and slopewash deposits reworked from eolian sand sheets (with coppice dunes) that overlie intermediate alluvium --** See descriptions of units **Qsec** above and **Qai** below**.**

Qsec/Qfo **Sheetflood and slopewash deposits reworked from eolian sand sheets (with coppice dunes) that overlie older alluvial fan deposits --** See descriptions of units **Qsec** above and **Qfo** below**.**

Qsec/Qao2 **Sheetflood and slopewash deposits reworked from eolian sand sheets (with coppice dunes) that overlie the middle subunit of older alluvium --** See descriptions of units **Qsec** above and **Qao2** below**.**

Qsgy **Highly gypsiferous sheetflood and slopewash deposits (middle to upper Holocene)** -- Unit Qse, as described above, containing significant amounts of gypsum, commonly forming a gypsic surface horizon (a petrogypsic horizon or comparable to stage III morphology in a calcic horizon). 1-3 m-thick.

Qsgy/Kgs **Gypsiferous sheetflood and slopewash deposits overlying Gallup Sandstone -- U**nit **Qsgy**, as described above, overlying the Gallup Sandstone (**Kgs**).

Qc **Colluvium (Holocene)** -- Gypsiferous sand and gravel deposited adjacent to steep slopes. Sand is mostly very fine- to medium-grained. Sediment lacks distinctive bedding. Only mapped locally adjacent to the Alamogordo fault scarp in the southern part of the quadrangle. Probably 1-3 m-thick.

Qls **Landslide (upper Pleistocene to Holocene)** -- Bouldery, unstratified deposit on hill immediately east of Crosby spring. Boulders composed of Dakota Sandstone.

Qec **Coppice dunes (upper Holocene) --** Mounds of sand accumulated under and in the immediate vicinity of mesquite bushes (and cresosote bushes, to a lesser extent). Mounds range from 20 to 200 cm in height. Inter-dune surfaces commonly show signs of erosion and may exhibit a lag of pebbles. Color of dune sand ranges from light brown to pale brown to brown (7.5-10YR 5-6/3), yellowish brown to light yellowish brown (10YR 5-6/4), and brown to light brown (7.5YR 5-6/4). Sand is very fine- to medium-grained, subrounded (lesser rounded and subangular), well- (mostly) to moderately-sorted, and composed of quartz, with 10-25% estimated lithic + mafic grains and 10-20% estimated potassium feldspar. 1-5% coarse to very coarse-grained sand that is scattered. Coppice dunes overlie a bioturbated eolian sand sheet or sheetflood deposits; this underlying deposit is grouped with **Qec**. The coppice dunes are likely upper Holocene in age, but underlying deposit may possibly be as old as middle Holocene. Loose. Deposit under the dunes is up to ~ 2 m-thick. Dunes cover 10-35% of the surface.

Unit Qec commonly is mapped as overlying other units:

Qec/Qfy -- Coppice dunes that overlie younger alluvial fan deposits -- See descriptions of **Qec** above and **Qfy** below.

Qec/Qfo -- Coppice dunes that overlie older alluvial fan deposits -- See descriptions of **Qec** above and **Qfo** below.

Qec/Qay-- Coppice dunes that overlie younger alluvium -- See descriptions of **Qec** above and **Qay** below.

Qec/Qao2-- Coppice dunes that overlie the middle subunit of older alluvium -- See descriptions of **Qec** above and **Qao2** below.

Qec/Qttrm – Coppice dunes that overlie the middle terrace deposit associated with the Three Rivers drainage -- See descriptions of **Qec** above and **Qttrm** below.

Qecr **Coppice dunes developed on an eolian sand ramp (middle to upper Holocene) --** Coppice dunes (as described in unit **Qec**) that overlie several meters of sand deposited as an eolian sand ramp. The sand ramp slopes away from a topographic high. Sand is mostly brown to light brown (7.5YR 5-6/4), very fine- to medium-grained (minor coarser sand), subrounded, moderately to well sorted, and composed of quartz grains with 10-15% inferred potassium feldspar and lithic grains). Loose and several meters thick.

Qecr/Tim -- Coppice dunes on a sand ramp that overlie megacrystic, alkali gabbro-diorite -- See descriptions of **Qecr** above and **Tim** below.

Qer **Eolian sand ramp that lacks coppice dunes (middle to upper Holocene) --** Up to several meters of sand deposited as an eolian sand ramp adjacent to a topographic high. The sand is similar to that described in unit **Qecr**.

Qed **Eolian sand in dune forms other than coppice dunes (middle to upper Holocene) --** Eolian sand in mound-like deposits that extend over several meters. East of Highway 54, near the northern quadrangle boundary, the dunes are longitudinal and their crests are mapped. These longitudinal dunes are aligned NE-SW, parallel to the dominant wind direction. Up to 3 m-thick.

Qe **Undifferentiated eolian sand deposits (middle to upper Holocene)** -- Unit includes undifferentiated Qse, Qsec, Qec, and Qecr (see descriptions of these units above). Up to several meters thick.

Unit Qe commonly is mapped as overlying other units:

Qe/Qay **Undifferentiated eolian sand overlying younger alluvium --** See descriptions of **Qe** above and **Qay** below.

Qe/Qao2 **Undifferentiated eolian sand overlying the middle subunit of older alluvium alluvium --** See descriptions of **Qe** above and **Qao2** below.

Qe/Tim **Undifferentiated eolian sand that overlies megacrystic, alkali gabbro-diorite and minor Mancos Shale --** See descriptions of **Qe** above and **Tim** below.

TERRACES, PEDIMENTS, AND TERRACE DEPOSITS

Qt **Undifferentiated terrace deposited by Three Rivers drainage (Pleistocene) --** Terrace deposits(?) whose surfaces (treads) are relatively flat and lie greater than 10 m

above active drainages. In general, surfaces are probably underlain by a thin deposit associated with a stream that formed the terrace. However, a post-terrace gypsum mantle obscures such a deposit, and all that is seen is a layer of pebbles and cobbles (minor boulders) overlying the gypsum. Because of the prevalent poor exposure, it is commonly uncertain whether a given terrace has a significant deposit or is simply an erosion surface. One area where exposure indicates significant thickness is found north of Boone Draw, near the eastern quadrangle boundary. Here, there is ~15 m of sandy gravel and very fine- to very coarse-grained sand interbedded with minor fine sand. The gravel is matrix-supported, subrounded to subangular, and consist of pebbles with 25-30% cobbles. Clasts are composed of igneous clasts with 15% Mesozoic sandstone; clast imbrications at one locality indicate a WSW flow direction. Very fine- to very coarse-grained sand is pale brown to very pale brown (10YR 6-8/3; 10YR 7/4)), subangular to subrounded, and moderately sorted; at least 25% of the sand is composed of gypsum grains. Fine-grained sediment occurs in intervals ~1 m thick that are internally massive, brownish yellow (10YR 6/6), locally clayey-silty, and composed of very fine- to fine-grained sand (about 20-35% of which is gypsum) that is subrounded to subangular and moderately sorted ; this sediment contains gypsum-cemented rhizoliths. Weakly to moderately consolidaetd

Qttrl **Lower Three Rivers terrace (upper Pleistocene**) **--** Terrace located on the north side of lower Three Rivers; surface stands a few meters above the Qay surface to the south. A strong desert pavement has developed on the tread of this terrace and strong gypsum surface indications are present. Surface clasts contain gravel derived from slopewash from adjoining **Qao1** topographic high to the north. Terrace is primarily an erosional feature.

Qttrm **Middle Three Rivers terrace (upper(?) Pleistocene) --** A prominent terrace located south of and 10-15 m above the Three Rivers active channel. A terrace at a similar level was included in this unit in the next canyon to the south. A thin gravel deposit, 0.2-3 m-thick, is likely associated with this terrace. However, this terrace overlies a very coarse paleovalley-fill **(Qao3**), so a definitive strath is difficult to establish. Immediately south of Three Rivers drainage, the strath was drawn using a boulder bed (2.1 km east of the Alamogordo fault) or the base of a cemented 4.5 m-thick interval (1.5 km east of the Alamogordo fault). Whether this boulder bed or cemented zone is associated with the terrace or the inferred, underlying paleovalley-fill is not certain. The paleovalley-fill is not included with the terrace because the terrace extends laterally beyond the location of the relatively narrow paleovalley. However, it is possible that the terrace and its inferred gravel deposit was formed immediately after the back-filling of the paleovalley with gravel. Gravel are subrounded to rounded, moderately to poorly sorted, and consist of pebbles and cobbles with lesser boulders. Clasts consist largely of andesite and intermediate intrusives, with minor coarse syenite. Generally 0.5-2.0 m-thick, but locally as thick as 5 m.

Qttru **Undifferentiated upper Three River terraces (lower to middle Pleistocene) --** Undivided, relatively thin gravel deposits underlying flat terrace surfaces above the middle Three Rivers terrace tread (greater than 10 m above the Three Rivers drainage).

Post-terrace gypsum mantle obscures the thin terrace deposit, and all that is seen is a layer of pebbles and cobbles (minor boulders) overlying the gypsum. These clasts are poorly sorted and include Tertiary andesite extrusives or coarse-grained syenite-granite (the latter commonly occuring as boulders or coarse cobbles). Because of the prevalent poor exposure, it is uncertain whether a given terrace has a significant deposit, or is simply an erosion surface. Clasts include pebbles, cobbles, and boulders of andesite, intermediate intrusions, and minor coarse syenite-granite. Although gravel were likely initially subrounded, spallation has created many angular and subangular clasts. Where a gravel deposit is relatively certain, a label of **Qttrug** is assigned (see below).

Qttrug **Gravelly sediment associated with undifferentiated upper Three River terraces (lower to middle Pleistocene)** -- Sandy gravel whose clasts consist of pebbles with subordinate cobbles and 1-10% boulders. Gravel composed of Tertiary intrusives and intermediate flow rocks, with trace to subordinate Mesozoic-Paleozoic sedimentary clasts (mostly sandstone and limestone). Trace to 5% coarse syenite-granite cobbles and boulders. Gravel are poorly sorted and subrounded. Spallation of exposed clasts has created abundant subangular and angular gravel on the surface. Clasts are very strongly varnished on the surface, and generally overlie a strong gypsic soil. 1-2 m-thick.

Qtg **Gravel terrace gravel deposit associated with drainages south of Three Rivers (upper Pleistocene)** -- Sandy gravel of a terrace deposit within 15 m of present drainage bottoms. Gravel are subrounded to subangular, poorly sorted, and consist of pebbles to boulders (mostly pebbles) of intermediate-mafic intrusive and extrusive clasts, with subordinate Mesozoic-Paleozoic clasts (mostly sandstone and limestone). Boulders of coarse-grained syenite-granite derived from plutons at the head of the Three Rivers drainage are found in northernmost terraces. Gravel deposited on top of Mesozoic strata or unit **Qao**. Unit generally forms unpaired terraces. Nature of surface varies; higher surfaces have good desert pavement development, but lower surfaces have weak pavements. 1-5 m-thick.

Qp/Qao2 **Pediment gravel (middle to upper Pleistocene)** -- Thin, strongly varnished pebbles and gravel overlying unit **Qao1** in the vicinity of Crosby well. Good pavement developement. Deposit related to a pediment developed in the area. This pediment is bout 6 m above the surface related to **Qao3** observed east of Kitty spring. Less than 1 m-thick.

ALLUVIAL FAN DEPOSITS

Qfy **Undivided younger alluvial fan deposits (uppermost Pleistocene to upper Holocene) --** Undifferentiated younger alluvium on alluvial fans, locally subdivided into allostratigraphic units **Qfy2** and **Qf3** (described below). Very fine- to medium-grained sand and clayey-silty fine sand interbedded with coarse channel-fills of medium- to very coarse-grained sand, pebbly sand, and sandy pebbles. Surface clasts are subangular to subrounded and composed of igneous rocks with 10-50% limestone +

sandstone rock types (which appear to be less resistant to weathering than the igneous rocks). Younger alluvium on the fans is generally divided into two subunits: the middle subunit (**Qfy2**) and the youngest subunit (**Qfy3**). Note that the oldest younger alluvial fan subunit (Qfy1), observed on the Tularosa NE quadrangle to the south (Koning and Kelley, 2009), is not mappable on this quadrangle. Qfy1-equivalent sediment on the distal Three Rivers alluvial fan is generally buried by units **Qfy2**, **Qec**, or **Qsec**, where it is part of the **Qsec/Qfy** or **Qec/Qfy** units. Here, sediment inferred to be correlative to Qfy1 is yellowish red (5YR 4-5/6), massive, composed of very fine- to very coarse-grained sand (mostly fine-upper to medium-upper), and contains trace-5% fines; sand is subrounded to subangular, moderately to well sorted, and composed of quartz, subordinate feldspar, and 5-10% mafic+ lithic grains; the soil developed on top of this inferred Qfy1 exhibits moderate, fine to coarse, subangular blocky, slightly hard to hard peds and 0-25%, very faint clay films on ped faces and as clay bridges; where observed, the soil lacks the calcium carbonate nodules characterizing the top soil of **Qai**, rather 1-15% gypsum filaments are observed. Other subunits of younger alluvial fan deposits include relatively coarse deposits (**Qfyc, Qfy23c,** and **Qfy2c**) and slightly coarser-grained **Qfy2** deposits underlying slight topographic highs (**Qfy2ch**), as described below. 2-6 m(?) thick.

Qfyc **Relatively coarse, younger alluvial fan deposits (middle to upper Holocene)** -- Younger alluvial fan deposits (including **Qfy2**, **Qfy3**, and **Qah**) that contain abundant gravelly interbeds or exhibit a general sandy texture. Located in the medial to proximal alluvial fans (generally east of Highway 54). Surface gravel are non- to weakly varnished and lack thick calcium carbonate coats. No strong gypsum indications on the surface. 2-6 m(?) thick.

Qfy3 **Youngest subunit of younger alluvial fan deposits (upper Holocene)** – Well-stratified arroyo and channel back-fills, composed of sand and silty fine sand intercalated with various proportions of gravel beds. Unit also occupies sheet-like bodies adjacent to historical channels. The proportion of gravelly beds progressively decreases westward. On the distal fans, gravel interbeds are very minor and the unit is primarily a sand, silty very fine- to fine-grained sand, and silt. On the distal fans, bedding is horizontal-planar laminated to thinly bedded, with minor planar-cross-laminations <3 cm-thick. Sand is pale brown to very pale brown (10YR 6-7/3), well to poorly sorted, subrounded (medium to very coarse sand) or subangular (very fine to fine sand), and composed of quartz, subordinate feldspar, and minor volcanic + mafic grains. This unit may be difficult to differentiate from historic alluvium, as both appear to have aggraded relatively quickly at a given location and lack buried soils (hence the well-developed stratification). However, in aerial imagery the surfaces associated with unit **Qfy3** exhibit only vague bar-and-swale topography; these features are much better defined on **Qah** surfaces. Loose to weakly consolidated and less than 2 m thick.

Qfy32 **A combination of the youngest (mostly) and middle (lesser) subunits of younger alluvial fan deposits** -- Refer to descriptions of **Qfy3** above and **Qfy2** below.

Qfy3h **A combination of the youngest subunit of younger alluvial fan deposits (mostly) and historic alluvium (lesser)** -- Refer to descriptions of **Qfy3** and **Qah** above.

Qfy2 **Middle subunit of younger alluvial fan deposits (lower(?) to middle Holocene)** – This unit underlies the majority of alluvial fan surfaces in the study area. Color is generally pale brown to light brown to light yellowish brown to brown (10YR-7.5YR 6/3-4; 7.5YR 5/4) or pink (7.5YR 7/3-4), with lower strata being redder. Sediment consists of very fine- to medium-grained sand and clayey-silty fine sand -- both are interbedded with very thin to thick, lenticular beds of medium- to very coarse-grained sand, pebbly sand, and sandy pebbles. The amount of clay-silt is estimated to be less than 10% in the proximal fans, but is commonly more in the distal fan near the western quadrangle border. The proportion of coarse channel-fills progressively decreases away from the mountain front. Within coarse channel-fills, gravel consists of pebbles with minor cobbles, and sand is fine- to very coarse-grained, poorly sorted, subrounded to subangular, and contains abundant lithic grains. In the medial and distal fans, the finer- grained(extra-channel) sediment generally dominates but contains 1-10% very thin to thin, pebbly lenses. Fine sand is mostly moderately to well-sorted, subangular to subrounded, and composed of quartz, 10-25% feldspar, and 5-15% lithic + mafic grains. The finer-grained sediment commonly includes 1-15% scattered pebbles (mostly 1-8%) pebbles and 1-15% scattered medium-upper to very coarse-sand (especially in the medial fans). Most of the clayey- to silty fine-grained sand is internally massive and weakly pedogenically modified; locally, minor laminations to thin beds are preserved. Buried soils exhibit moderate ped development, weak (weak stage I) calcic + gypsic soil horizons (marked by scattered filaments, typically 1-20% surface coverage) and no to very weak (i.e., very few and very faint) clay bridges. Minor calcium carbonate nodules may be found in lower strata. Both fining-upward and coarsening-upward trends noted, as manifested by the amounts of interbedded, gravelly sediment. Base of unit is typically not exposed, but would coincide with the top of the calcic or gypsic soil horizon associated with the top of units **Qfo** or **Qai** (see description of those units below). Uppermost Pleistocene and lower Holocene sediment is probably relatively thin and minor (less than 1 m), and may be incorporated into the cumulic soil overlying the calcic horizon at the top of unit **Qai**. Greater than 80% of unit is middle to upper Holocene in age. Surface of **Qfy2** is commonly eroded and covered by a lag of unvarnished to weakly varnished pebbles. Where not eroded, there is generally a thin, quartz-rich, very fine- to fine-grained sand layer near the surface -- probably brought in by eolian processes and then fluvially reworked by sheetflooding. The top soil of **Qfy2** exhibits weak development marked by a stage I calcic + gypsic soil horizon, where clasts are commonly totally covered by a dusting of calcium carbonate, or have thicker (0.1-0.2 mm-thick), partial calcium carbonate coats. Unit correlates to **Qf3** in the Tularosa NE quadrangle to the south. Moderately to well consolidated and 2-6(?) m-thick.

Qfy2mh **A combination of the middle subunit of younger alluvial fan deposits (mostly) and historic + modern alluvium (lesser)** -- Refer to descriptions of **Qfy2, Qam,** and **Qah** above.

Qfy2c **Relatively coarse sediment of the middle subunit of younger alluvial fan deposits (lower(?) to middle Holocene)** --Younger alluvial fan deposits of **Qfy2** that contain abundant gravelly interbeds or exhibit a general sandy texture. Located in the medial to proximal alluvial fans (generally east of Highway 54). Surface gravel are non- to weakly varnished and lack thick calcium carbonate coats. No strong gypsum indications on the surface. 1-6 m(?) thick.

Qfy23c **Relatively coarse sediment of the middle and youngest units of younger alluvial fan deposits (middle to upper Holocene)** -- Similar to unit **Qfy2c** (described above) but deposit is inferred to include younger (i.e., upper Holocene) sediment. 1-6m(?) thick.

Qfy2ch **Middle subunit of younger alluvial fan deposits with a gravel lag capping a subdued topographic high (middle Holocene)** -- Sandy **Qfy2,** with minor pebble lenses, exhibiting a gravel lag on its surface. This lag gravel has inhibited erosion, creating a subdued topographic high whose surface is generally 50-150 cm higher than the surrounding, eroded **Qfy2** surface. Underlying sand is yellowish brown to light yellowish brown (10YR 5-6/4), mostly fine- to medium-grained, subangular to subrounded, and composed of quartz, 10-20% feldspar, and 10-15% mafic +volcanic lithic grains. Surface gravel are subrounded to subangular and composed of very fine to very coarse pebbles and 0.5-10% cobbles; clast density is generally 30-50%. Surface gravel is generally non- to weakly varnished (minor moderate); only trace to 10% of clasts exhibit distinctive, thick calcium carbonate coats on their undersides. Weak to moderate desert pavement development and no to very sparse strong surface-gypsum indications. Unit correlates to **Qfy2ug** in the Tularosa NE quadrangle to the south. Less than 2 m thick.

Qfyo **Younger alluvial fan deposits and subordinate older alluvial fan deposits (middle-upper Pleistocene and Holocene)** -- Refer to descriptions of **Qfy**, **Qfy2**, and **Qfo**.

Qfo **Undivided older alluvial fan deposits (upper Pleistocene)** -- Intercalated clayey sand and sandy gravel. Commonly forms slight topographic highs. Clayey sand generally is light brown (7.5YR 6/3-4), highly gypsiferous, and mostly contains very fine to fine sand grains. The sandy gravel is in vague, very thin to thin beds that are internally horizontal-planar. Gravel is subangular to subrounded and include very fine to very coarse pebbles and 5-10% cobbles. Clasts are composed of a variety of igneous rocks (mostly intermediate to mafic), limestone, and sandstone. Sand associated with the gravel is brown (7.5YR 4/4), fine-upper to very coarse-upper, subangular, poorly sorted, and a lithic arenite. Sand and gravel clasts are commonly covered by clay coats. Moderately to well consolidated. Unit is recognized by its reddish color and surficial features. These surficial features include moderately to strongly varnished clasts, a moderately to well developed desert pavement, and a strong gypsic-calcic soil horizon (locally a petrogypsic horizon that parallels the modern landscape). In areas of poor exposure, **Qfo** assignment was commonly based on the observation of 10% or greater strong gypsum indications (such as gypsum crusts) on the surface. Unit is commonly covered by eolian sediment in the north (mainly **Qec** and **Qsec**) and a thin veneer of

Qse sand in the south (**Qse** is generally less than 30 cm thick and not mapped separately). This "clean" surficial sand mantles the strong gypsic soil of **Qfo** and is brown to light brown (7.5YR 5-6/4), very fine- to fine-grained, subangular to subrounded, well sorted, and composed of quartz, 10-20% feldspar, and 10-12% mafic + volcanic lithic grains. Deposit grades downward into undifferentiated, basin-fill alluvium of the Santa Fe Group. Base of unit not defined because only the upper 1-2 m of **Qfo** was observed in the field. >2 m thick.

ALLUVIAL SLOPE DEPOSITS

Qay **Undivided younger alluvium (latest Pleistocene to Holocene (uppermost Pleistocene to upper Holocene)** -- Color is generally pale brown to light yellowish brown to light brown (10YR-7.5YR 6/3-4). Sediment consists of a clayey-silty very fine- to fine-grained sand interbedded with very thin to medium, lenticular beds of medium- to very coarse-grained sand, pebbly sand, and sandy pebbles. Most of the clayey- to silty fine-grained sand is internally massive and pedogenically modified (marked by moderate ped development and stage I gypsum accumulation. Scattered pebbles and minor, scattered medium- to very coarse-sand are present. Both fining-upward and coarsening-upward trends noted, as manifested by the amounts of interbedded, gravelly sediment. Locally subdivided into allostratigraphic units **Qay3, Qay2,** and **Qay1** (youngest to oldest and described below). Base of unit defined at top of calcic horizon associated with the top of unit **Qai** (see description of that unit below). Uppermost Pleistocene and lower Holocene sediment is probably relatively thin and minor (less than 1 m), and incorporated into the cumulic soil overlying the calcic horizon at the top of unit **Qai**. Greater than 80% of unit is middle to upper Holocene in age. Unit correlates to **Qf3** in the Tularosa NE quadrangle to the south. Moderately to well consolidated and 1-6 m-thick.

Qaym -- Younger alluvium and subordinate modern alluvium -- Refer to descriptions of **Qay** and **Qam** above.

Qay3 **Youngest subunit of younger alluvium (upper Holocene)** -- Well-stratified sand and minor gravel. Unconformably overlies **Qay2**. Stratification is laminated to very thin to medium, planar-horizontal to wavy to cross-stratified. No soil development. Sand is light yellowish brown to pale brown (10YR 6/3-4), very fine- to very coarse-grained, subrounded to subangular, moderately to poorly sorted, and contains abundant lithic grains. Surface is relatively fresh, with bar and swale topography up to about 50 cm-tall. No desert pavement development or clast varnish. The age of this unit ranges from historical to 3,000 yrs old. Loose to weakly consolidated. 1-2 m-thick.

Qay3hm **A combination of the youngest subunit of younger alluvium deposits (mostly) and historic + modern alluvium (lesser)** -- Refer to descriptions of **Qay3, Qah,** and **Qam** above.

Qay3h **The youngest subunit of younger alluvium (mostly) and subordinate historic alluvium** -- Refer to descriptions of **Qay3** and **Qah** above.

Qay2 **Middle subunit of younger alluvium (lower(?) to middle Holocene) --** Pale brown to light yellowish brown (10YR6/3-4), with lesser pink, reddish yellow, and brown colors. Sediment consists of a clayey-silty very fine- to fine-grained sand interbedded with very thin to medium, lenticular beds of medium- to very coarse-grained sand, pebbly sand, and sandy pebbles. In general, the clayey- to silty fine-grained sand is internally massive and pedogenically modified (marked by moderate ped development and stage I gypsum accumulation. Scattered pebbles and minor, scattered medium- to very coarse-sand are present. Both fining-upward and coarsening-upward trends noted, as manifested in the proportion of gravelly beds. Subunit comprises most of the undifferentiated **Qay** unit. Unit commonly grades up-slope into **Qse** deposits, and most of this unit represents sheetwash deposits. Differentiated from **Qse** by the presence of medium to thick channel-fills. Generally moderately to well consolidated and 1-6 m-thick.

Qay2m **Middle subunit of younger alluvium with subordinate modern alluvium (middle Holocene to modern) --** See descriptions of **Qay2** and **Qam** above.

Qay2ch **Middle subunit of younger alluvium with a gravel lag capping a subdued topographic high (middle Holocene) --** Similar to what is described for unit **Qfy2ch**, but located east of the Alamogordo fault (in the southeastern part of the quadrangle) in an area that has experienced notable surface erosion. 1-2 m thick.

Qay23 **A combination of the middle (mostly) and youngest (lesser) subunits of younger alluvium (middle Holocene to upper Holocene) --** See descriptions of **Qay2** and **Qay3** above.

Qay1 **Oldest subunit of younger alluvium (lower(?) Holocene) --** A small, gravelly unit in the northeastern corner of the quadrangle. See descriptions of **Qay2** and **Qay3** above. Identified using aerial photography and not field-checked. Correlative sediment in the Oscura quadrangle to the north consists of subequal debris flow and stream flow sediment. Debris flow sediment is matrix-supported and in medium to thick, lenticular to tabular beds; clast sizes range from pebbles to boulders. Stream flow sediment is also in medium to thick, lenticular to tabular beds but is clast-supported and contains mostly pebbles. Clasts are subangular, moderately sorted (especially for stream flow sediment) to poorly sorted (especially in debris flows). Clasts correlate to Godfrey Group lavas. Sand is light yellowish brown (10YR 6/4), very fine- to very coarse-grained, subrounded (mostly) to subangular, and poorly sorted. Very fine and fL sand is rich in quartz and feldspar. Debris flow sediment is light brown to light yellowish brown (10YR 6/4) and has abundant vfL-fL sand and an estimated 3-15% clay-silt. Surface soil may have a 20-30 cm-thick, stage II Bk horizon [description is from Koning et al., 2010]. Estimated 1-3 m thickness.

Qai **Intermediate alluvium (latest Pleistocene) --** Light brown (7.5YR 6/4), clayey very fine- to fine-grained sand (minor medium- to very coarse-grained sand), locally interbedded with lenses of gravel and coarse sand and commonly grading downward into sandy gravel. Scattered coarser sand and pebbles may be present. Lower sandy gravel is in very thin to medium, lenticular to tabular beds; gravel are clast-supported, subrounded, and poorly sorted; matrix is pale brown (10YR 6/3), very fine- to very coarse-grained sand that is subrounded, poorly sorted, and contains abundant lithic grains. A nodular, stage II to II+ calcic horizon has developed on top of the unit. The calcium carbonate nodules in this horizon are commonly 0.5-2.0 cm. This calcic horizon is about 10-70 cm-thick. Unit is inset into **Qao2** and **Qao1** and generally overlain by unit **Qay**. It commonly fills topographic lows. Only subaerially exposed in a few places near the quadrangle's eastern boundary because it is generally overlain by unit **Qay**. 1-3 m(?) thick.

Qao **Older alluvium (Pleistocene) --** Undifferentiated older alluvium. Generally subdivided into allostratigraphic units **Qao3**, **Qao2**, and **Qao1** (see descriptions below). Unit recognized by its red hue and abundant gypsum. Rhizoliths commonly seen that are cemented by gypsum. Commonly internally massive or in thick, vague beds. Varying proportions of gravelly channel-fills. Base defined as top of Santa Fe Group deposits (**Tsf**). Well consolidated and up to 25 m-thick.

Qao3 **Younger subunit of older alluvium (upper Pleistocene) --** Paleo-valley fills that are inset into older alluvium (**Qao2**). South of Boone Draw, unit commonly fines-upward from a sandy gravel at its base to clayey very fine- to fine-grained sand at its top. Finer sediment is a light brown (7.5YR 6/4) color. Scattered coarser sand and pebbles may be present. Gravel is clast-supported, highly gypsiferous, and includes pebbles with lesser cobbles and boulders. Matrix in gravelly sediment is pale brown (10YR 6/3), very fine- to very coarse-grained sand that is subrounded, poorly sorted, and contains abundant lithic grains; beds are very thin to thick and lenticular to planar. Clasts are rounded to subangular and poorly sorted. The upper finer-grained sediment has 5-10% pebbles (scattered or in thin lenses), is internally massive, and has gypsum filaments. Between Crosby well and Kitty spring, the preserved tread of this unit is 4-6 m lower than a pediment surface on **Qao2** to the south (**Qp**). Locally, sediment extends hundreds of meters away from paleovalleys as a tabular deposit up to a few meters thick. A strong gypsum horizon is developed on the surface of the unit (comparable morphology to a stage III calcium carbonate horizon), clast varnish is relatively strong, and there is a well-developed desert pavement where unit is not covered by slopewash. (**Qao**). Where this unit has been buried or recently exhumed, a nodular, stage II to II+ calcic horizon may be developed on top of the unit. The calcium carbonate nodules in this horizon are commonly 0.5-2.0 cm across. This calcic horizon is about 10-70 cm-thick. Paleo-valley in-fill is up to about 6 m-thick south of Boone Draw. South of the Three Rivers drainage, this unit is notably gravelly and 10-14 m-thick.

Qao2 **Middle subunit of older alluvium (middle to upper Pleistocene) --** The most common older alluvium subunit, this deposit has a reddish hue and contains abundant gypsum. Color is light brown to reddish brown (7.5YR 6/3-6) to pink (7.5YR 7/3) or

brown to dark grayish brown (10YR 5/3-4/2). Sediment consists of gypsiferous, very fine- to medium-grained sand and clayey fine sand, with minor medium- to very coarse-grained sand and pebbles (scattered or in very thin to medium lenses). Internally massive and commonly affected by pedogenesis (illuviated clay and ped development), with common rhizoliths cemented by gypsum and local calcium carbonate nodules in the fine-grained sediment. Less commonly, the sediment is in medium to thick, tabular beds. Very fine- to medium-grained sand is subangular to subrounded and consists of quartz, 5-15%? feldspar, and 15% volcanic grains. Coarse and very coarse sand is composed of subrounded to subangular volcanic grains. Interbedded in the sand are varying proportions of gravelly channel-fills up to 1 m thick; sand in these channel-fills is horizontal-planar laminated to very thinly bedded. Gravel are generally clast-supported, subrounded to subangular, and composed of pebbles with 5-10% cobbles. Base of deposit overlies Mesozoic strata or various Tertiary igneous rocks. Base appears to be several meters below the base of unit **Qao1**. A strong gypsum horizon is developed on the surface of the unit (comparable morphology to a stage III calcium carbonate horizon or else a petrogypsic horizon), clast varnish is relatively strong, and there is a well-developed desert pavement where unit is not covered by slopewash. Several different erosion surfaces have developed on this unit, which are most obvious immediately adjacent to the Alamogordo fault. Well consolidated and greater than 5 m-thick.

Qao2c Coarse-grained middle subunit of older alluvium (middle to upper Pleistocene) -- Clast-supported, sandy gravel filling paleo-valleys. Very thin to thin, planar-horizontal beds; 10% medium, lenticular beds. Gravel consist of pebbles with minor cobbles and boulders, moderately to poorly sorted, subrounded (minor subangular), and composed of various Tertiary intrusives with minor limestone and sandstone. Sand in matrix is light yellowish brown (2.5Y 6/3), mostly medium- to very coarse-grained, subrounded (minor subangular), poorly sorted, and rich in lithic grains. Top of sandy gravel is at the same height as adjoining **Qao2**, so it is inferred to be older than unit **Qao3**. Mapped near the mouth of Rocky Arroyo. Weakly conslidated and up to 5-6 m-thick.

Qao2tr Middle subunit of older alluvium associated with 3 Rivers drainage (middle to upper Pleistocene) -- Sandy gravel interbedded with subordinate floodplain deposits consisting of fine sand and 1-10% silt-clay. Gravelly beds are thin to thick and lenticular to tabular, with minor tangential, very thin cross-stratifed beds (foresets up to 60 cm thick). Gravel is clast-supported, subrounded, poorly sorted, and consists of pebbles, 15-35% cobbles, and 1-3% boulders composed of intermediate volcanic rocks of the Walker Group and 10-15% trachybasalts of the Godfrey Hills Group; trace boulders from the Three Rivers stock. Channel-fill matrix is pale brown to grayish brown (10YR 6/3-5/2) and light brownish gray to light gray (10YR 6-7/2). The matrix is gypsiferous and composed of poorly sorted, fine- to very coarse-grained sand (mostly medium-upper to very coarse upper, subrounded sand). Fine-lower to medium-lower sand is a mix of quartz, feldspar, and volcanic + mafic grains. Up to 3% clay (as sand-size grains or as clay films). Gypsum crystals occupy up to 2% of the volume (2-5 cm long) and there is variable sand-size gypsum grains in the matrix. Floodplain sediment is light reddish brown (5YR 6/4) to brown, light brown, or reddish yellow (7.5YR 5/4

and 6/4-6). It is thinly to medium-bedded and consists of very fine- to medium-grained sand (mostly very fine to fine) that is subrounded to subangular, moderately to well sorted, and composed of quartz, 15-20% feldspar, and 5-25% mafic + volcanic grains. Local root traces. Unit is inferred to fill a west-trending paleovalley associated with the Three Rivers drainage. Unit is weakly to well consolidated and greater than 15 m thick.

Qao1 **Older subunit of older alluvium, occupying high-level topographic positions (upper Pliocene to middle Pleistocene) --** Generally a sandy gravel with subordinate to subequal interbeds of clayey-silty, gypsiferous, very fine- to fine-grained sand containing minor medium to very coarse sand. Finer-grained sediment appears to dominate progressively south of the Three Rivers drainage. Gravel contains pebbles with variable cobbles, locally with minor boulders. Gravel are subrounded to subangular, poorly to moderately sorted, and composed of intermediate to mafic intrusive and rocks together with Mesozoic sandstone. Sand is pale brown to very pale brown (10YR 6-8/3) or light yellowish brown to light brown (10-7.5YR 6/4), very fine to very coarse-grained, subrounded to subangular, and moderately to poorly sorted. Base of deposit is generally several meters above the base of unit **Qao2**. South of the cross-section line, where exposure does not permit comparison of strath heights, this unit is assigned to topographically high alluvium whose tread is at least 6 m above the tread of adjacent **Qao2**. Prevalent petrogypsic horizon developed on its surface with very strongly varnished surface clasts. Differentiation of this unit from **Qao2** becomes increasingly difficult southwards from Boone Draw. It is possible that south of Boone Draw, at least some of what is mapped as **Qao1** is actually **Qao2** that has witnessed relatively little erosion. 5-25 m-thick.

Qao1c **Coarse, gravelly strata of older subunit of older alluvium, occupying high-level topographic positions (lower Pleistocene) --** Gravelly sediment that caps. Clasts are composed of various igneous rocks as well as Mesozoic sandstone +/- Paleozoic limestone. The gravel is subrounded to subangular, poorly sorted, and consists of pebbles and subordinate cobbles.

QTg **High-level gravelly deposits capping ridges (Pliocene to lower Pleistocene) --** Poorly exposed, sandy gravel capping Permian bedrock near the southern quadrangle boundary**.** Base of deposit is more than 15 m above adjacent drainage bottoms. Surface clasts are subrounded to angular (angular clasts likely due to spallation), poorly to very poorly sorted, and consist of very fine to very coarse pebbles, subordinate cobbles, and 1-5% boulders. Gravel are composed of various igneous rocks and minor sandstone + limestone. 1-12 m thick.

Qtgh **High-level terrace gravel deposit associated with drainages south of Three Rivers (middle to lower Pleistocene) --** Sandy gravel of a terrace deposit more than 15 m above present drainage bottoms. Unit not exposed, but gravel on surface are angular to subrounded (mostly subangular to subrounded) and consist of pebbles and cobbles with 1-10% boulders. Where present, an eroded horizon of relatively large clasts is used to map the base of the terrace deposit. Gravel are poorly to very poorly sorted and are composed of various Tertiary intrusive clasts, with subordinate Mesozoic and Paleozoic

sedimentary clasts (mostly sandstone and limestone). 1-3 m-thick. Convert to QTg (south) and Qao1c (north).

SANTA FE GROUP

Tsf **Santa Fe Group basin-fill (Miocene to lower Pliocene?)** -- Clayey-silty, very fine- to medium-grained sand, locally with minor scattered medium- to very coarse-grained sand and 1-10% pebbles. Colors range from very pale brown to light yellowish brown (10YR 7/3-6/4) to light brown (7.5YR 6/4) to pink (7.5YR 7/3). Thin to thick (mostly thin to medium), tabular beds that are internally massive. Sand is subrounded to subangular, modertely sorted, and composed of quartz and plagioclase, with ~10% estimated potassium feldspar and 10% estimated lithic grains. Paleosols are locally common; these are characterized by calcic horizons (stage II morphology in limited exposures) underlain by gypsic horizons; locally, the calcic horizons are overlain by thin, yellowish red (5YR 5/6), illuviated clay (argillic?) horizons. Other lithologic types include minor gravelly beds, either as: 1) local, very thin to medium lenses of sandy pebbles and sandstone, locally moderately cemented by calcium carbonate, within the aforementioned, relatively fine-grained sediment, or 2) thin to thick beds of clast-supported, sandy pebbles and cobbles (minor boulders); gravel are subrounded to rounded, imbricated (indicating a westward paleoflow direction), and composed of Tertiary intrusive clasts, andesite, and subordinate Mesozoic sandstone; matrix is fine- to very coarse-grained sand that is subrounded and poorly sorted. Gravel is commonly strongly impregnated by calcium carbonate. Exposed in the northeastern quadrangle, where it lies beneath an unconformity at the base of gravelly **Qao1** deposits. Here, it differs from **Qao1** by its smaller gravel size and better cementation and consolidation. On the footwall of the Alamogordo fault, unit probably fills large-scale embayments or paleovalleys, particularly in the Three Rivers area. Greatest exposed thickness is 2 m, but unit is 120 m (400 ft) thick at the Lewelling #1 well (see cross-section). On the immediate fault hanging wall, unit is up to ~700 m-thick (2300 ft) (see cross-section).

TERTIARY INTRUSIVES

Numerous intrusive rocks related to the Sierra Blanca volcanic complex are located in this quadrangle. These rocks occur as dikes (marked on map by a line with "d's"), sills, or laccoliths. Laccoliths are generally restricted to the Mancos Shale, whereas sills are common in the Crevasse Canyon Formation. Age discussed in accompanying report.

Ti **Undifferentiated intrusives (probably middle to upper Eocene) --** Inferred intrusive rocks identified on aerial photography but not field-checked.

Titd **Porphyritic biotite trachyte (upper Eocene to lower Oligocene) --** A very hard, porphyritic (5-15% surface coverage by phenocrysts), light reddish gray to light gray (fresh) to light cream-colored (weathered) dike rock that extends 5 km in a ENE direction north of Boone Draw. Dike is at least 4 m-wide. Groundmass is aphanetic.

Phenocrysts include feldspar (0.5-10 mm), pyroxene (0.2-6 mm), and subordinate biotite (0.2-3.0 mm).

Timp **Intrusions with megacrystic, aligned plagioclase (upper Eocene) --** A distinctive hypabyssal rock containing 5-20% large, euhedral phenocrysts (0.5-2.0 cm-long) of aligned feldspar in a groundmass consisting of feldspar with 20% mafic grains (0.2-0.4mm). Light gray to gray.

Tita **Porphyritic trachyandesite (middle to upper Eocene) --** Porphyritic hypabyssal rock that generally fills dikes, and less commonly small laccoliths. Rock is light gray to gray and consists of a fine-grained groundmass (0.1-0.2 mm grain size) hosting minor phenocrysts up to 0.2-10 mm in length. Phenocrysts are subhedral to euhedral and include pyroxene(?) and smaller plagioclase.

Titb **Trachybasalt (middle to upper Eocene) --** Aphanetic hypabyssal rock commonly filling dikes. Dark gray in color. Minerals include plagioclase and unidentified dark mafics. No olivine observed in hand lens.

Tid **Equigranular, alkali gabbro-diorite or syenogabbro-diorite intrusions occupying sills and laccoliths (middle to upper Eocene) --** Light gray to gray, equigranular to slightly porphyritic hypabyssal rocks occupying sills and laccoliths. Texture is commonly subhedral. Grain size of ground mass is 0.1-0.5 mm, less commonly to 1.0 mm. Mineral assemblage consists of plagioclase with 15-30% hornblende and pyroxene. Exposed rock commonly develops a strong varnish.

Tids **Equigranular, alkali gabbro-diorite or syenogabbro-diorite as sills (middle to upper Eocene) -- Tid, as described above, that occupies a definitive sill.**

Tim **Megacrystic, alkali gabbro-diorite or syenogabbro-diorite occupying sills and laccoliths (middle to upper Eocene) --** Gray to light gray, porphyritic hypabyssal rocks occupying sills and laccoliths. Texture is commonly subhedral, with phenocrysts being subhedral to euhedral. Grain size of groundmass 0.2-0.5 mm, less commonly to 1.0 mm. Mineral assemblage of groundmass consists of plagioclase with 15-25% hornblende and pyroxene. Phenocrysts consist of hornblende and subordinate pyroxene (5-25% of rock voume and up to 20-30 mm long) and smaller plagioclase (5-20% of rock volume). Exposed rock commonly develops a strong to very strong varnish. Most laccoliths and sills consist of this rock type, including the prominent ridge at the Three Rivers Petroglyph site.

Tims **Megacrystic, alkali gabbro-diorite or syenogabbro-diorite as sills (middle to upper Eocene) -- Tim**, as described above, that occupies a definitive sill.

Timta **Mafic-intermediate intrusions (middle to upper Eocene) --** An intermediary unit between units **Tim** and **Tita**, particularly in regards to degree of porphyritic character and the grain size of the phenocrysts.

Timtab **Mafic-intermediate intrusions containing biotite (middle to upper Eocene) --** Similar to unit **Timta** but containing bronze-colored biotite crystals.

MESOZOIC STRATA

Kccu **Crevasse Canyon Formation, upper unit (Upper Cretaceous, Coniacian North American Stage) --** A prominent ledge-forming sandstone in the upper part of the Crevasse Canyon Formation. Overlies sandstone and shale beds of **Kccm**. Overlying strata not exposed. Sand is white to light gray, medium- to coarse-grained, subrounded to subangular, well-sorted, and composed of quartz with 1-5% mafics and cherty lithics. Bedding is laminated to thin, and tangential cross-stratified to planar-horizontal bedded. Sand is strongly cemented. Interpreted to correlate to the basal unit of the Cub Mountain Formation of Arkell (1983), but we follow the stratigraphic schemes of Weber (1964), Lucas et al. (1989) and Cather (1991) in keeping this sandstone in the upper Crevasse Canyon Formation. Not observed south of Three Rivers drainage. Up to 110 m-thick in the northeast corner of the quadrangle, but thins to the south.

Kccm **Middle Crevasse Canyon Formation (Upper Cretaceous, Coniacian North American Stage) --** Fluvial strata consisting of interbedded sandstone channel-fills and fine-grained, mudstone-rich floodplain deposits; very minor coal beds. Sandstone channel-fill complexes may be up to 6 m-thick, are well-cemented, and form ledges. Colors of the sandstone range from pale yellow, golden, light olive gray, pale olive, very pale brown, and light brownish gray. Beds are generally tangential to trough cross-stratified (laminated or very thin to thin beds), with subordinate to subequal horizontal-planar bedding (laminated to thin). Sandstone is mostly fine- to medium-grained, subrounded to subangular, well-sorted, and composed of quartz, feldspar, and 5-10% lithic grains; sandstone was classified as sublithic to subarkosic by Arkell (1982). Floodplain deposits consist of mudstone and very fine- to fine-grained sandstone and silty sandstone, with local, very minor coal beds. Mudstone is pale yellow to light gray to gray to light olive gray in color and locally fissile. Carbonaceous shale is dark gray to black in color. Base of unit not well-exposed on this quadrangle, but noted to be gradational in Arkell (1983). Thickness not well constrained, due to variability in dips, but on the scale of 450 to 600 m.

Kccl **Lower Crevasse Canyon Formation (Upper Cretaceous, lower Coniacian North American Stage) --** Interbedded sandstone and shale interpreted to reflect marginal marine (shoreface, foreshore, lagoonal pond, and deltaic) and fluvial depositional environments (Arkell, 1983). Unit conformably overlies the uppermost shoreface sandstone associated with unit **Kgs**. One or more coal beds are present near the base of the deposit, interbedded with mudstone and very fine- to fine-grained sandstones; this is assigned to the Dilco Member of the Crevasse Canyon Formation. Above this coal is another coarsening-upward, regressive sequence like those described for **Kgs** (see below); the nearshore sandstone in this interval is correlated with the Dalton Sandstone of the Crevasse Canyon Formation. The upper contact of this unit is placed at highest,

golden brown, highly calcareous, very fine- to fine-grained silty sandstone bed containing marine or brackish water fossils; this bed is generally 30-100 cm-thick. This golden brown, fossiliferous sandstone(s) is relatively continuous throughout the study area and commonly forms ledges. Age from Hook (2010) and Hook and Cobban (2012). 50-150 m-thick.

Kccl-Tim – Lower Crevasse Canyon Formation intruded by subordinate megacrystic trachyte porphyry -- Refer to descriptions of units **Kccl** and **Tim** above.

Kgs **Gallup Sandstone (Upper Cretaceous, lower Coniacian North American Stage)** -- Interbedded nearshore sandstones and deeper-water shales that display coarsening-upward, regressive sequences in good exposures to the north (Greg Mack, 2010, personal commun.; Koning et al., 2011). These regressive sequences are very likely present in this quadrangle as well, although not well-exposed. Gray to yellow marine shales are found at the base of the regressive sequence. These grade upward into lower shoreface sandstones that are commonly very thinly to thickly, tabular-bedded (mostly very thin to thin beds; beds are internally massive [locally bioturbated and burrowed] to horizontal-planar-laminated to hummocky laminated). Sand is very fine- to fine-grained, locally silty, calcareous, subrounded to subangular, well-sorted, and composed of quartz with 1-10% lithic grains. Colors range from light gray to olive-yellow to pale olive to light yellowish brown to pale brown to pale yellow. Upper shoreface sandstones are slightly coarser (mostly fine- to medium-grained) and in very thin to thick, tabular beds that are internally horizontal-planar-laminated or cross-stratified (tangential, low-angle, or trough-cross-laminated to very thinly bedded; foresets are up to 20 cm thick). Sand is pale yellow to light gray to pale brown to white, subrounded to subangular, well sorted, and composed of quartz with minor feldspar(?) and 1-10% lithic grains. The sandstone commonly weathers to a yellow-golden color. Oyster beds are relatively common and include a diagnostic species restricted to the lower Coniacian (*Flemingostrea elegans*; Hook, 2010). ~170 m thick.

Km **Mancos Shale (Upper Cretaceous, middle Cenomanian to lowest Conician North American Stage)** -- Fissile shale that is planar- to wavy-laminated. Strata hosts laccoliths in the southeast part of the quadrangle; emplacement of these laccoliths has folded and deformed the adjoining Mancos Shale, which is commonly metamorphosed into black to gray argillite. This undivided unit includes the lower tongue of the Mancos Shale (**Kml**, see below), the D-Cross Member of the Mancos Shale (not differentiated on this map), as well as the intervening pale yellow to white, fine-grained, shoreface sands of the Tres Hermanos Formation (also not differentiated). Unit gradational overlies the Dakota Sandstone. Age assignment is from Hook and Cobban (2012). Cross-section A-A' and well data indicate a thickness of 185-215 m.

Kml **Mancos Shale, lower tongue (Upper Cretaceous, middle Cenomanian to lower Turonian North American Stage)** -- Fissile shale that is planar- to wavy-laminated; colors range from gray to light gray to light olive gray to light greenish gray. Thickness of 40-45 m-thick was assigned to this unit on the Oscura quadrangle to the north (Koning et al., 2010).

Kd **Undifferentiated Dakota Sandstone (Upper Cretaceous, middle Cenomanian North American Stage) --** Combined unit of upper and lower Dakota Sandstone (units **Kdu**, **Kdl**, and **Kdlvf**), which are described in detail below. Not differentiated due to insufficient exposure or extensive faulting. Age assignment is from Hook and Cobban (2012). 45-55 m-thick.

Kdu **upper Dakota Sandstone (Upper Cretaceous, middle Cenomanian North American Stage) --** Intercalated light gray siltstone, very fine-grained sandstone, and light to dark gray shale with subordinate beds of fine- to medium-grained sandstone. Shale is laminated and friable. Sandstone beds are medium to thick, tabular, and internally cross-stratified (very thin beds to laminations that are trough-cross-stratified to tangential-cross-stratified; up to 20 cm-thick); also planar-laminated. Trough cross-stratification commonly indicates a northeast paleoflow direction. Sand is white, well-sorted, subrounded to subangular, and composed of quartz. Sandstone beds are well-cemented. Uppermost sandstone beds are extensively burrowed, with *ophiomorpha* burrows common. Slightly purplish brown desert varnish forms on weathered sandstone. Top contact placed at top of upper quartz arenite sandstone with *ophiomorpha* burrows, which is overlain by dark gray shale of the Mancos Formation. 25-30 m-thick

Kdl **lower Dakota Sandstone (Upper Cretaceous, middle Cenomanian North American Stage) --** Ledge-forming, quartz arenite sandstone. Beds are laminated to very thin and tangential- to trough-cross-stratified; also some planar-horizontal-beds (laminated to medium). Sand size is fine-upper to medium-upper. Sand is white, subrounded to subangular, and mostly well-sorted. Locally, beds of aforementioned sand are mixed with minor lithic grains (including chert), coarse- to very coarse-grained sand (composed largely of lithic grains), and sparse, very fine to very coarse, subrounded to rounded pebbles of quartz, chert, and quartzite. Lower contact is a scoured unconformity, and deposit locally fills paleovalleys at its base (**Kdlvf**, described below). Slightly purplish brown desert varnish forms on weathered sandstone. Approximately 20 m-thick.

Kdlvf **Lower Dakota Sandstone, basal valley-fills (Upper Cretaceous, lower(?) to middle Cenomanian North American Stage) --** Subequal mudstone and sandstone that fills paleovalleys up to ~6 m deep. The mudstone is reddish brown (2.5YR 4/3) and in medium to thick, tabular beds. Sandstone is in medium to thick beds that are internally horizontal-planar laminated to thinly bedded. The sand is white to very pale brown to yellow (2.5YR 8/1 and 10YR 7/4-6), weathering to very pale brown (10YR 7/4). Sand is fine- to medium-grained, subrounded to subangular, well sorted, and a litharenite with 5-13% lithic grains and approximately 5% feldspar. Up to 6 m thick.

Trm **Moenkopi Formation (Middle Triassic, Anisian North American Stage) --** Cross-stratified, fine- to coarse-grained sandstone (mostly fine- to medium-grained). Colors of the sand range from reddish brown to light reddish brown to pale-weak red to pinkish gray. Varying proportions of weak red to reddish brown shale, claystone, and siltstone;

these fine-grained lithologies are subordinate to the south, but may increase in abundance northwards. Sandstone is extensively cross-stratified (commonly trough- to tangential- cross-stratified and laminated to very thinly-bedded; 10-15 cm-thick foresets); minor planar-horizontal bedding and thin to medium, lenticular beds. Sandstone is subrounded to subangular, moderately to well sorted, and a lithic arenite (5-25% lithic grains, including mica, and ~5% estimated potassium feldspar). Locally, very minor (1-5%) beds of pebbly medium- to very coarse-grained sandstone (subrounded and composed of quartz with abundant chert and quartzite grains); pebbles are very fine to coarse and composed of rounded-subrounded chert and quartzite. Lower contact is a planar to scoured unconformity over the Artesia Group (scour relief of 1-3 m). Strata immediately below the overlying Dakota Sandstone may locally be bleached to a pale green and yellowish gray color. Assigned to Anton Chico Member by Lucas (1991); correlation to this member was verified in a field visit by Lucas during the spring of 2009. No fossils observed. Mostly 30-50 m-thick, but possibly as much as 70 m-thick at a location 0.5 m-thick of lower Three Rivers drainage.

PALEOZOIC STRATA

Pag **Grayburg Formation, Artesia Group (upper Permian, middle Guadalupian North American Stage) --** Very fine- to fine-grained sandstone and silty to clayey very fine- to fine-grained sandstone; subordinate siltstone and shale. Colors range from orange to red to light red to reddish brown (most to least common). Strata are generally in very thin to thick, tabular (minor irregular) beds. Reduction (bleached) spots 0.5-2 mm in diameter cover 1-15% of rock area, with higher coverage along bedding and fault planes (where they are dm-scale and irregular). Sand is subangular to rounded (mostly subrounded), well-sorted, and composed of quartz, with less than 10% possible feldspar. No fossils observed. Thick gypsum or anhydrite beds are absent to the north but increase to the south (to about 5%-10% of the unit; more common towards the top). Gypsum and anhydrite beds are generally deformed. Although definitively Artesia Group, we assign this to the Grayburg Formation because of lithologic characteristics, thickness, and the fact that higher formations of this group extend progressively shorter distances from the deepest parts of the Delaware Basin to the south (Kelley, 1971 and 1972). We did not recognize the Queen Formation of the Artesia Group because we did not note scattered large, rounded, frosted quartz grains indicative of the upper part of this formation (Tait et al., 1962). Orangish color, fine texture, quartz arenite composition, and reduction spots serve to differentiate this unit from the overlying Moenkopi Formation. Lower contact with San Andres Formation is a disconformity (see report for more discussion). Thickness is difficult to estimate based on map data because of irregular bedding attitudes where this unit is relatively well-exposed to the south. Well data at cross-section A-A' indicate a thickness of 90-110 m.

Psaf **Fourmile Draw Member of the San Andres Formation (upper Permian, Guadalupian North American Stage) --** Micritic, dark gray limestone, grayish tan to light gray dolomite, and gypsum. Beds are medium to thick and tabular. Carbonates

become more dolomitic up-section, and the proportion of gypsum beds increases up-section. Approximately 100-120 m-thick.

Psafd **Dissolution-collapsed Fourmile Draw Member of the San Andres Formation (upper Permian) --** Chaotic assemblage of limestone and fine-grained sandstone that involves the upper Fourmile Draw Member and overlying Grayburg Formations. Interpreted to be due to dissolution of gypsum beds in the Fourmile Draw Member.

Psar **Rio Bonito Member of the San Andres Formation (upper Permian, Guadalupian North American Stage) -- Use Oscura quad.**

Psah **Hondo Member of the San Andres Formation Formation (upper Permian, Guadalupian North American Stage) --** This sandstone marker bed is intercalated with limestone beds of the upper Rio Bonito Member of the San Andres Formation. In the northern quadrangle, it occurs about 10 m below the upper Rio Bonito Member contact. It is yellow, fU-mL, subangular to subrounded, well sorted, and a quartz arenite in composition. Interbedded in gray limestone. Up to 2 m thick.

SUBSURFACE STRATA DEPICTED ONLY IN CROSS-SECTION
Note: Below the Bursum Formation, depth picks of Paleozoic strata are from King and Harder (1985).

Qa **Undivided alluvium (Quaternary) --** Clayey-silty, very fine- to medium-grained sand intercalated with coarser channel-fills composed of medium- to very coarse-grained sand and pebbly-cobbly sand. This unit includes generally consists of Pleistocene alluvium (units **Qai**, **Qao3**, **Qao2**, and **Qao1)**. Holocene alluvium (e.g., **Qay**, **Qah**, and **Qam)** are minor.

QTbf **Basin-fill (Quaternary to Tertiary) --** Clayey-silty, very fine- to medium-grained sand intercalated with coarser channel-fills composed of medium- to very coarse-grained sand and pebbly-cobbly sand. Likely interbedded with relatively clean, eolian sand intervals. This undivided unit fills the Tularosa Basin. Includes the Santa Fe Group (**Tsf**) and all of the Quaternary units listed above.

Tla **Lewelling unit, axial(?) sediment (upper Oligocene to early Miocene(?)) --** Light gray, monolithic siltstone and very fine-grained sandstone likely representing floodplain facies along an inferred axial drainage (probably flowing north or south). This clastic sediment includes grains of pyroxene and minor biotite that are speculated to have been eroded off of Sierra Blanca to the east. Some of the pyroxene grains are up to 2 mm long. Sediment is arkosic near base of unit. Resistivity and gamma ray logs indicate that there are ~25% sandy channel-fills interbedded in the aforementioned, fine-grained sediment. The sandy channel-fills have a relatively high gamma-ray signature, so that increasing gamma ray signatures correspond to increasing

resistivity values and vice-versa. Unit described using geophysical well logs and cuttings of the Lewelling No. 2 well. 45 m thick, but top is likely eroded.

Tlw2b **Upper Lewelling unit, relatively fine-grained, westerly derived sediment (upper Oligocene to early Miocene(?))** -- Intercalated floodplain and channel-fill facies deposited from a drainage sourced to the west or southwest (west of the inferred axial drainage associated with unit **Tla**). Pyroxene and biotite minerals are absent to very sparse. There are subequal silty floodplain sediment versus sandy channel-fills. The floodplain sediment consists of light gray siltstone and very fine-grained sandstone. Inferred channel-fills consist of fine- to very coarse-grained sandstone containing a mix of volcaniclastic and arkosic compositions. Sand is mostly very fine- to medium-grained and locally shows evidence of cementation. The sandy channel-fills have a relatively high gamma-ray signature, so that increasing gamma ray signatures correspond to increasing resistivity values and vice-versa. Unit described using geophysical well logs and cuttings of the Lewelling No. 2 well. 45 m thick, but top is likely eroded.

Tlw2a **Upper Lewelling unit, coarser-grained, westerly derived sediment (Oligocene)** -- Westerly-southwesterly derived fluvial system, as described in **Tlw2b** but having a 50-65% vs 35-50% ratio of sandstone channel-fills versus silty floodplain sediment. Sand is brown to gray and very fine- to very coarse grained -- mostly medium- to very coarse grained. The floodplain sediment consists of light gray siltstone and very fine-grained sandstone. Inferred channel-fills consist of fine- to very coarse-grained, subangular to angular sandstone containing a mix of volcaniclastic and arkosic compositions. Volcanic grains are largely composed of quartz-poor, plagioclase-phyric andesite-dacite. Quartz is relatively abundant in the fine-grained sand fraction. Unit probably consists of amalgamated channel-fills. The sandy channel-fills have a relatively high gamma-ray signature, so that increasing gamma ray signatures correspond to increasing resistivity values and vice-versa. Unit described using geophysical well logs and cuttings of the Lewelling No. 2 well. The sandy channel-fills have a relatively high gamma-ray signature, so that increasing gamma ray signatures correspond to increasing resistivity values and vice-versa. The transition between this unit and the underlying one (Tlw1) is abrupt, so the base of this unit may possibly correspond to a disconformity. 29 m thick.

Tlw1b **Lewelling unit, westerly derived sediment (upper Eocene to Oligocene)** -- Brown to gray sandstone interpreted to have been deposited by a northeast- to east-flowing drainage(s), probably on a piedmont. Unit lacks floodplain facies, based on geophysical well logs and the paucity of mudstone and siltstone in the cuttings. Inferred channel-fills consist of fine- to very coarse-grained, subangular to angular sandstone containing a mix of volcaniclastic and arkosic compositions. Volcanic grains are largely composed of quartz-poor, plagioclase-phyric andesite-dacite. Arkosic sediment generally consists of foliated Proterozoic(?) gneisses and granitoids, as well as quartzite. Unit described using geophysical well logs and cuttings of the Lewelling No. 2 well. 595-600 m thick.

Tlw1a **Lewelling unit, cemented westerly derived sediment (upper Eocene to Oligocene) -** Brown to gray sandstone interpreted to have been deposited by a northeast- to east-flowing drainage(s), probably on a piedmont. **Similar to unit Tlw1b but more cemented, as evidenced by cemented sandstone fragments in the cuttings and by slower drilling rates.** Unit described using geophysical well logs and cuttings of the Lewelling No. 2 well. 150 m thick.

Py **Yeso Formation (lower Permian) --** Yellow and red siltstone, limestone, and gypsum. 630 m-thick.

Pa **Abo Formation (lower Permian) --** Reddish color; consists of overbank deposits of mudstone and clayey fine-grained sandstone that are intercalated with coarse channel-fills of sandstone and pebbly sandstone. Approximately 450 m-thick.

Pb **Bursum Formation (uppermost Pennsylvanian(?) to lowermost Permian) --** Marine strata (shales and limestone beds) interbedded with fluvial sediment of overbank reddish shale together with channel-fill sandstone and pebbly sandstone. Approximately 500 m-thick.

IPh **Holder Formation (upper Pennsylvanian) --** Limestone, gray and red calcareous shale, sandstone, and conglomerate (from Pray, 1961, fig. 3). 120 m-thick.

IPb + IPg **Beeman and Gobbler Formations, undifferentiated (lower to upper Pennsylvanian) --** Interbedded limestone, shale, and sandstone (from Pray, 1961, fig. 3). 400-430 m-thick.

MDS **Undifferentiated strata of Mississippian, Devonian and Silurian age --** Unit may include Lake Valley, Percha, and Fusselman formations, among others discussed in Pray (1961) and listed in King and Harder, 1985, fig. 21). 64-85 m-thick.

O **Undifferentiated strata of Ordivician age --** Unit includes Montoya and El Paso Formations (King and Harder, 1985, fig. 21). 120-150 m-thick.

pC **Precambrian rocks --** Rhyolite or granite, reddish and composed largely of quartz and feldspar (from mud log of the Lewelling #2 well).

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The map has not been reviewed according to New Mexico Bureau of Mines and Mineral Resources standards. Revision of the map is likely because of the on-going nature of work in the region. The contents of the report and map should not be considered final and complete until reviewed and published by the New Mexico Bureau of Mines and Mineral Resources. 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 the State of New Mexico, or the U.S. Government. Cross-sections are constructed based upon the interpretations of the authors made from geologic mapping, and available geophysical (regional gravity and aeromagnetic surveys), and subsurface (drillhole) data.

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