GEOLOGIC MAP OF THE SKUTE STONE ARROYO,

7.5-MINUTE QUADRANGLE, SIERRA COUNTY, NEW MEXICO

Geology by

Daniel Koning, Andy Jochems, and Colin Cikoski

New Mexico Bureau of Geology and Mineral Resources

New Mexico Institute of Mining and Technology

801 Leroy Place

Socorro, NM 87801

Second of two-year STATEMAP quadrangle

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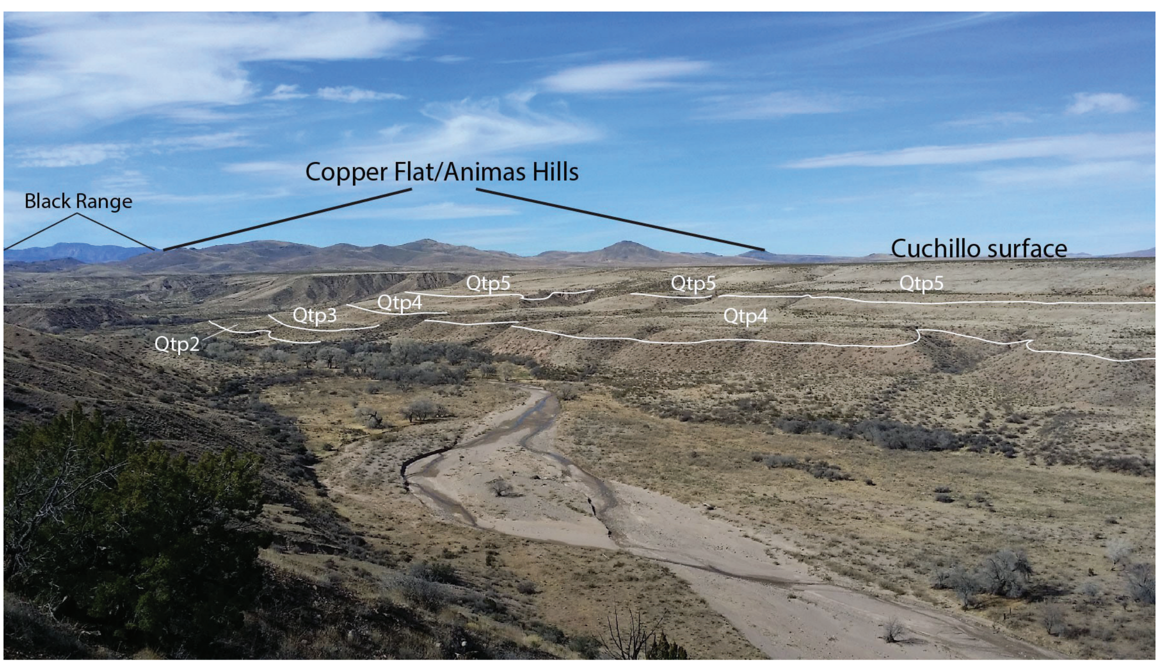

View to the northwest along Percha Creek; photo taken ~1 km downstream of Clark Ranch. Middle to late Pleistocene terraces are shown (Qtp2 through Qtp5) as well as prominent physiographic features. Copper Flat (left background) is the source of distinctive Cretaceous andesite clasts that increase in abundance up-section through the middle Santa Fe Group and Palomas Formation. In the foreground, surface water flow in Percha Creek is observed infiltrating into the subsurface.

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EXECUTIVE SUMMARY

The Skute Stone Arroyo quadrangle lies 25 km southwest of the town of Truth of Consequences, New Mexico, in the west-central part of the Palomas Basin. This basin is an east-tilted half-graben that formed during tectonic extension related to the Rio Grande rift. The western end of the hanging wall ramp has been sufficiently tilted and uplifted to form the Animas block and eastern Black Range. Rivers draining these uplifts flowed east across this quadrangle and deposited sand, gravel, silt, and clay on a piedmont between 27 and 0.8 million years ago. This package of clastic sediment is referred to as the Santa Fe Group. Over the past 0.8 million years, these rivers have undergone marked incision, resulting in prominent canyons that include Arroyo Seco, Las Animas Creek, Percha Creek, and Trujillo Canyon. Gravelly terraces, generally 1-3 m thick, flank the margins of these canyons and can generally be subdivided into 5 geomorphic levels. The floors of the canyons are underlain by Holocene (possibly minor latest Pleistocene) deposits of sand, gravel, and silty to clayey sand. This valley floor sediment interfingers with, or is overlain by, coarser alluvial fans deposited at the mouths of steeper side canyons.

Our geologic mapping has yielded several exciting discoveries relevant to Palomas Basin tectonic development and stratigraphy. Santa Fe Group stratal dips progressively steepen with increasing age. Plotting stratal dips vs. age demonstrates a relatively steady tilt rate during Miocene-Pleistocene rifting, with possibly slower rates between 4 and 2.5 Ma. Northwest- to north-striking normal faults have developed on this quadrangle during rift-related extension, but they have produced relatively minor offset (<15 m) in post-5 Ma strata.

Our mapping delineates the base of the Palomas Formation. This relatively coarse, 1-300 m thick unit occupies the upper Santa Fe Group and has received much attention from earlier geologic and hydrologic studies. The base overlies redder and slightly finer strata correlative to the Rincon Valley Formation. This contact is relatively conformable and gradational over much of the quadrangle, but westward it becomes unconformable. Where it is conformable, dark gray basalt clasts—similar to 5.2–4.5 Ma basalts upstream to west—appear several meters above the base, and lower Palomas strata gradually become coarser and less red up-section. In the western quadrangle, ~4.5 Ma basalt flows are interbedded in lower Palomas Formation strata.

Strata predating the Palomas Formation becomes progressively less cemented, redder, and finer-grained eastward (up-section). Stratigraphically lower, coarser strata correlates to the Hayner Ranch Formation to the southeast, which are gradationally overlain by the aforementioned Rincon Valley Formation. The latter grades laterally eastward from a gravelly sand to a clay deposited on a playa floor, with playa facies present only in the subsurface in the eastern part of the quadrangle.

The Palomas Formation contains three general sediment packages. The lower package is coarse-grained and pinkish gray to light brown, the middle is relatively fine-grained and very pale brown to pink, and the upper package coarsens and becomes redder up-section. These packages thin westwards, with most of them pinching out in the same general longitude (107° 26.5-27.8' W). Near the southern quadrangle boundary, strongly developed calcic soils at the tops of Palomas Formation units are increasingly common westward. The uppermost 1-50 m of the upper unit, which has >65% coarse channel fills, extends 3-4 km west of the aforementioned pinch-out zone and has strong soil development in its upper part (where stacked paleosols are as much as 6 m thick). The upper unit, although coarse, contains trace-20% clay in the matrix and generally lies above groundwater. The lower coarse unit, however, generally has ≤1% clay-silt and projects into the saturated zone. Its texture and subsurface projection suggest that the lower coarse unit has a high likelihood of being a productive aquifer.

GEOGRAPHIC SETTING AND CLIMATE

The Skute Stone Arroyo quadrangle is located in the west-central part of the Palomas Basin, about 25 km southwest of the town of Truth or Consequences (Figure 1). The western border of the quadrangle lies just 3 km east of the copper porphyry deposit known as Copper Flat, which hosted the mineral lodes (primarily gold and copper) of the Hillsboro Mining District. We informally refer to the high hills immediately surrounding Copper Flat as the "Copper Flat hills" (Figure 1).

The region sports sparse vegetation characteristic of the northern Chihuahuan Desert. Common shrubs are creosote and mesquite. Sparse juniper trees grow on north-facing slopes. Riparian vegetation, including cottonwood trees and Arizona sycamore, are limited to areas of shallow groundwater in canyon bottoms, particularly western Percha Creek and Las Animas Creek (sycamore trees being only found in the latter).

The climate of the Skute Stone Arroyo quadrangle is remarkably arid. In the summer (June through August), average temperature highs are 34-36°C (93-96°F) and average lows are 17-19°C (63-67°F). In the winter (December through February), average temperature highs are 13-17°C (56-63°F) and average temperature lows are -3-0°C (27-32°F). Average yearly precipitation is 25.4 cm (10 inches), of which about a third accumulates as snowfall. Most precipitation falls in the months of July through September (the summer monsoon), with the months of February through May being particularly dry. All climate data listed above are averaged monthly values using the years of 1951 through 2005 and taken from the Western Regional Climate Center (2015).

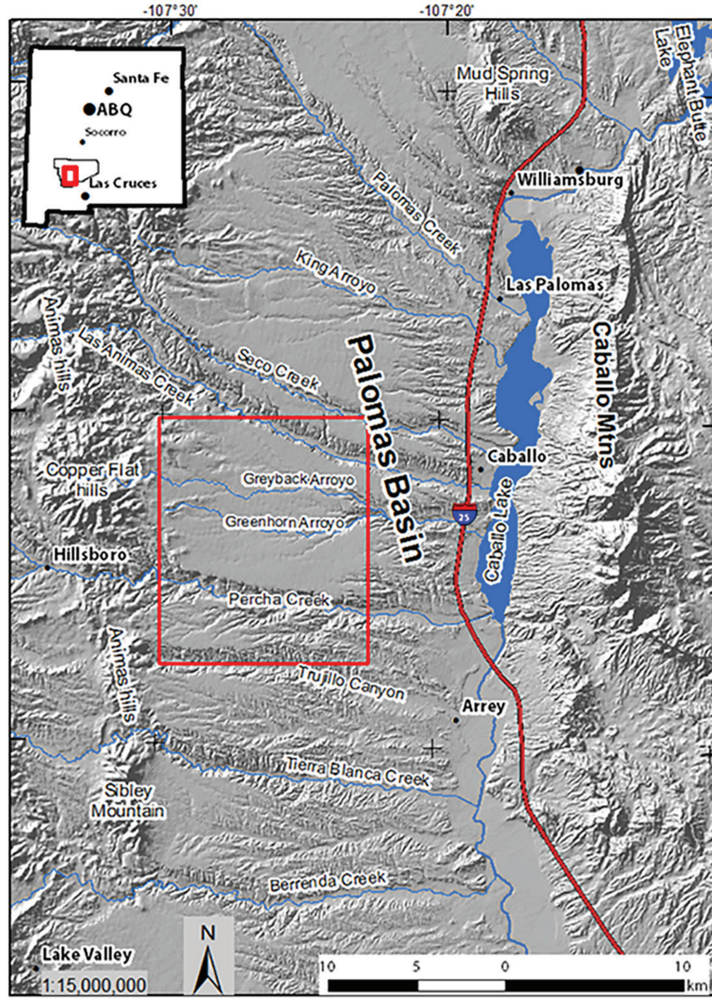


Figure 1—Shaded relief map of the central and southern parts of the Palomas Basin showing towns and topographic features. The red rectangle denotes location of the Skute Stone Arroyo quadrangle. On the statewide inset in the upper-left hand corner, the map location (thick red line) within Sierra County (thin black line) is shown. ABQ=Albuquerque.

The quadrangle lies a few kilometers east of the Animas uplift (also called the Animas block) and exhibits moderate topographic relief (Figures 1–3). The highest elevation of the quadrangle (5500 ft) coincides with unnamed hills in the northwestern corner. The lowest elevation (4400 ft) is located at the bottom of Percha Creek along the southern part of the eastern quadrangle border. The Cuchillo surface, a prominent geomorphic surface that spans most of the Palomas Basin (McCraw and Love, 2012), extends across the Skute Stone Arroyo quadrangle (Figure 2). This surface has witnessed various degrees of erosion. Where little eroded, the Cuchillo surface is relatively planar and dips 0.7-0.8° eastward. In the central part of the quadrangle, the surface is moderately eroded by Greenhorn and Greyback Arroyos. Extensive erosion has resulted in badland topography in the southeastern part of the quadrangle (Figures 1–3).

The quadrangle contains several large, east- to southest-flowing drainages (Figures 2–3) that have incised 50-90 m (160-300 ft) into the Cuchillo surface. Arroyo Seco crosses the extreme northeast corner of the quadrangle and, befitting of its name, is dry. Paralleling Arroyo Seco 2.5 km (1.6 mi) to the south-southwest, Animas Creek has a total watershed area of 33856 hectares (83,659 acres) (Jones et al., 2013). In the Skute Stone Arroyo quadrangle, this drainage is ephemeral except for the eastern 3 km (1.9 mi) reach (below 4500 ft elevation). Both Arroyo Seco and Animas Creek flow north of the Copper Flat hills and head in the southern Black Range. Draining an area of 31298 hectares (77,339 acres) (Jones et al., 2013), Percha Creek also heads in the southern Black Range and flows past Kingston and Hillsboro, around the south side of the Copper Flat hills, and then goes easterly in the southern Skute Stone Arroyo quadrangle. The southern border of the quadrangle extends across the northern slopes of Trujillo

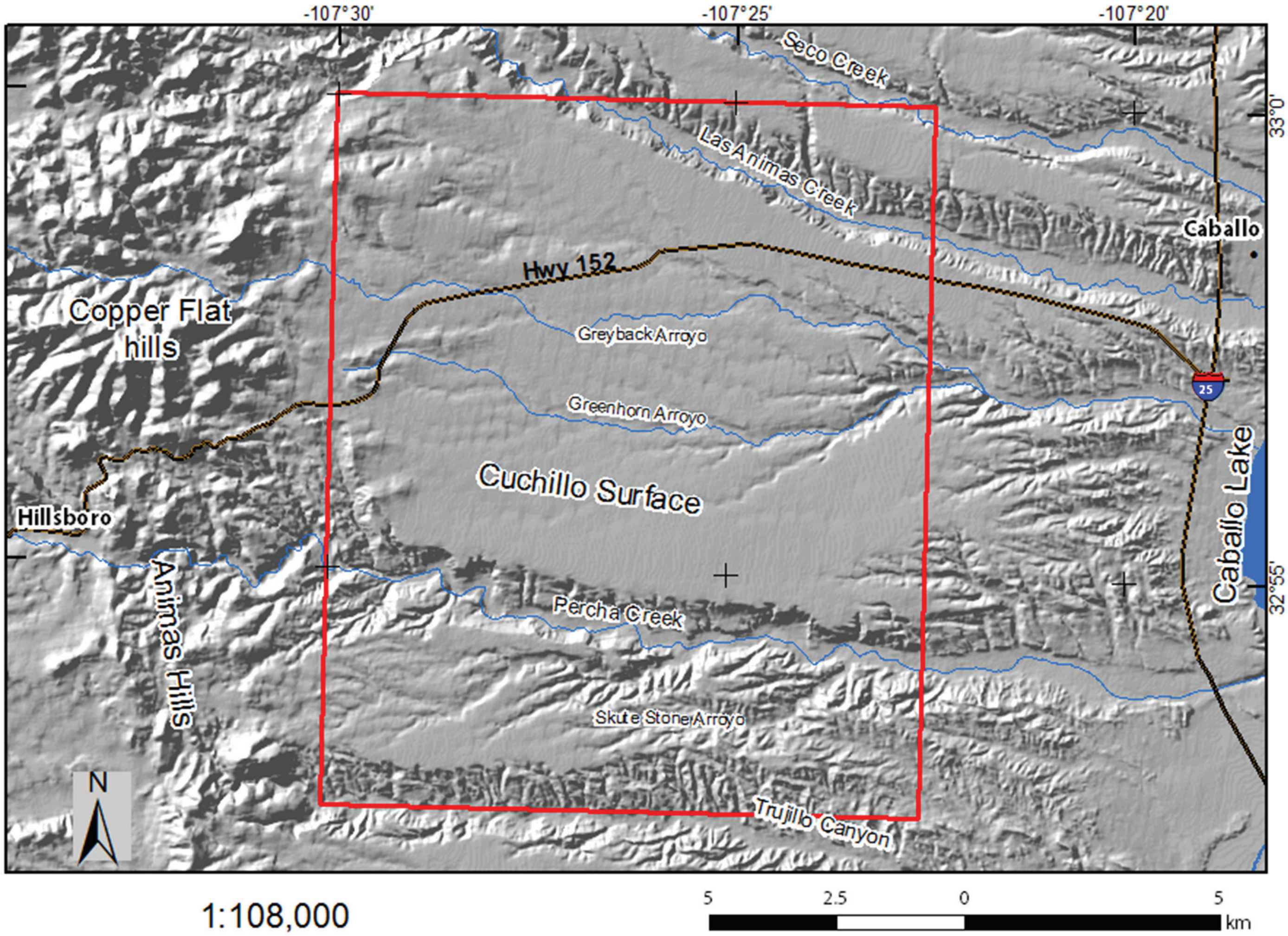


Figure 2—Shaded relief map showing physiographic features of the Skute Stone Arroyo quadrangle. Red rectangle shows approximate quadrangle boundary. The gently sloping Cuchillo surface is prevalent throughout this part of the Palomas Basin and marks the constructional top of the Palomas Formation, except near the western basin margin where it is erosional in nature.

Canyon. In Percha Creek and Trujillo Canyon, minor stream discharge occurs most of the year near the western quadrangle boundary.

Three drainages are relatively small, heading within the quadrangle or extending 3-7 km (1.9-4.3 mi) west of the western quadrangle border.(Figure 2) The head of Greyback Arroyo is found in the Copper Flat area, from where it flows easterly in a shallow arroyo that progressively deepens eastward to 40 m depth (120 ft). Just beyond the eastern border of the quadrangle, Greyback Arroyo merges with a southern tributary called Greenhorn Arroyo, which flows westward across the central part of the quadrangle. Like Greyback Arroyo, Greenhorn Arroyo deepens progressively eastward to 40 m depth (120 ft). Combined, Greyback and Greenhorn Arroyos have a combined drainge area of 14099 hectares (34,840 acres) (Jones et al., 2013). Skute Stone Arroyo, the namesake of the quadrangle, is a large southern tributary to Percha Creek; it is incised as much as 70 m (220 ft) near the eastern quadrangle boundary.

TECTONIC SETTING

The Palomas Basin corresponds with a north-trending, east-tilted half-graben (Lozinsky, 1987; Adams and Keller, 1994) that is ~100 km (60 mi) long and ~30 km (19 mi) wide. It is one of many en echelon basins associated with the Rio Grande rift, which has been a relatively active tectonic feature from the late Oligocene to present (Chapin and Cather, 1994; Machette et al., 1998). The master faults of the half-graben generally lie at the western foot of the Caballo Mountains (a footwall uplift) and strike north, but near Truth or Consequences the fault system bends to the northwest and wraps around the Mud Springs Hills (Figure 3). The master fault system includes the Mud Springs,

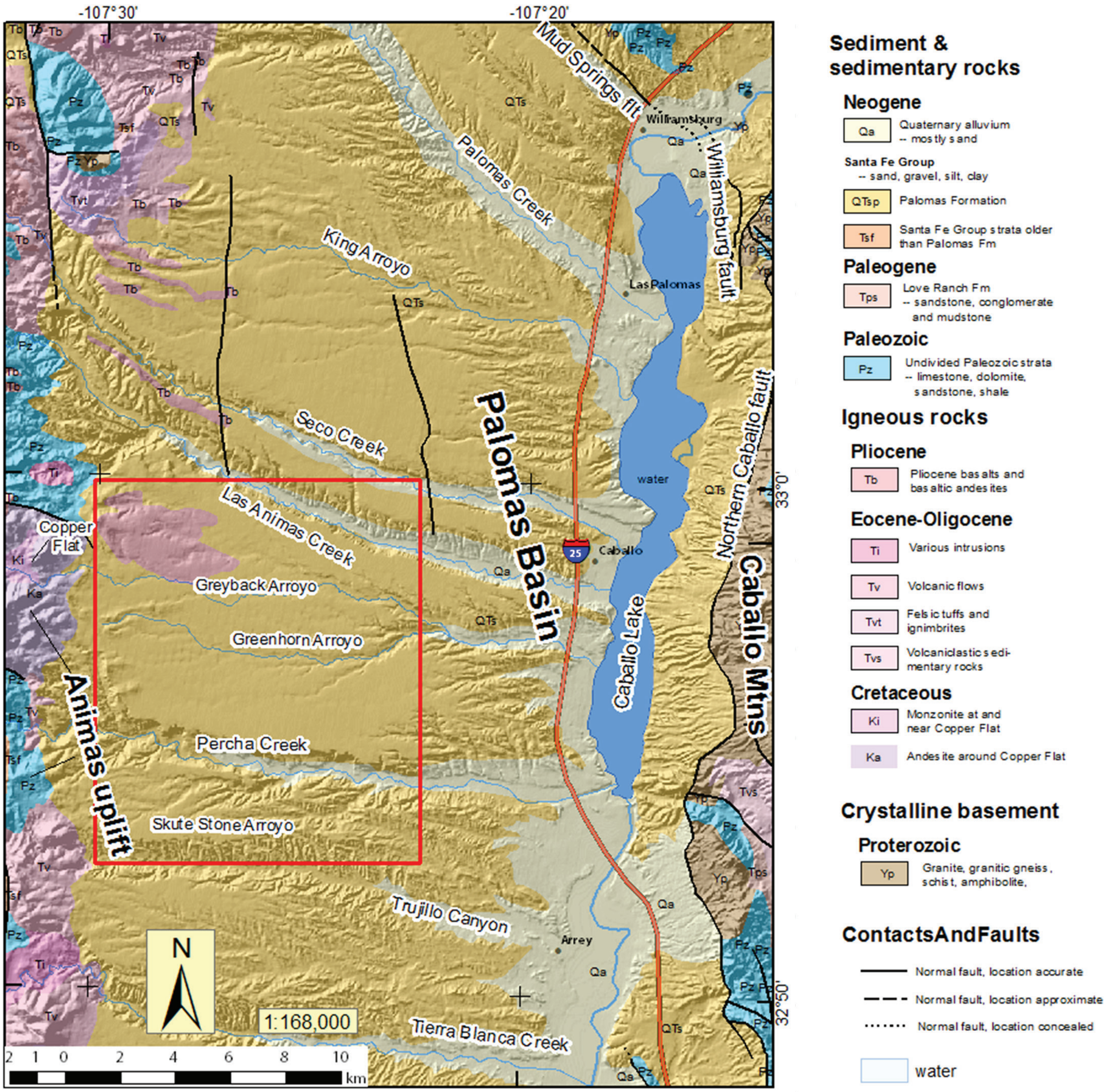


Figure 3—Geologic map of Palomas Basin (from NM Bureau of Geology, 2003).

Williamsburg, and Northern Caballo faults (sensu Seager and Mack, 2003) and the Red Hills fault (Seager and Mack, 2003). Note that the Red Hills fault lies south of the area shown in Figure 3. The Williamsburg, Northern Caballo, and Red Hills faults are interpreted to have experienced Holocene movement (Foley et al., 1988; Seager and Mack, 2003). Several middle-late Quaternary faults offset the Cuchillo surface in the interior of the Palomas basin, forming scarps <5 m tall (less commonly 5-10 m tall) (Machette et al., 1998). These north-striking faults (010° ± 25°) have experienced both west-down and east-down normal displacement (Machette et al., 1998).

Coinciding with the western end of the distal hanging wall ramp of the Palomas half-graben, the Animas Hills were progressively uplifted during eastward tilting of this tectonic feature and have been referred to as the Animas uplift by Seager et al. (1984) (Figure 3). Bounded on its west side by the Berrenda fault, this uplift exhibits a relatively complete section of Cambrian through Pennsylvanian strata. These sedimentary rocks are unconformably overlain by 300 m of Creatceous, Eocene, and early Oligocene volcanic strata (Jochems et al., 2014; Hedlund, 1977)).

PREVIOUS WORK

Several publications present regional geologic maps or cross-sections relevant to the Skute Stone Arroyo quadrangle, one of which focused on gold placer deposits (Segerstrom and Antweiler, 1975). Early geologic mapping efforts were conducted by Kuellmer (1956), Dane and Bachman (1961), and Hedlund (1977). The Skute Stone Arroyo quadrangle was included in the geologic compilation of Seager et al. (1982). A diagrammatic east-west cross-section passing near the middle of the quadrangle was presented in Seager et al. (1984). Mapping by Jochems et al. (2014) in the eastern Hillsboro quadrangle was utilized in the construction of Cross-section A-A'. Quaternary fault maps of the Palomas Basin were prepared by Machette (1987) and Machette et al. (1998). Hawley and Kennedy (2004) depict a 1:100,000 scale geologic map that encompasses the southern half of the Skute Stone Arroyo quadrangle, a cross-section through Trujillo Canyon, as well as a structural contour map of the base of the Santa Fe Group. Useful geologic mapping peripheral to the Skute Stone Arroyo quadrangle include Harrison et al. (1993), Jochems and Koning (2015), and Seager and Mack (2005).

Numerous hydrogeologic studies have been conducted in the area since the 1950s. Four regional geohydrologic studies are noteworthy and contain tabulations of useful well data (Conover, 1954; Murray, 1959; Davies and Spiegel, 1967; Wilson et al., 1981). Wilson et al. (1981) mentions the presence of 900-1000 ft-thick coarse material in Sections 31 and 32 (T15S, R5W), which appear to lie between two geomorphic lineaments. Davie and Spiegel (1967) conducted an important geohydrology study of the middle to lower parts of Animas Creek . Appendix A lists several groundwater-related environmental investigations related to a potential renewal of mining at Copper Flat. One particularly useful consultant report for the Skute Stone Arroyo quadrangle is Jones et al. (2013), which presents a groundwater model, well logs, well construction diagrams, a geologic map, and a cross-section.

Late Cenozoic stratigraphic investigations of the Palomas Basin provide a critical context in which to compare Santa Fe Group basin-fill stratigraphy on this quadrangle. A quintessential work on the Caballo Mountains and adjoining Palomas Basin is Kelley and Silver (1952). A few decades later, detailed mapping in the southernmost Palomas Basin and environs provided critical details on Santa Fe Group stratigraphy (Hawley et al., 1969; Seager et al., 1971; Seager and Hawley, 1973; Seager and Clemons, 1975; Clemons, 1979; Seager, 1995; Seager and Mack, 1991). Stratigraphic and sedimentologic work that includes the western piedmont facies of the Palomas Formation (germane to the Skute Stone Arroyo quadrangle) includes Lozinsky and Hawley (1986a,b), Grunwald (1990), Foster (2009), Seager and Mack (2003), and Mack et al. (2000, 2002, 2012).

MAPPING METHODS

The procedures used to produce this geologic map can be divided into five phases. In contrast to a decade ago, these methods heavily employ digital methods and the input of map data directly into ARC geodatabases by the field mappers. The first phase entails identifying units and contacts with aerial photography coupled with field checks. Stereogrammetry software recently acquired by the N.M. Bureau of Geology (i.e., Stereo Analyst for ARCGIS 10.1, an ERDAS extension, version 11.0.6) results in relatively accurate placement of geologic contacts directly into the ARC geodatabase. Then, specific areas were identified for detailed field mapping based on degree of exposure, uncertainty in aerial photograph interpretations, or problematic geologic relations. The second stage consists of several weeks of detailed field mapping. The third stage involves updating the geologic line work from field observations and entering point data into the ARC geodatabase. Simplifying the map for the purposes of 1:24,000 scale presentation comprises the fourth stage. The fifth stage involves map production and layout. Shortened descriptions are presented in the map layout, with detailed versions of the descriptions given in Appendix B.

Surface characteristics aid in mapping Holocene and middle-late Pleistocene units. Older deposits generally have older surfaces, so surface processes dependent on age -- such as desert pavement development, clast varnishing, calcium carbonate accumulation, and eradication of original bar-and-swale topography -- can be used to differentiate terrace, alluvial fan, and valley floor deposits. Locally, erosion may create a young surface on top of an older deposit, so care must be exercise in using surface characteristics to map Quaternary deposits.

STRATIGRAPHY

The Skute Stone Arroyo quadrangle is underlain primarily by sediments of the Santa Fe Group, with minor basalt flows and dikes near the quadrangle's western boundary. As proposed by Spiegel and Baldwin (1963), the Santa Fe Group comprises the predominately clastic sediment, together with interbedded volcanic rocks, that fills the Rio Grande rift. The Santa Fe Group can be readily subdivided into two packages on this quadrangle. On top lies 1-300 m of coarse, weakly cemented sediment that contains sparse, dark gray basaltic detritus; this coarser interval correlates to the Palomas Formation of Lozinsky and Hawley (1986a,b). Beneath lies oranger sediment that progressively becomes more cemented down-section. These strata correlate to the Rincon Valley and Hayner Ranch Formations proposed by Seager et al. (1971), but are grouped below as "strata underlying the Palomas Formation" or "pre-Palomas Formation strata." Detailed sedimentologic descriptions for all units are found in Appendix B.

Santa Fe Group strata underlying the Palomas Formation

Beneath the Palomas Formation lies sandy conglomerate that grades upward into sandstone and pebbly sandstone. The degree of cementation increases down-section. These strata were deposited on a piedmont slope by east- to southeast-flowing streams, as shown by paleocurrents plotted on the geologic map. The sand fraction is dominated by volcanic grains (especially in the medium to very coarse sand fraction) that tend to be subrounded to subangular, and poorly to moderately sorted.

Figure 4—Photograph of the lower cemented unit in Percha Creek (unit Tslc). Tslc is composed of sandy conglomerate and pebbly sandstone that are strongly cemented, primarily by silica. In this location, strata dip 5-6 degrees to the east.

Lower pre-Palomas Formation strata consists of well-cemented sandy conglomerate. In western Percha Creek, the lower ~300 m (unit Tslc) is particularly coarse and well-cemented, primarily by silica (although some beds feature crystalline calcite). The strong degree of cementation results in prominent ledges, cliffs, and relatively narrow gorges (Figure 4). Beds are tabular to lenticular to cross-stratified. The 50-60 m of sediment overlying Tslc in Percha Creek (unit Tsm) is still mostly a sandy conglomerate to conglomeratic sandstone and relatively well-cemented. However, unit Tsm contains subordinate sandy siltstone beds, the gravel is less cobbly, and the cement consists of a mix of silica and calcium carbonate. The lower proportion of silica (compared to calcium carbonate) cement in Tsm creates outcrops that are not as resistant to weathering as the underlying Tslc unit (Figure 5). The gravel composition of these two units is depicted in Table 1. Clast count data are provided in Appendix C.

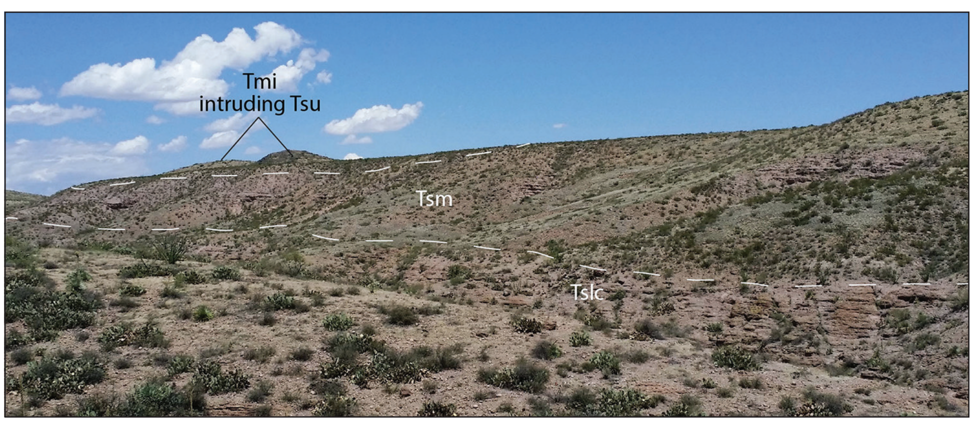


Figure 5—Photograph of units Tsm and Tslc in lower Wicks Gulch, a northern tributary to Percha Creek near the western quadrangle border. View is to the north. Unit Tsm is not as strongly cemented as unit Tslc and contains subordinate sandy siltstone beds, finer gravel, and cement consisting of a mix of silica and calcium carbonate. Consequently, unit Tsm tends to form less prominent cliffs and ledges than Tslc. Knobs at the top of the ridge are mafic intrusions (unit Tmi).

In Trujillo Canyon, well-cemented strata correlative to Tslc and Tsm are combined into unit Tsml, which is 550-1100 m thick. Here, well-cemented sandy conglomerate near the western boundary of the quadrangle grades westward (up-section) into conglomeratic sandstone exhibiting smaller clast sizes. The cement is a mixture of silica and calcium carbonate. Very thin to medium, lenticular beds characterize most of the sandy conglomerate (Figure 6), whose gravel fraction consists of pebbles, 10-35% cobbles, and 1-5% boulders. In contrast to the Percha Creek area, rhyolite clasts are more abundant in Trujillo Canyon exposures. Moving eastward (up-section), the unit becomes less gravelly and cross-stratification is more common. The sand fraction is mostly medium- to very coarse-grained. The amount of clay in the matrix is <1% except below the upper contact, where it is estimated to be 1-3%. At a distance of ~0.4 km from the western quadrangle border, we noted conspicuous strata consisting of thin to thick, tabular beds that are internally massive, matrix-supported, and have minor clay-silt mixed with very fine to very coarse sand (Figure 7). These are interpreted as debris flows. Most of the unit, however, is interpreted to have been deposited by predominately stream-flow depositional processes, consistent with sandy conglomerate beds characterized by clast-supported, imbricated gravel. Paleosols are very sparse in the unit and characterized by 10-30 cm-thick argillic horizons (>30% ped coverage by distinct clay films). The lack of paleosol preservation indicates high sedimentation rates or dynamic stream behavior that inhibited formation of stable geomorphic surfaces. This unit, as well as units Tslc and Tsm, are mostly correlative to the Hayner Ranch Formation proposed by Seager et al. (1971). We await formal assignment of Hayner Ranch Formation to these units until mapping is completed between this quadrangle and the Hatch area.

Table 1—Typical clast composition of Santa Fe units in Skute Stone Arroyo quadrangle (in %)

Unit	Basalt	Cretaceous andesites	Rhyolite (mostly crystal-poor)	Basaltic andesite	Tuff	Dacite–andesite	Paleozoic rocks
QTpuc	0.5-4	2-5	~50	5-7	1-7	20-40	0.5-3
QTpu	0.5-2	1-5	25-50	5-10	5-10	25-40	1-5
QTput**	1-10	1-10		≤40	≤50		1-10
QTpm	1-3	2-3	40-50	10-15	10-20	20-35	0-1
QTpl	Trace to 2	2-5	40-50	3-5	5-10	30-40	1-5
QTplt	Trace to 1	1-7	30-50	5-10	7-25	25-40	1-8
Tsu	1-3% red. brown	0-3, increasing up-section	10-50, more to north	10-15	5-25	15-35	Trace-5, only near top
Tsml	trace		~50	10-15	5-30	10-35	
Tsm			5-10	10-25	10-35	30-40	
Tslc			10-15	20-45	10-20	5-10	≤5 (chert)

*Tsml is for strata south of Percha Creek; Tsm and Tslc are in Percha Creek.
** Data is for Percha Creek only

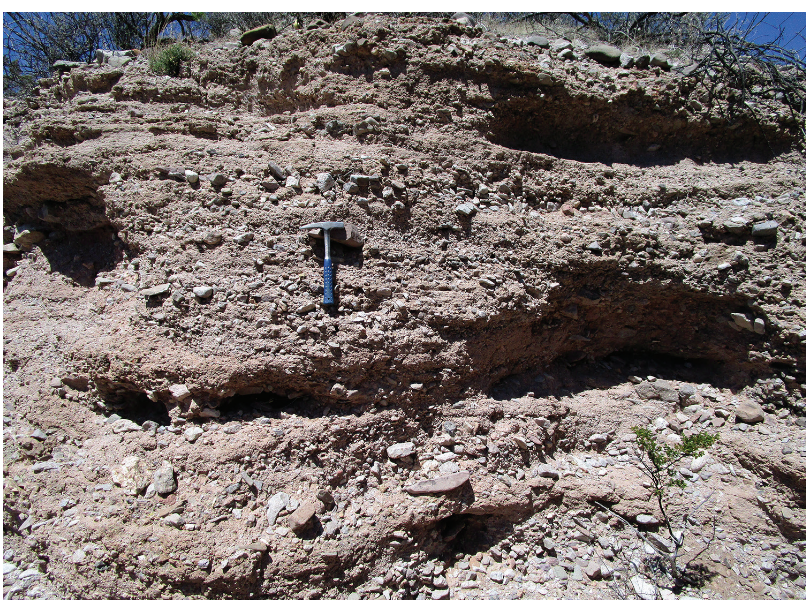


Figure 6—Photograph of upper Tsml strata in Trujillo Canyon. Note the lenticular gravel beds and high degree of cementation, which is characteristic of this unit. Rock hammer for scale.

Figure 7—Matrix-supported debris flow deposit exposed in western Trujillo Creek, unit Tsml. Pencil for scale in the lower left hand corner of the photograph.

The upper unit of pre-Palomas formation strata (Tsu) is markedly redder and finer than underlying strata (i.e., units Tsml, Tsm, Tslc), with average and median clast sizes also being smaller (Appendix C). Most of this unit consists of weakly to moderately cemented pebbly sand interbedded with minor sandy pebbles; only ~10-15% of the unit is relatively coarse (with about subequal sandy gravel and pebbly sand) (Figure 8). Pebbly sand beds are laminated to thin and tabular. Clast- to matrix-supported sandy gravel beds are very thin to medium and lenticular (minor tabular forms). Cross-stratification is relatively minor (10-15% of beds). Pebbles dominate the gravel fraction, with only 1-15% cobbles and trace to 1% boulders. As much as 1-3% basalt clasts are found in the gravel fraction; but compared to those in the Palomas Formation they are less dark, being mostly reddish brown in color. We believe these particular basalt clasts are derived from a different volcanic flow completely removed by later erosion. The sand fraction is mostly medium- to very coarse-grained. Compared to underlying strata, this unit has more clay-dominated fines in the matrix (1-5%) that impart a reddish color. Clay and calcium carbonate in the matrix impart a weak cementation, with 1-15% zones of moderate to strong cementation created by calcium carbonate. This unit is notably finer than underlying strata and is correlated to fine-grained strata in the lower part of the Percha Creek well (712-1000 ft depths), illustrated in the lower part of Figure 9 and described in Appendix D. The contact between Tsu and underlying strata is gradational over 2-30 m; this transition is locally mapped as a separate unit (Tsut). Unit Tsu is very likely correlative to the Rincon Valley Formation proposed by Seager et al. (1971), but formal assignment is pending until the completion of mapping between the exposures on this quadrangle and those in the southern Palomas basin (depicted in Seager et al., 1982).

Figure 8—Photograph illustrating the reddish Tsu unit in Trujillo Canyon. This unit is mostly pebbly sand with minor sandy pebble interbeds that are generally less than 30 cm thick.

Palomas Formation

The relatively coarse, upper strata of the Santa Fe Group has been formally designated as the Palomas Formation (Lozinsky and Hawley, 1986a,b). Stratigraphic sections measured by Grunwald (1990) along Animas Creek demonstrated that the Palomas Formation coarsens up-section. This formation was deposited on a piedmont slope by eastward flowing streams, consistent with paleocurrent data shown on the map.

On this quadrangle, the lower Palomas Formation exhibits pinkish gray to light brown colors and manifests a coarse texture, which contrasts with the underlying redder, relatively fine-grained Tsu unit. In most of the quadrangle the contact between the two is gradational.over 10–60 m We mapped this transitional zone as a separate unit (QTplt).

The transitional zone in the lowermost Palomas Formation (QTplt) is 1-60 m thick, (mostly 10–60 m) reddish, and composed of pebbly sandstone and subordinate sandy gravel. The gravel fraction contains trace to 1% dark gray, vesicular basalt clasts. Gravel are comprised of pebbles, 5-30% cobbles, and 0-3% boulders (coarsening to the west). In Trujillo Canyon, the top contact of the western extent of the transitional zone coincides with a well-developed calcic soil (1-2 m thick, stage III+ morphology). Near the western pinch-out of the transitional unit, this upper zone of strongly developed calcic soils thickens to several meters and is interpreted as a cumulic soil(s). In the Percha Creek well, this unit is correlated

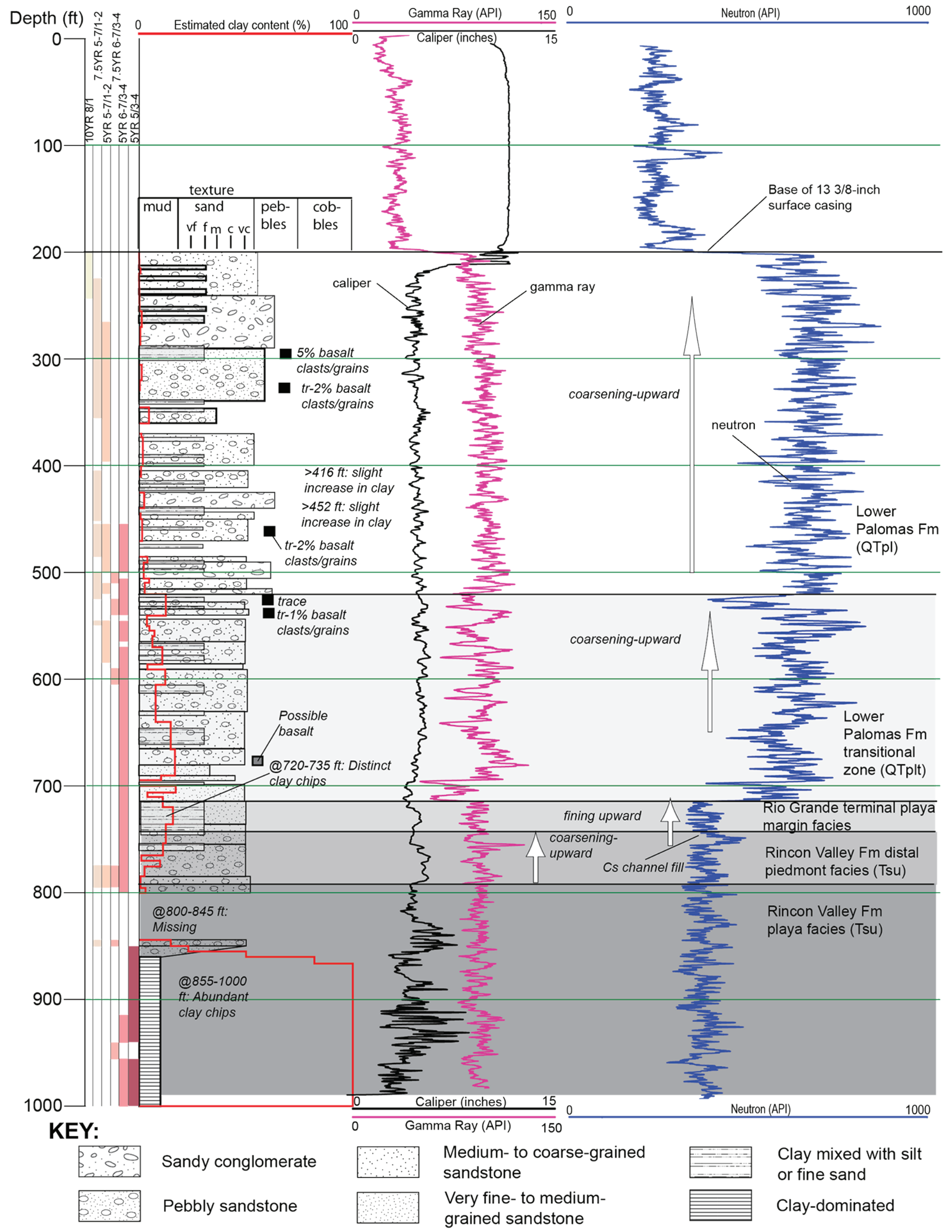


Figure 9—Illustration of lithologic and geophysical data (i.e., caliper, gamma ray, and neutron logs) from the Percha Creek well (James Witcher, unpublished data). Complete lithologic descriptions are found in Appendix D and geophysical logs are presented in Appendix E. Color of cuttings is depicted by the colored, vertical rectangles at the extreme left of the figure. Graphic column of lithology to right of the color column is from cuttings descriptions, but the small, shaded rectangles within this graphic column represent clayey intervals interpreted from the geophysical logs. Interpreted lithologic unit is labeled on the extreme right.

to a 192 ft-thick interval (520-712 ft depth) of pebbly sand with subordinate interbeds of sandy to gravelly clay or silt (Figure 9; Appendices D and E).

The base of the transitional zone is placed at a color and texture change (Figure 10). Below the contact, reddish yellow to yellowish red (5YR 4-6/6) colors dominate and the sediment consists of slightly clayey, pebbly sand with minor interbeds of sandy pebble beds; cobbles are very sparse (<1%). Above the contact, light reddish brown to light brown (5-7.5YR 6/3-4) colors dominate, there are 5-30% cobbles, and there are more sandy pebble beds. The lowest occurrence of dark gray basalt clasts lie several meters above the eastern exposures of this contact in Trujillo Canyon and Percha Creek. The base of the transitional zone is relatively sharp and planar. No paleosols are preserved, except near the western pinch-out of the unit (i.e. west of UTM Easting 269550 m E, NAD83, zone 13). In this pinch-out zone, the base coincides with a 2 m thick, stage III+ calcium carbonate horizon and thus is clearly disconformable in that location.

Figure 10—Photograph illustrating the base of the Palomas Formation in Trujillo Canyon. Arrows point to the contact between units QTplt (top) and Tsu (bottom). Ruler is 15 cm long.

We differentiate five units in the Palomas Formation above the lower transitional zone that are largely arranged in a layer-cake fashion. Except for the uppermost unit (QTpuc), these units pinch out to the west. The lowest unit is relatively coarse and tan to gray (QTpl), while the middle unit is finer-grained and tan-colored (QTpm). Overlying another transitional interval (QTput), the upper unit (QTpu) is relatively red and coarsens upward into gravel-dominated strata (QTpuc). All these units coarsen to the west, transitioning from the distal or medial piedmont subfacies to the proximal piedmont subfacies (as defined by Lozinsky and Hawley, 1986a,b) -- with the lateral coarsening best illustrated in the upper units. Clast compositions are listed in Table 1 and clast count data are given in Appendix C. Except for the middle unit, the sand fraction is mostly medium- to very coarse-grained and dominated by subrounded volcanic grains.

The lowest unit (QTpl) is relatively coarse-grained, 1-155 m thick, and lacks significant fines in the matrix (≤1% silt-clay) (Figure 11). It consists of pinkish gray to light brownish gray to light brown, sandy gravel and pebbly sand channel-fills interbedded with minor silt and fine sand beds. The sandy gravel exhibits very thin to medium beds that are tabular to lenticular. Locally, the coarse channel fills display lateral accretion sets up to 100 cm thick. The pebbly sand is typically in laminated to very thin, horizontal-planar beds or cross-stratified (<30 cm thick, typically planar foresets). The gravel fraction is comprised of pebbles, 5-40% cobbles, and 0-15% boulders that are mainly clast-supported, consistent with predominately stream-flow deposition (compared to debris flows). In Trujillo Canyon, this unit has a distinctive, well-developed calcic soil in its upper 1-12 m (stage III to V carbonate morphology,

Figure 11—Sandy gravel of the lowest unit of the Palomas Formation (unit QTpl) in Trujillo Canyon. This unit lacks fines in the sand and gravel matrix (≤1% silt-clay). The paucity of fines and the unit's coarse texture suggests it may be a productive aquifer where saturated in the eastern part of the quadrangle. Map board for scale.

mostly III+), increasing in thickness to the west.

Figure 12—Exposure of strata equivalent to the middle unit of QTm near the central part of the southern quadrangle border. This unit consists predominately of silt and very fine- to fine-grained sandstone that is very pale brown to pink. Interbedded in this fine sediment are subordinate gravelly channel-fills. Rock hammer for scale.

Exposures of the middle unit (QTpm) typically feature very pale brown to pink, fine-grained sediment (Figure 12). Strata consists of silt and very fine- to medium-grained sand interbedded with subordinate gravelly channel fills (10-20% near the eastern quadrangle border, increasing to 30-50% in the middle of the quadrangle). The coarse channel-fills are commonly strongly cemented and typically ribbon-like in geometry, but locally they occur as tabular, complexes. Gravel is comprised of >80% pebbles, 1-20% cobbles, and 1-10% boulders that are mainly clast-supported. Fine-grained beds are thin to thick, tabular, and mostly internally massive; these fine beds contain 0-5% scattered pebbles and 0-5% very thin lenses composed of sandy pebbles. Locally, calcic paleosols displaying stage II carbonate morphology (common calcium carbonate nodules) are observed in silty beds. This unit is 5-35 m thick. In Trujillo Canyon, calcic paleosols become more abundant and better developed (up to stage III morphology) west of UTM easting 272,700 m (NAD83, zone 13).

Between the middle and upper unit lies a transitional interval (QTput) that is 9-52 m thick and becomes increasingly redder up-section. It consists of interbedded: 1) reddish brown to light brown to pink, extra-channel sand to silt, and 2) brown to pinkish gray channel-fill gravel in medium to very thick, broadly lenticular beds to ribbon-like forms (Figure 13). Gravelly channel-fills constitute 35-65% of the unit's volume and channel-fill complexes can be followed laterally as much as ~150 m. Clast imbrication is common and suggests a predominance of stream-flow deposition compared to debris flows.

Figure 13—Photograph illustrating the upper unit of the Palomas Formation (QTpu). This unit is markedly bi-modal, containing coarse channel-fill complexes interbedded with clayey-silty, very fine- to medium-grained sand. Photograph taken in lower Skute Stone Arroyo.

The upper part of the Palomas Formation consists of coarsening-upward, light reddish brown to reddish brown, interbedded coarse channel fills and extra-channel sediment underlying the Cuchillo surface. Matrix clay appears to be more abundant than in lower strata (0-15%), occurring as sand-size flakes and clast coatings, and imparts a reddish to reddish yellow color to the sediment. The upper Palomas Formation is subdivided into two units based on the proportion of coarse channel fills relative to extra-channel sediment: Qtpu contains ≤65% coarse channel fills whereas

QTpuc (upper coarse unit) contains >65% coarse channel fills. The two units interfinger laterally with one another (with QTpuc being to the west and north and QTpu to the east and south), but upper QTpuc strata conformably prograde eastward over QTpu. Unit QTpu is 15-41 m thick and pinches out to the west. Unit QTpuc ranges from 1-3 to 90 m thick (thickening to the north) and extends westward as a relatively thin blanket of coarse sediment 2.5-3.5 km beyond the general pinch-out of underlying Palomas Formation units, where it unconformably onlaps older pre-Palomas Formation strata (Figure 14). Along Animas Creek, unit QTpuc transitions westward into a relatively massive to vaguely bedded, clast- to matrix-supported sediment interpreted to largely reflect debris flow deposition (Figure 15).

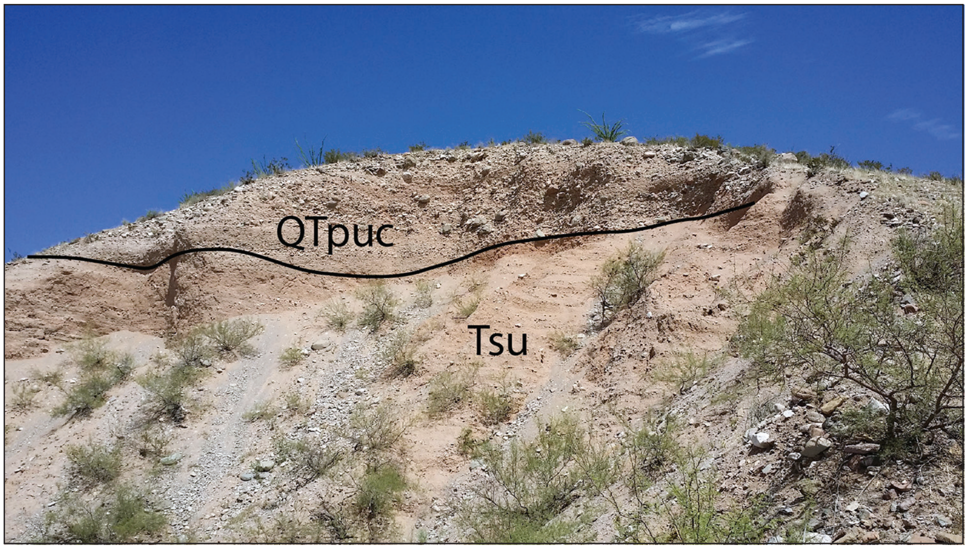


Figure 14—Photograph of the upper coarse unit of the Palomas Formation (QTpuc) unconformably onlapping pre-Palomas strata (Tsu). The contact is highly scoured. Unlike many locations in the Palomas basin, the upper gravels of QTpuc here do not host strongly developed (stage III-IV) pedogenic carbonate. Creosote bushes on top of exposure are <1.2 m (4 ft) tall. Photograph taken near Coalson Ranch immediately north of Percha Creek.

In the upper Palomas Formation, coarse channel-fill complexes are 1-3 m thick (locally as much as 5 m thick), extend laterally hundreds of meters, and are comprised of sandy gravel and subordinate pebbly sand. The coarse channel-fills have scoured bases and abrupt tops, the latter being consistent with abandonment of a given channel by avulsion processes. Channel-fill sandy gravel, which is commonly imbricated, exhibits thin to thick, lenticular to tabular beds. Pebbly sand beds are laminated to very thin, and horizontal-planar or low-angle cross-stratified. Locally, cross-stratification is present that can be categorized as two types: 1) planar foresets likely related to gravel bars (up to 30 cm thick, with very thin beds); and 2) lateral accretion sets (up to 1 m thick). There is a higher proportion of cobbles and boulders in the unit's coarse channel fills compared to underlying strata (30-50% cobbles and 10-30% fine to coarse boulders, coarsening to the west; Appendix F).

Extra-channel sediment in the upper Palomas Formation consists of medium to thick, tabular (internally massive) beds composed of two sediment types associated with a particular depositional process: 1) poorly sorted sediment deposited by debris flows or hyperconcentrated flows -- consisting of very fine- to

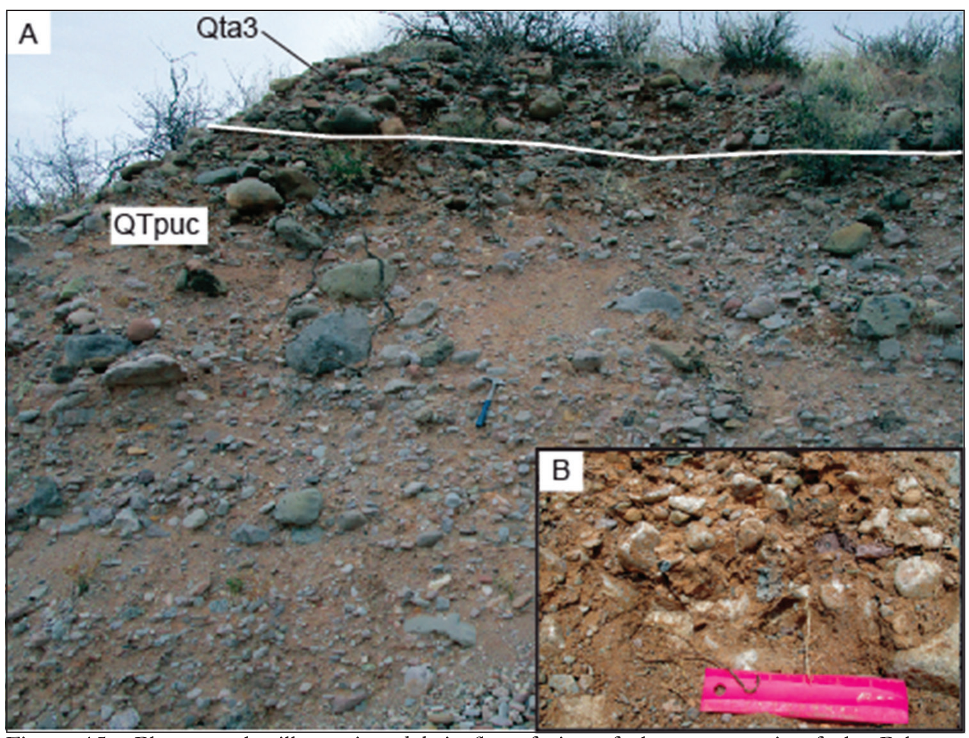


Figure 15—Photographs illustrating debris flow facies of the upper unit of the Palomas Formation (QTpuc), as observed in Las Animas Creek. A) Note the general matrix-supported texture and abundance of boulders in this exposure (UTM coordinates: 273095 m E, 3653395 m N; zone 13, NAD83). Brownish sandy gravel at top of exposure is a middle Quaternary strath terrace (Qta3) about 1 m thick. B) The matrix of Unit QTpuc is relatively clayey, such as shown in the inset photo (from a site 1.1 km downstream of photo shown in A).

medium-grained sand or clayey-silty very fine- to medium-grained sand (with minor, scattered medium-upper to very coarse sand and <20% pebbles); and 2) well-sorted silt and very fine- to fine-grained sand.deposited as overbank sediment The proportion of the latter increases down-section. The extra-channel sediment is locally overprinted by paleosols showing reddening, variable clay illuviation, and ped development (categorized as Bw and Bt soil horizons).

An interesting characteristic of unit QTpuc is that its upper 1-6 m contains strong soil development in both gravels and extra-channel sediment. In Percha Creek, these paleosols are 1-2.5 m thick and consist of strongly developed calcic horizons (stage III to IV morphology). In western Trujillo Creek, there is up to 6 m of stacked illuviated-clay and calcic horizons (stage III morphology).

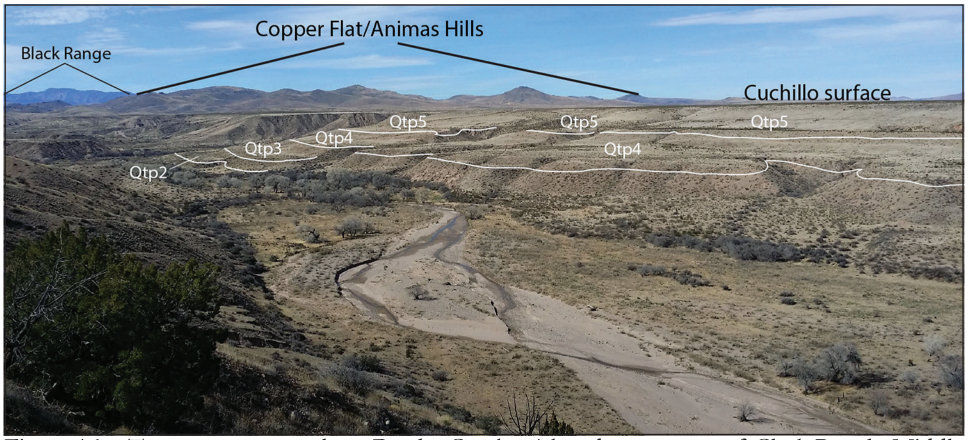


Figure 16—Terrace sequence along Percha Creek ~1 km downstream of Clark Ranch. Middle to late Pleistocene terraces are delineated and labeled (Qtp2 through Qtp5). View is toward the northwest.

Pleistocene terraces

Allostratigraphic units of gravelly terrace deposits were differentiated for Animas Creek, Percha Creek, and Trujillo Canyon. In each of these canyons, the lowest (youngest) deposit is labeled with a suffix of 1; consecutively higher terraces are given progressively higher numeral suffixes (Figure 16). Five allostratigraphic terrace deposits were mapped in each of these canyons, some of which are further subdivided. However, correlating these terraces between canyons is difficult. More dating work is necessary to establish a robust inter-canyon terrace correlation for the major canyons.

These terrace deposits are generally 1-3 m thick and might be considered as strath terraces (Figure 17) unless they are eroded. Locally, some of the mid-level terraces are appreciably thicker (up to 8 m) and can be called fill terraces. The lowest Percha Creek terrace (Qtp1) is 2 to >8 m thick, with the upper part commonly composed of very fine- to medium-grained sand. It is possible that higher terraces in this canyon and elsewhere also fined upward (became less gravelly up-section) and were once relatively thick, but subsequent erosion removed the non-gravelly, upper strata. The surfaces of the middle to higher terraces tend to be moderately to well varnished. Surficial reworking of the terrace tread has resulted in preservation of relatively poor soils (with stage I or I+ carbonate morphology), with some exceptions. Unit Qta4 has an argillic soil horizon and/or a strong calcic horizon (stage III to IV morphology). The topsoil of Qta5 has a stage III+ to IV calcic soil horizon(s). Unit QTp4 is is commonly capped by continuous stage II carbonate horizons and

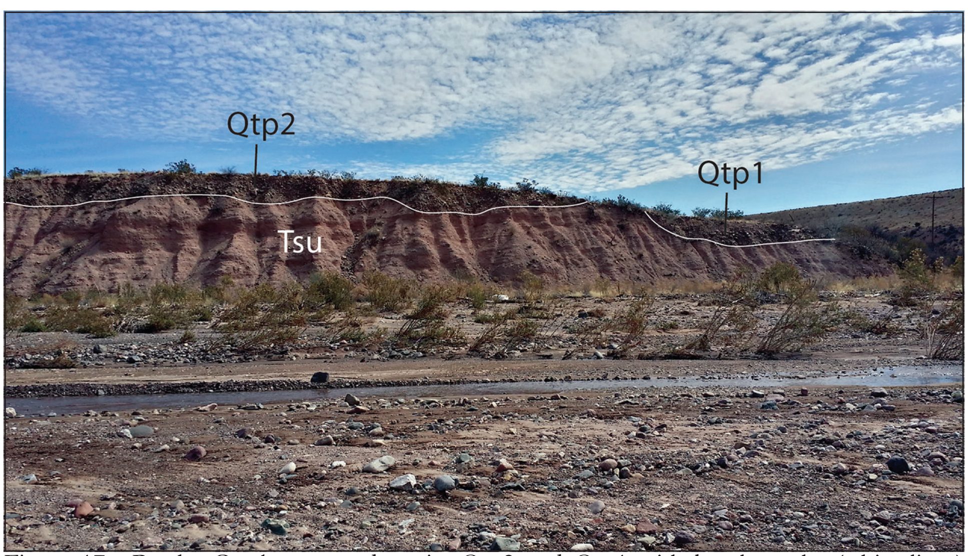


Figure 17—Percha Creek terrace deposits Qtp2 and Qtp1 with basal straths (white lines) cut on the upper unit of Tsu upstream of Clark Ranch. Both deposits are under 3 m thick (creosote bushes atop each deposits are ≤1.2 m tall). Percha Creek flows from left to right across photograph; view is toward the east.

discontinuous Btk horizons up to 35 cm thick. Unit Qtp5 and Qtt3 may have cambic horizons (upper 20 cm) underlain by calcic horizons featuring stage III morphology.

Terraces were also mapped for lower-order drainages, such as Greyback and Greenhorn arroyos. Qtg1 is the lowest of these terraces with the next highest being Qtg2. It was difficult to correlate higher terraces with confidence, and these are grouped into Qtguh. Unit Qtgu indicates a non-correlated terrace that might be in a geomorphically low or high position for a given drainage.

Alluvial fans extend across many of the terraces, and are differentiated according to the terrace over which they prograde. Exposures along Percha and Animas Creeks indicate that basal strata in some of these fans (i.e., Qfa4, Qfp3) are overprinted by appreciable soil development characterized by calcium carbonate accumulation (mostly commonly, stage II to II+ carbonate morphology) and root traces. Where present, these basal soils indicate that following abandonment of a terrace tread there was either: 1) incision of the side drainages (though such incised channels have not been directly observed), or 2) a long period of geomorphic stability prior to upstream drainage erosion and transport of sediment to the fan.

Pleistocene terrace deposits are generally readily recognized in the study area by their coarseness and brown color (Figures 15 and 17). The brown color of the terrace matrix contrasts with the red to orange colors of the older Qtpuc, QTpu, and Tsu units. Appendix F presents a comparison of clast sizes for various terraces along Animas Creek. The appreciably weaker cementation of the terrace gravels help in differentiating a terrace deposit from older pre-Palomas Formation strata, such as units Tsml, Tsm, or Tslc.

Valley floor alluvium and valley-margin alluvial fans

Numerous Holocene units were differentiated on the valley floors in the study area. Including the subsurface, the volumetrically greatest unit is likely Qay. In large drainages, this deposit consists of brown, relatively fine sand interbedded with subequal to minor gravelly beds (Figure 18). In small, steep canyons this unit is predominately a sandy gravel. Based on radiocarbon dating in the Williamsburg quadrangle to the northeast (Jochems and Koning, 2015a, b), this unit accumulated in the Holocene (possibly latest Pleistocene) since an incision event sometime in oxygen isotope stage 2. Alluvial fan deposits of Qfay interfinger with Qay along the valley margins, and are composed of sandy gravel with variable interbeds of fine-dominated sand (the latter being negligible at the mouths of small, steep gullies).

Figure 18—Example of a middle to late Holocene deposit (Qay) along lower Skute Stone Arroyo. Note the lenticular, gravelly channel-fills interbedded in brownish, fine sand. Rock hammer for scale.

In the late Holocene, one or more erosional events resulted in incision of the Qay and Qfay deposits. This was followed by another period of aggradation over the past ~600 years. This later aggradation laid down a plethora of deposits we call "historical" (50-600 years), "modern" (0-50 years), or "recent" (0-600 years). These later deposits are relatively coarser than Qay and Qfay, generally lighter in color, and consist primarily of sandy gravel and gravelly sand (Figure 19).

Figure 19—Historical alluvium (Qah) in lower Skute Stone Arroyo. Note the overall coarse texture. The sandy gravel is in very thin to medium, tabular to lenticular beds. The gravel includes pebbles, 30% cobbles, and 5% boulders. Rock hammer for scale.

In the larger drainages --such as Trujillo Canyon, Percha Creek, and Las Animas Creek -- these young deposits very likely overlie Qay, but the associated contact has not been observed. In Percha Creek and Las Animas Creek, much of the valley floor is underlain by alluvium of unit Qahap, which is comprised of interbedded floodplain deposits and coarser channel-fills (Appendix G). The floodplain deposits occur in tabular beds and consist of very fine to medium-grained sand, silty-clayey very fine- to medium-grained sand, and silt. Weakly developed, buried soils are common at the tops of individual beds in the floodplain facies, and these beds locally fine upward. Coarse channel-fills consist of sandy gravel and pebbly sand that are: 1) in lenticular, thin to medium beds, 2) in very thin to thin, tabular beds (particularly for pebbly sand); or 3) cross-stratified (less common). The collective package of young sediment in the larger drainages (modern, historic, and Holocene) is 6-16 m thick (Davie and Spiegel, 1967; Harvey Chatfield, pers. commun., Aug of 2014). More details about these young units are presented in Appendices B and G.

Basalt flows and dikes (early Pliocene)

In the northwestern quadrangle lie two major basalt flow packages. One lies southeast of the major bend in Highway 152 and the other lies to the north. Being lithologically similar, the lava in these flow packages is typically very dark gray (weathering to tan, brownish gray, or reddish brown colors), aphanitic to sparsely porphyritic, and relatively non-vesicular. Locally, the flows weather hackly or into 0.5-1.0 cm-thick plates. Phenocrysts include 1-4% olivine and pyroxene that are commonly weathered to iron-oxide minerals. The southern flow locally contains as much as 10% olivine phenocrysts (0.1-1.0 mm long) and 1% pyroxene phenocrysts (up to 2 mm long). The groundmass has abundant plagioclase laths ($\leq$0.1 mm long). The northern flow package is up to ~30 m (~100 ft) thick and divided into an upper (Tbu) and lower (Tbl) flow, separated based on an inferred flow break or local intervening sediment. The upper and lower parts of the southern flow package are most resistant to weathering, with the medial part being platy and a slope-former. No evidence of interbedded sediment was found within the southern flow package. A lava associated with the lower flow of the northern package was sampled in Greyback Arroyo, where it intersects Highway NM-152, and dated at 4.5 $\pm$ 0.10 Ma using K/Ar methods (Seager et al., 1984). About 750 m to the northwest, this same flow returned a $^{40}Ar/^{39}Ar$ age of 4.46$\pm$0.04 Ma (sample 140715a, Appendix H). Two $^{40}Ar/^{39}Ar$ ages of 4.46$\pm$0.03 Ma and 4.58$\pm$0.07 Ma (the latter a few m stratigraphically lower than the 4.46 Ma sample) indicates the lower southern flow package generally correlates to the lower norther flow package (samples WS-113b and WS-112, respectivly: Appendix H). Although these basalts overlie 1-10(?) m of sandy gravel correlated with the lower Palomas Formation (QTpl), no non-basaltic gravel overlies these flows. These flow packages probably flowed down paleovalleys. An older paleovalley, whose sides are plastered by a 5.18$\pm$0.08 Ma basalt (sample WS-103, Appendix H), is located 1.3–1.5 km to the southwest of the southern flow package (Figure 20).

The basalt flows likely issued out of north-south fissures, one of which correspoinds to a basalt dike preserved south of Highway 152 that projects a short distance to the west of the preserved portions of the aforementioned flow packages. South of Highway 152, this basaltic dike intrudes reddish gray to reddish yellow hydromagmatic deposits that are 0.4-2.1 m thick. The intrusive basalt is very dark gray to black, dense to vesicular, fine- to medium-grained, and aphanitic to slightly porphyritic. Vesicles are tightly packed and ≤3mm long where present; they may be partially or wholly filled by silica and/or zeolites. Phenocrysts include 2-8% olivine (commonly cumulophyric), trace to 4% pyroxene (≤1.5 mm, commonly altered to Fe-oxide minerals), and 1-2% plagioclase (≤0.5 cm). The dike is 1-3 m wide and locally transitions laterally into small basaltic plugs up to 30 m across.

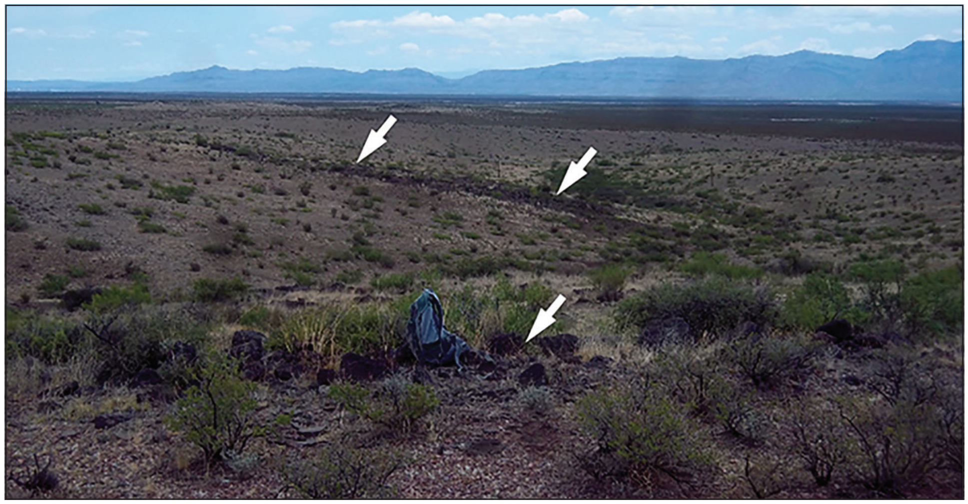


Figure 20—Two lower Pliocene basalt flows dipping relatively steeply (9°) towards the axis of a modern drainage (UTM coordinates: 266730 m E, 3648340 m N, NAD83, zone 13). View is to the northeast. These are interpreted as plastering the sides of a paleovalley after flowing out of a fissure a short distance to the west.

AGE INTERPRETATIONS FOR SEDIMENT

Radiocarbon ages

Two radiocarbon dates (Appendices G, I) were obtained from two respective pits in valley floor alluvium underlying Animas Creek (unit Qahap). In the northwest pit, sample 14-SSA-2 was collected from ripple cross-laminated sand at a depth of 140 cm. In the southeast pit, sample 14-SSA-5 was collected 64-67 cm below ground surface in a massive and bioturbated fine-grained deposit (silt to very fine to fine sand). Calibrating the radiometric ages with calendar ages yields a range of values (Appendix I), but collectively the age results indicate that the 60-150 cm depth interval is 224–12 years old (referenced to the year 1950 A.D.). Using these radiocarbon ages and the age range of Qay (see below), historic alluvium and historic alluvial fan sediment on this quadrangle is interpreted to be 600-50 years old.

In the Williamsburg quadrangle, charcoal collected from sediment correlative to Qay returned conventional radiocarbon ages of 540 ± 30, 2480 ± 30, and 9590 ± 30 years before the year 1950 A.D. (Jochems and Koning, 2015a, b). The older age was collected ~2.5-3.0 m below the ground surface. Therefore, Qay is interpreted to span the Holocene, and it may possibly be latest Pleistocene in age near its base. Qfay, which interfingers with or progrades over Qay, is assigned a general Holocene age but may also possibly be as old as latest Pleistocene.

Age interpretations for pre-Palomas strata

No direct age control is available for pre-Palomas Formation units on this quadrangle, except that they are older than the 5.2–4.5 Ma basalts. Based on our inference that units Tslc, Tsm, and Tsml generally correlate to the Hayner Ranch Formation, and that unit Tsu partly correlates to the Rincon Valley Formation, we follow Seager and Mack (2003) in interpreting the following ages for these units. In the southern Caballo Mountains and Hatch area, the Hayner Ranch Formation is bracketed between late Miocene strata on top (i.e., Rincon Valley Formation) and the

27.4-27.0 Ma Thurmon Formation (Boryta, 1994; Boryta and McIntosh, 1994) at its base, so there it is late Oligocene through middle Miocene(?) in age. On the distal hanging wall ramp in the northern Palomas Basin, deposition of lower, coarse Santa Fe Group strata began ca. 19 Ma (Koning et al., 2014; McLemore et al., 2012). Accordingly, Tsm is probably middle Miocene and Tsml spans the early to middle Miocene (and possibly late Oligocene). The Rincon Valley Formation contains the Selden basalt tongue (Kottlowski, 1956, 1960), dated at 9.8±0.4 Ma (Seager et al., 1984) and lies below the Pliocene-age Palomas Formation. Since its top appears to be relatively conformable with the Palomas Formation in the eastern part of the quadrangle, we interpret that the Rincon Valley Formation ranges in age from 13(?) Ma to 5 Ma.

Age interpretations for Palomas Formation strata

Our provisional age control for the lower Palomas Formation is heavily based on our inferred correlation of dark gray basalt clasts to the 5.2–4.5 Ma Pliocene flows in the western part of the quadrangle and the Hillsboro quadrangle (age control from Seager et al., 1984; Andy Jochems, unpublished data; Appendix H). If this inferred correlation is correct, then the middle to upper parts of the transitional basal unit of the Palomas Formation (QTplt) are younger than 5.2–4.5 Ma, since it contains clasts of this basalt. We use an age of ~5.2 to ~4.2 Ma for unit QTplt and an age range of ~4.2 to ~3.8 Ma for unit QTpl; the minimum age for QTpl is constrained by our inferred age for QTpm (see below).

The middle part of the Palomsa Formation is probably within the range of ~3.8 to 2.6 Ma. Unit QTpm is relatively fine-grained compared with underlying and overlying parts of the Palomas Formation. A noteworthy fine-grained, middle unit of the Palomas Formation exists west of Truth or Consequences (Foster, 2009; Mack et al., 2012), from which a 3.1 Ma ash was collected near the middle of the unit (Mack et al., 2009). If that fine-grained unit indeed correlates with QTpm, then QTpm is probably ~3.8 to 2.6 Ma. The minimum age of unit QTpm is relatively well constrained because its uppermost strata host the Williamsburg Local Fauna site, which is interpreted to be 2.6-3.0 Ma (Morgan et al., 2011; Morgan and Lucas, 2012).

Stratigraphic relations on the Williamsburg quadrangle (Jochems and Koning, 2015a) indicate that units QTput and QTpu are 2.6-1.8 Ma. These units overlie strata hosting the 3.0-2.6 Ma Williamsburg Local Fauna site (uppermost QTpm) (Morgan et al., 2011; Morgan and Lucas, 2012). The lower contact of QTpu lies very near the Kelly Canyon Local Fauna site, which is interpreted to be ~2.0-2.6 Ma (Morgan et al., 2011; Morgan and Lucas, 2012; Jochems and Koning, 2015). Uppermost strata of QTpu contain rabbit teeth thought to be ~2.0 Ma (Jochems and Koning, 2015a; Gary Morgan, pers. commun., 2014). Therefore, we interpret that QTpu ranges in age from 2.5-1.8 Ma. The underlying QTut unit is probably ~2.0-2.6 Ma.

The uppermost unit of the Palomas Formation (QTpuc) contains notable soil development consisting of 1-6 m of calcic horizons displaying stage III to IV carbonate morphologies and lesser argillic horizons. Thus, this unit incorporates much geologic time. It overlies unit QTpu, which has an interpreted age of 2.5-1.8 Ma (see above), and underlies the ~0.8 Ma Cuchillo Surface (age from Mack et al., 1993, 1998, 2006; Mack and Leeder, 1999). Therefore, QTpuc is interperted to be 1.8-0.8 Ma on the Skute Stone Arroyo quadrangle.

STRUCTURE

Stratal tilts

As mentioned above, the Skute Stone Arroyo quadrangle lies in the Palomas half-graben, which is tilted to the east against a large, west-down, normal fault system at the western foot of the Caballo Mountains and Mud Springs Hills (Seager and Mack, 2003). Consistent with this half-graben setting, strata on this quadrangle dip to the east. In general, strikes are northerly, mostly ranging from 325° to 045°. However, in western Percha Creek (west of UTM easting 270500 m E), strata strike consistently northeast.

Stratigraphically lower strata dip more steeply than stratigraphically higher strata, indicating that rift sedimentation occurred concomitantly with half-graben tilting (Figure 21). Older pre-Palomas Formation (Tslc, Tsm, Tsml) strata are most tilted, where dips of 5-7°E are typical. The youngest pre-Palomas Formation unit (Tsu) generally dips 2-4°E. Above its transitional base, lower Palomas Formation strata (QTpl) are tilted ~2°E. Upper Palomas Formation strata (QTpm, QTput, QTpu, and QTpuc) are typically sub-horizontal (≤2°E). An exception is along Las Animas Creek, where 3-5° bedding dips are common in QTpuc. Exposure is poor in this area, and these steeper dips may be due to drag along obscure, undetected faults or may reflect cross-stratification in unit QTpuc. Keeping in mind the poor age constraints for the older units, a plot of dip versus age, Figure 21, suggests relatively constant tilt rates over the past 20-25 million years, with possibly slower rates between 4 and 2.5 Ma.

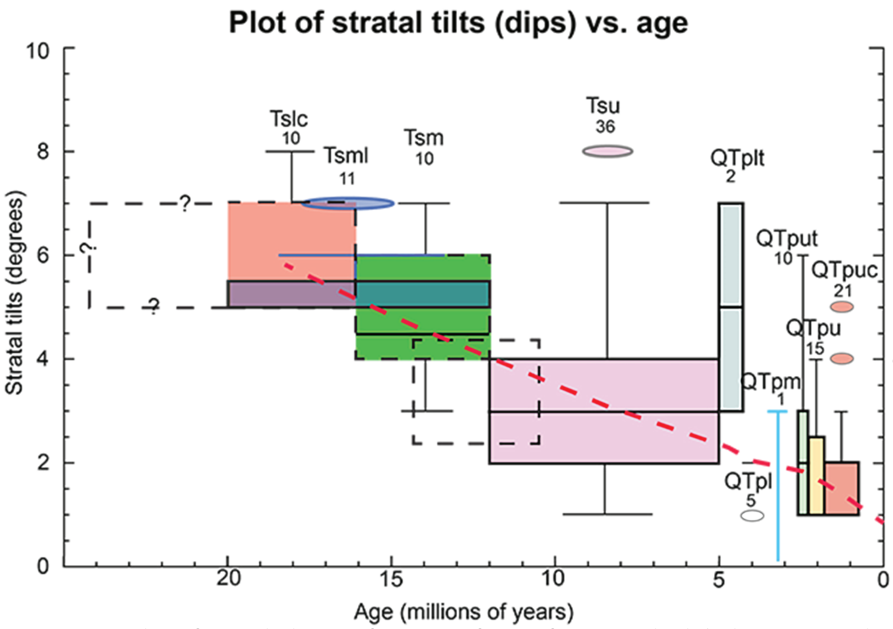


Figure 21—Plot of stratal tilts as a function of age of a particular lithologic unit; color-coded according to unit. Age control is discussed in the text; note that the age ranges of older Miocene units are poorly constrained. Plotted numerals represent the number of dip data associated with a particular lithologic unit. The line within a box represents the median, the ends of the boxes are quartiles (25th and 75th percentiles) on either side of the median, the whiskers show the 5th and 95th percentiles, and the circles are data outliers. Dashed red line is an eye estimate of a "best fit" through the approximate medians of the data bins; this best fit considers the number of data per bin and cross-section dips.

Faults

Surprisingly few faults were noted in surface exposures on the western quadrangle, but fault scarps on the Cuchillo Surface indicate several north- to northwest-trending faults in the central and eastern parts of the quadrangle north of Percha Creek. Immediately south of Percha Creek, in Section 22 (T16W, R6W), two opposing faults bound a horst block. The western fault of this pair strikes northwest and an exposure on its north end indicates a dip of 72°W. An exposure along a small fault trending ~045° on the north slope of Percha Creek (UTM coord of 276484 m E, 3643798 m N) indicates left-oblique motion (slicks plunge 54°\260° on a fault plane that strikes 054° and dips 80°NW). The orientation of htese slickenlines is consistent with an east-west, regional extension direction.

A major east-down, concealed fault is drawn in the northwestern part of the quadrangle, near Highway 152, based on well data and interpretations presented in Jones et al. (2013). However, this fault does not deform the 4.5 Ma basalt flow northwest of Highway 152 nor is there surficial evidence for faulting. Accordingly, motion along this fault must have occurred prior to 4.5 Ma.

Hinge zones and pinch-outs

An interesting phenomena observed on this quadrangle are westerly pinch-outs in upper Santa Fe Group units. Western pinch-outs of Palomas Formation units (except for the uppermost one, unit QTpuc) in the southern half of the quadrangle occur in the same general zone of longitude (i.e., between UTM eastings 269000 and 272500 m E). Northward thickening of unit QTpuc obscures where pinch-outs occur for older units in the northern half of the quadrangle. Field observations in Trujillo Canyon suggest that the upper part of Tsu (which lacks reddish brown basalt clasts) may pinch-out ~0.5 km west of the Palomas Formation pinch-outs. However, no evidence of pinch-outs are identified in the quadrangle for lower Tsu strata and older units (Tsm, Tslc, Tsml), although a down-section increase in dips indicate they probably thin to the west in a wedge-shaped manner. Therefore, obvious pinching out of units is restricted to latest Miocene and Plio-Pleistocene strata. We preliminarily interpret that this may relate to a different basin-wide fault configuration for pre latest-Miocene strata compared to latest Miocene and Plio-Pleistocene strata, consistent with the paleo-fault interpretations in the southern Caballo Mountains (Mack et al., 1994; Seager and Mack, 2003).

PALEODEPOSITIONAL ENVIRONMENTS OF SANTA FE GROUP

We conclude this report with a brief discussion of paleodepositional during the late Oligocene through early Pleistocene aggradation of the Santa Fe Group, after which incision occurred that isolated the Cuchillo Surface. Throughout this time period, there were two large alluvial fans on the quadrangle; a finer-grained, inter-fan area is inferred in the western quadrangle east of the Copper Flat. The northern alluvial fan extended across the northern 4-5 km of the quadrangle, its southern margin trending northwest. We interpret that it was deposited by a paleodrainage heading in the Black Range that approximately coincided with what is now Las Animas Creek and Arroyo Seco. Paleocurrents in the northern 4-5 km of the quadrangle (all in the upper Palomas Formation) are generally to the southeast, indicating the axis of this alluvial fan was north of the Skute Stone Arroyo quadrangle.

The southern alluvial fan was associated with a paleo-drainage fed by Black Range streams now associated with Percha Creek and Trujillo Canyon. Consistent southeast paleoflow directions in Trujillo Canyon and the unnamed drainage to the north of it in the western part of this quadrangle, coupled with slightly northeast paleoflow directions in the central and eastern parts of Percha Creek, indicate that the axis of the southern alluvial fan was immediately south of modern-day Percha Creek (UTM northing of 3643100 to 3643400 m N, NAD 83, zone 13).

The toes of these alluvial fans flanked a playa lake system in the Miocene and an axial river floodplain in the Plio-Pleistocene (Seager and Mack, 1990; Mack et al, 2006). Percha Creek well data (Figure 9) suggest an interesting phenomena at the end of Tsu (Rincon Valley Formation) deposition. From 742 to 791 ft depths, a rightward-sloping (in down-hole direction) gamma ray curve and coarse cuttings are consistent with a prograding distal piedmont. But at 720-741 ft depths, a low neutron curve value and the presence of distinctive clay chips (similar to those in the playa facies below 791 ft) suggest playa margin facies possibly related to a growing terminal playa of the Rio Grande when the latter entered the Palomas Basin at 4.9-5.3 Ma (Mack et al., 1998, 2006; Koning et al., 2015).

The presence of Cretaceous igneous rocks and Paleozoic limestones in pre-Palomas Formation strata can be used to infer when the Animas Block (the uplifted region east of the Berrenda fault zone) was uplifted, which must have effected fluvial paleo-geomorphology. These clast types increase in abundance up-section in unit Tsu (Table 1), which is inferred to correlate with the Rincon Valley Formation (see discussion above). Therefore, the Animas Block experienced uplift during the latter part of the late Miocene, concurrent with movement along the Berrenda fault zone. During the early part of this uplift, the Percha-Trujillo Canyon paleo-drainage was able to erode a wide area of the Animas block between the Copper Flat hills south to at least Trujillo Canyon. At some point in time, however, superposition locked Trujillo Canyon in the high hills ~2 km WNW of the southwestern corner of the quadrangle. Whether Percha Creek started incising into bedrock at the same time as Trujillo Canyon is not clear. Because gold veins and related dikes are largely hosted in Cretaceous volcanic rocks (Lindgren et al., 1910; Hedlund, 1977; Jochems et al., 2014), the presence of Cretaceous volcanic gravel in the upper Santa Fe Group could serve as a rough proxy for the presence of, but not the concentration or grade of, placer gold in the sediment.

HYDROGEOLOGIC INFERENCES

Texture and degree of cementation can strongly influence groundwater flow through clastic sediment, including the Miocene through Quaternary sediment that underlies most of the Skute Stone Arroyo quadrangle. In the following, we consider these properties for various map units and how they might impact groundwater flow.

The lower Santa Fe Group units (units Tslc, Tsm, Tsml), particularly Tslc, exhibit pervasively strong cementation that would inhibit groundwater flow, but their associated coarse sediment likely extends farther eastward than the stratigraphically higher Tsu unit. These cements include silica and calcium carbonate, with calcium carbonate becoming more abundant to the east (up-section). These units are broadly correlative to the Hayner Ranch Formation to the southeast (Seager et al., 1971). However, their associated streams likely did not directly link to these southeastern exposures, but rather ended in playas in topographic lows to the east of the quadrangle (e.g., Mack et al., 1994;Seager and Mack, 2003, Figure 114). The fact that these units are coarser than unit Tsu strongly suggests that Hayner Ranch playas were narrower and that gravelly piedmont sediment extended farther into the basin (i.e., eastward) than those associated with unit Tsu. If the degree of cementation decreases eastward, then it is possible that these lower units may be potential aquifers in the subsurface near the eastern quadrangle boundary, given suitable water quality.

The upper Pre-Palomas Formation unit Tsu, correlative to the Rincon Valley Formation of Seager et al. (1971), is a pebbly sandstone where exposed in the western quadrangle. However, subsurface correlations indicates it grades laterally eastward into clayey deposits in the easternmost part of the quadrangle (cross section A-A’). These clays are part of a wide playa lake system that existed in the late Miocene (Seager and Mack, 2003). While the distalmost deposits of the lower part of Tsu may be saturated near the middle of the quadrangle, increasingly higher concentrations of clay to the east would result in poor to very poor permeability values, making this unit an aquiclude or aquitard near the eastern quadrangle border.

Figure 22 shows the potentiometric surface for groundwater in the map area, constructed from groundwater levels measured in December of 2012 (Jones et al., 2013). Wells in the central and eastern part of the map are screened in the Palomas Formation (upper Santa Fe Group), so the potentiometric surface in those areas reflect groundwater conditions for the Palomas Formation. A local steepening of potentiometric gradients occurs in the northeast corner of the quadrangle between Las Animas Creek and Greyback Arroyo, about 1 km east of 107°25’ W longitude. This steepening spatially coincides with mapped faults and strongly suggests that these faults are acting as groundwater flow barriers, consistent with Jones et al. (2013). Near the western quadrangle border, wells are likely screened in pre-Palomas Formation units, and their lower permeability may be reflected in the steeper potentiometric gradient in the western quadrangle. Note that there

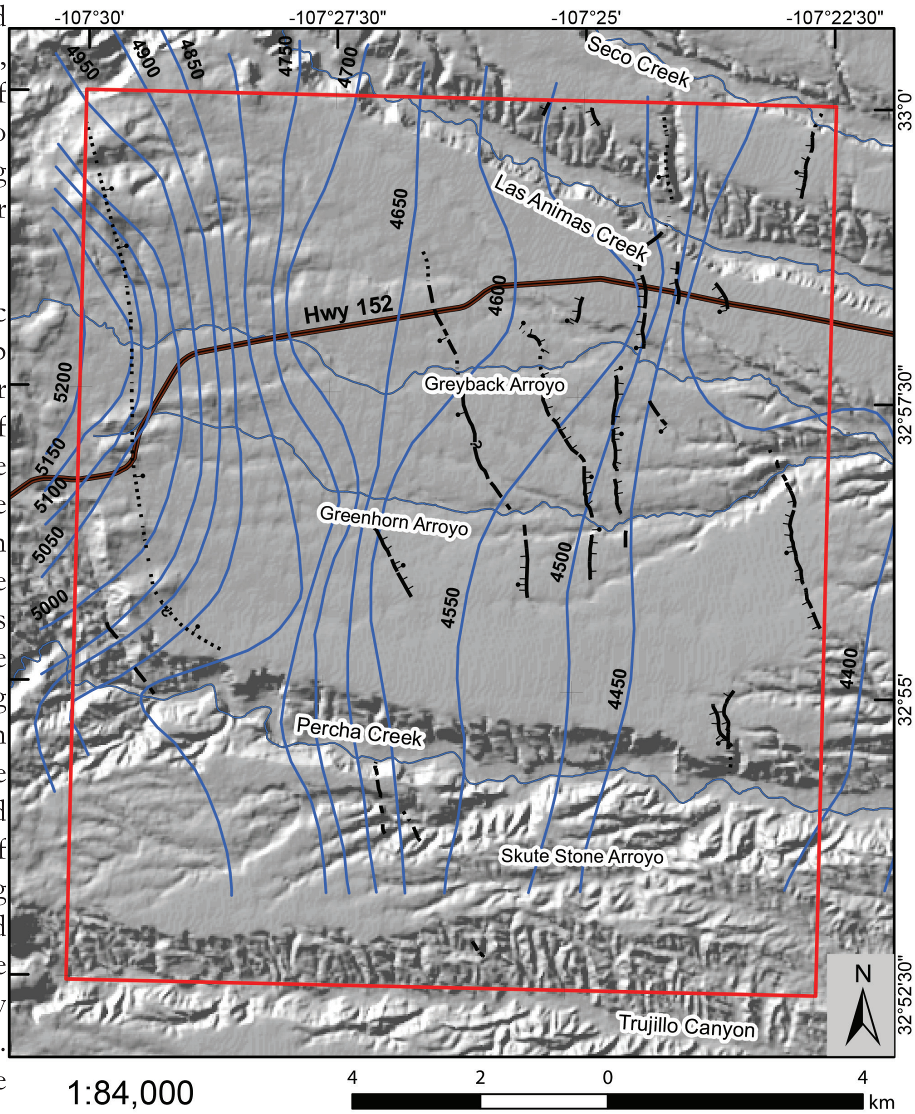
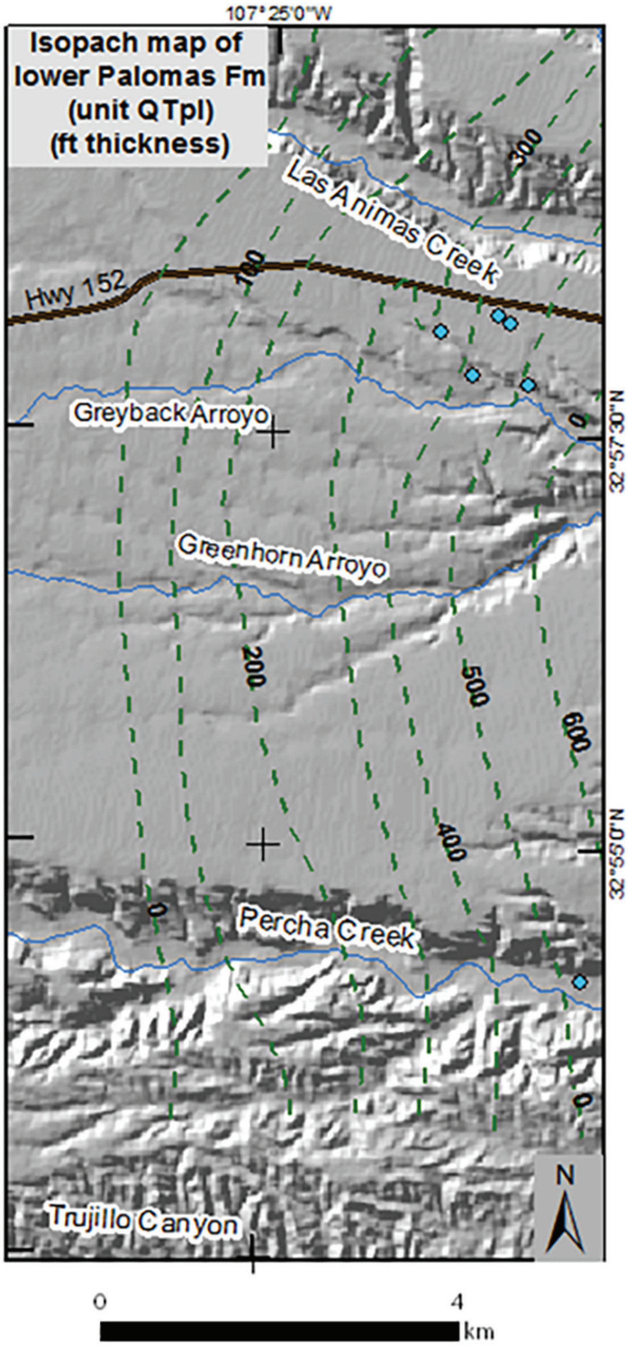


Figure 22—Map showing the potentiometric surface for the Santa Fe Group from ground water data collected in December-2012 (Jones et al., 2013). Contours are in feet and represent elevation above sea level. Also shown are faults (symbology follows the legend of the Skute Stone Arroyo geologic map). Approximate quadrangle boundary is shown by the red rectangle.



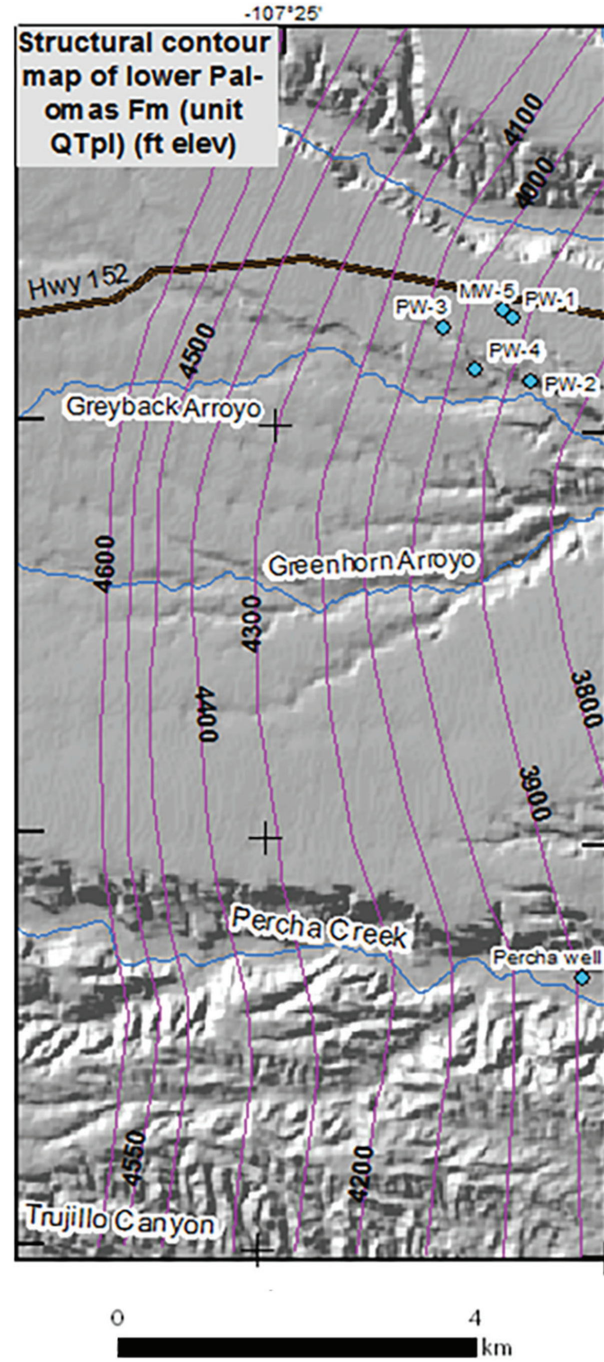


Figure 23—Structural contour map of the base of unit QTpl. Contours are in feet and represent elevation above sea level. Wells used for making the structural contour map are also depicted (blue circles).

Figure 24—Isopach map of unit QTpl; contours are in feet and represent unit thickness.

is a convex-upstream curvature to the contours in the western Las Animas Creek (in the map area) and westernmost Percha Creek, indicating discharge from the Santa Fe Group aquifer into shallow alluvium (Davie and Spiegel, 1967).

The Palomas Formation is generally not ubiquitously cemented; the main factors influencing its aquifer potential are: 1) extent of saturation, dependent on its depth of burial and depth of the potentiometric surface, 2) gross texture, and 3) amount of interstitial clays. The upper units of the Palomas Formation (QTpuc, QTpu, QTput) are generally above the saturated zone. Moreover, trace to 20% interstitial clay in the gravelly channel-fills partially to totally plug up the interstitial pore spaces, decreasing permeability. Coarse channel fills in the relatively fine-grained, middle unit (QTpm) can transmit groundwater where this unit is saturated near the eastern quadrangle border. Coarse channel-fills in this unit (and possibly lowermost QTpu) can transmit groundwater relatively effectively under the eastern part of Animas Creek, as indicated in Figure 22, by a corresponding low potentiometric surface gradient in the Santa Fe Group aquifer (Davie and Spiegel, 1967).

The Santa Fe Group stratigraphic unit with the most potential for being a productive aquifer is the lower Palomas Formation (QTpl). The lower Palomas Formation consists of sandy gravel and pebbly sand channel-fills interbedded with minor silt and fine sand beds. The overall coarse texture and low amounts of observed fines in the sand-gravel matrix (≤1% silt-clay) would both enhance the groundwater yield and permeability properties of this unit. But local precipitation of calcium carbonate cement, such as seen in Trujillo Creek, would result in decreased groundwater yield in those locations. Given its potential to be a productive aquifer, we have created an isopach map map of unit QTpl (Figure 23); this map was created by subtracting the interpreted elevation of the base of the unit (Figure 24) from the potentiometric surface of Jones et al. (2013) (Figure 22). The lower gradational zone of the Palomas Formation (QTplt) thickens notably to the east, but it is overall finer-grained than unit QTpl (Figure 9) and therefore would probably be a less productive aquifer than QTpl.

Quaternary valley fill units also may constitute aquifers, but only locally in the larger drainages -- particularly Percha and Las Animas Creeks. These units are non-cemented and contain much sand-gravel channel-fills. In Percha Creek and Las Animas Creek, Qahap and Qay units are locally thick enough to extend beneath the alluvial groundwater table. Where saturated, these Quaternary valley fill units are likely hydraulically connected to the underlying Santa Fe Group units (Davies and Spiegel, 1967). In outcrop, channel-fills in these units lack appreciable silt-clay in the matrix and are relatively abundant, implying a high degree of channel fill connectivity in the subsurface. Davie and Spiegel (1967) liken these alluvial valley fills to a highly permeable drain. Where the valley-fill is saturated, this “drain” receives and conveys subsurface discharge from the underlying Santa Fe Group, and it controls water levels in the Santa Fe Group.

An interesting feature of the quadrangle is a reach of generally perennial flow in eastern Las Animas Creek. This perennial flow begins where the channel deepens and narrows at a location 0.5 km downstream of the west-down fault crossing the canyon (this fault crossing is in SE1/4 SE1/4 Section 24, T15S R6W); the perennial flow continues past the eastern boundary of the quadrangle (Bill Bussman, pers. commun., Jan. of 2016). Relatively abundant Arizona sycamore trees (Platanus wrightii) grow in the valley bottom east of this canyon-crossing fault. The fact that Arizona sycamores are found near the perennial stream reach (on the quadrangle) is not unexpected because this tree is most productive when the groundwater table averages less than 2 m below the surface during growing season and where the groundwater table fluctuates less than 1 m annually (Stromberg, 2001). Moreover, Arizona sycamore seedling growth is most rapid in areas of perennial stream flow (Stromberg, 2001).

The coincidence of the fault with the upstream limit of sycamore trees in this quadrangle strongly suggests that the fault controls the depth to the shallow groundwater table. The fault zone likely acts as a groundwater barrier due to cementation and gouge development because such features are generally observed in fault exposures in the Santa Fe Group. This barrier might specifically result in: 1) upwelling of relatively deep groundwater in the Santa Fe Group immediately up-gradient (west) of the fault, 2) lateral flow of groundwater into the Las Animas Creek drainage from either the north and/or south (aided by the concave-to-west shape of the fault trace), or 3) reduction of thickness of latest Pleistocene-Holocene valley fill (which includes units Qay, Qahap, and Qam) at the fault due to relatively hard fault zone cementation, causing a rise in the water table -- to the surface, in this case -- in order to allow the same volumetric flow rate of valley-fill groundwater upstream of the fault as downstream of the fault (Figure 25). Analysis of available well logs with lithologic control neither confirms nor denies the third possibility. But the fact that the fault influences the potentiometric surface of the Santa Fe Group (Figure 22) suggests that the first and second mechanisms are more likely. Groundwater infiltration in valley-fill alluvium downstream of the fault is likely hampered by the underlying, relatively fine-grained QTpu unit (Figure 25). Further detailed studies should be done to test these three hypothesis regarding why the groundwater appears to be relatively shallow east of this fault.

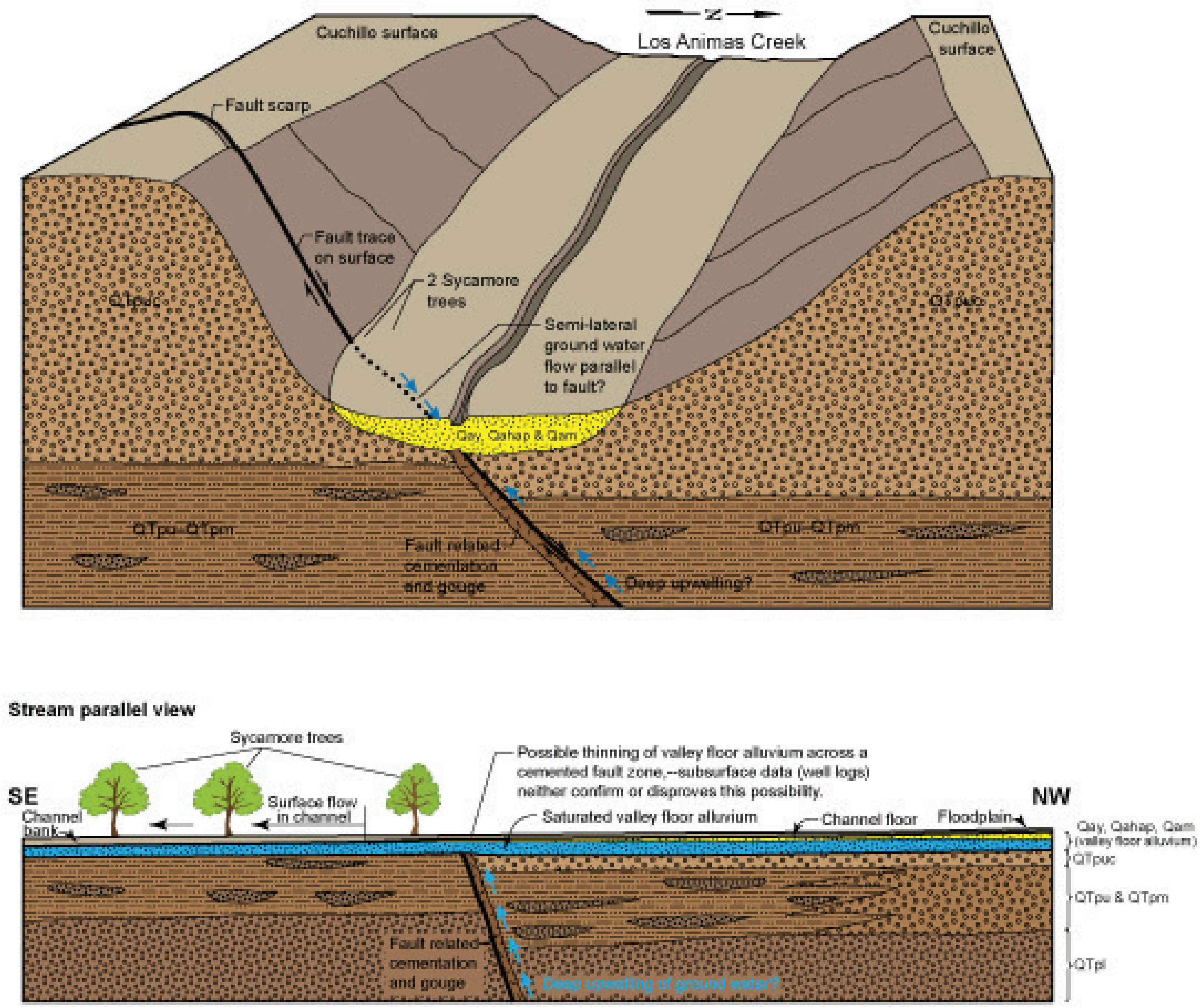


Figure 25—Three-dimensional block diagram illustrating Quaternary stratigraphy, structure, and possible groundwater flow paths that discharge at the head of a perennial stream reach in lower Animas Creek. The head of this perennial stream reach coincides with a north-striking fault crossing the main canyon (specifically, SE1/4 SE1/4 Section 24, T15S, R6W). The two most-favored hypotheses explaining shallower groundwater that maintains this perennial stream (as well as sycamore tree growth) downstream of the fault crossing are: upwelling of relatively deep groundwater in the Santa Fe Group immediately up-gradient (west) of the fault, 2) lateral flow of groundwater into the Las Animas Creek drainage from either the north and/or south (aided by the concave-to-west shape of the fault trace). View is to the west.

APPENDICES

Appendix A: Environmental Consultant Reports Relating To Coppeer Flat and Applicable to the Skute Stone Arroyo Quadrangle

Appendix B: Detailed Unit Descriptions for Skute Stone Arroyo Quadrangle

Appendix C: Table of Clast Type and Diameter For Unit Tslc

Appendix D: Description of Cuttings from Percha Creek Water Well

Appendix E: Electric Well Log for Caballo Lake-Percha Creek Field Area. Well ID: Hatch Well No.1-Deepen

Appendix F: Table of Maximum Clast Sizes Measured in the Northern Half of the Skute Stone Arroyo Quadrangle

Table of Maximum Clast Sizes Measured in the Southern Half of the Skute Stone Arroyo Quadrangle

Appendix G: Annotated Figures of Soil Profile for Las Animas Creek

Appendix H: Summary Table and Report of $^{40}Ar/^{39}Ar$ Data.

Appendix I: Report of Radiocarbon Dating Analyses

APPENDIX A

ENVIRONMENTAL CONSULTANT REPORTS RELATING TO COPPEER

FLAT AND APPLICABLE TO THE SKUTE

Stone Arroyo Quadrangle

Adrian Brown Consultants, Inc., 1996, Copper Flat Project hydrologic impact evaluation: unpublished consultant report prepared for Alta Gold, September 26, 1996.

Daniel B. Stephens & Associates, Inc., 1998, Environmental Evaluation Report, Copper Flat Project: unpublished consultant report prepared for New Mexico Energy, Mineral and Natural Resources Department, Mining and Mineral Division, Santa Fe, NM, February 6, 1998.

Greene, D.K., and Halpenny, L.C., 1976, Report on development of ground-water supply for Quintana Minerals Corporation Copper flat Project, Hillsboro, New Mexico: Tucson, Water Development Corporation, 32 p.

Greene, D.K., and Halpenny, L.C., 1980, Basic-data report—Quintana Minerals Corporation Copper Flat Project Production Well No. 4, Hillsboro, New Mexico: Tucson, Water Development Corporation, 28 p.

INTERA et al., 2012, Baseline Data Characterization Report for the Copper Flat Mine, Sierra County, New Mexico: unpublished consultant report prepared for New Mexico Copper Corporation; submitted with the Mine Operation and Reclamation Plan on July 18, 2012.

John Shomaker and Associates, 2011, Amendment to the Stage 1 Abatement Plan Proposal for the Copper Flat Mine: unpublished consultant report prepared for New Mexico Copper Corporation, October of 2011.

John Shomaker and Associates, 2012, Hydrogeologic analysis of the proposed pumping test

for New Mexico Copper Corporation Supply Wells (LRG-4652, LRG-4652-S, LRG

4652_S_2, LRG-4652-S-3), Appendix I of the Environmental Assessment for the Copper

Flat Pumping Test, Sierra county New Mexico: unpublished report for BLM, June 2012

Newcomer, R.W., Jr., and Finch, S.T., Jr., 1993, Water quality and impacts of proposed mine and mill, Copper Flat mine site, Sierra County, New Mexico, in Shomaker, J.W., Newcomer, R.W., Jr., and Finch, S.T., Jr., of John W. Shomaker and Associates, Hydrologic assessment, Copper Flat Project, Sierra County, New Mexico: unpublished consultant report for Gold Express Corporation, 31 p., 4 appendices.

Shomaker, J.W., 1993, Effects of pumping for water supply and mine dewatering, Copper Flat Project, Sierra County, New Mexico, in Shomaker, J.W., Newcomer, R.W., Jr., and Finch, S.T., Jr., Hydrologic assessment, Copper Flat Project, Sierra County, New Mexico: John W. Shomaker, Inc., Albuquerque, NM; for Gold Express Corporation, 19 p., 4 appendices.

Steffen Robertson and Kirsten, Inc., 1996, Copper Flat Mine mining permit application, Volume 4—Technical Design Documents (Part 3): unpublished consultant report prepared for Alta Gold Company, Project No. 68603 [Appendices A to H prepared by Adrian Brown Consultants, Inc. (ABC) for SRK (ABC Project No.1356A/960909)] variously paged.

U.S. Bureau of Land Management, 1996, Draft Enviromental Impact Statement-Copper Flat Project: U.S. Department of Interior, Bureau of Land Management, Las Cruces Distric Office, variously paged.

APPENDIX B.

DETAILED UNIT DESCRIPTIONS FOR SKUTE STONE ARROYO QUADRANGLE

Descriptions By Daniel Koning, Andy Jochems, and Colin Cikoski

In these descriptions, 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. Gravel composition was determined both by visual estimations (using percentage charts) and by clast counts (Appendix C). 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). Description of sedimentary and igneous rocks was based on inspection using a hand lens.

VALLEY FLOOR DEPOSITS (QUATERNARY)

Anthrogenic

daf Dam-related artificial fill (modern)—Valley bottom sand and gravel that has been moved by humans to form dams for impounding water or tailings.

draf Dredging-related spoils (historic or modern)—Pebbles and cobbles in mounds, usually conical shaped, that reach up to 4 m tall; mounds are the product of gold placer dredging along modern valley floors in the northwest part of the quadrangle.

Sedimentary

Qam Modern alluvium (0 to ~50 years old)—Coarse sand and gravel that underlies the floors of active channels, which are typically incised into either Qah or Qay. Sedimentary characteristics similar to those of historic alluvium (Qah). Gravel is subrounded (minor rounded), poorly sorted, volcanic, and comprised of pebbles with 15-30% cobbles and 1-10% boulders. Sand is gray to grayish brown to light brownish gray to brown (10YR 6/1-2 to 5/2-3), mostly medium- to very coarse- grained (minor fine-grained), subangular to subrounded, poorly sorted, and dominated by volcanic lithic grains. Surface is non-varnished and exhibits fresh bar- and-swale relief of 10-50 cm, locally up to 100 cm. Inferred to have a scoured basal contact and an estimated thickness of 1-3 m.

Qamh Modern and historical alluvium, undivided (0 to ~600 years old)—Modern alluvium (Qam) and subordinate historical alluvium (Qah). See detailed descriptions of those individual units.

Qamy Modern and younger alluvium, undivided (Holocene)—Modern alluvium (Qam) and subordinate younger alluvium (Qay). See detailed descriptions of those individual units.

Qah Historical alluvium (50 to ~600 years old)—Well-defined interbeds of pebbly sand and sandy gravel. Sandy gravel occurs in very thin to medium, lenticular to tabular beds (within medium beds, local planar cross-stratification may be present with very thin foresets). Gravel consist of very fine to very coarse pebbles, subordinate cobbles, and lesser boulders (0-5%) that are clast-supported, commonly imbricated, subrounded, and moderately to poorly sorted. Sand in gravelly beds is brown (10YR 5/3), medium- to very coarse-grained, subrounded (minor subangular), poorly sorted, and a volcanic litharenite. In pebbly sand beds, sand is very fine- to medium-grained with minor coarse to very coarse sand; sand is subrounded (lesser subangular) and moderately to poorly sorted. Top soil characterized by a very weak soil with a weak Stage I calcic horizon. Surface has distinct bar- and swale- relief (10-30 cm) and no to very weak clast varnishing. These surface characteristics, in addition to the relatively distinct bedding, serve to distinguish Qah from Qay. Weakly consolidated and inferred to be 2-4 m thick.

Qahap Historical alluvium in Animas and Percha Creeks (50 to ~600 years old)—Interbedded floodplain deposits and channel-fills underlying much of Animas Creek and Percha Creek valleys. Floodplain deposits consist of very fine to medium-grained sand, silty-clayey very fine- to medium-grained sand, and silt. Colors range from light brownish gray to dark grayish brown to pinkish gray (10YR 4-6/2; 7.5YR 7/2) to brown (7.5-10YR 4-5/3) to pale brown (10YR 5/3) to light brown (7.5YR 6/3). Sediment occurs in medium to thick, mainly tabular beds that are internally massive as well as very thin to thin beds. Fining upward trends are locally observed within a bed, and the presence of 1-20% coarse-very coarse sand and 0-10% pebbles results in moderate (lesser poor) sorting. Buried soils on top of individual floodplain deposits are relatively common and characterized by: 1) weak to moderate ped development (fine to very coarse, subangular blocky); 2) faint clay films on ped faces; 3) weak calcium carbonate precipitation (stage I morphology). Channel-fills consist of sandy gravel and pebbly sand that are: 1) in lenticular, thin to medium beds, 2) very thin to thin, tabular beds (particularly for pebbly sand); 3) cross-stratified (less common). Gravel are clast-suppported, commonly imbricated, and comprised of very fine to very coarse pebbles with minor cobbles and 5-10% boulders; gravel are subrounded to rounded, poorly sorted, and composed of volcanic clasts that may have partial coatings of calcium carbonate. Channel-fill sand is brown to dark grayish brown to grayish brown (7.5YR 5/2-3; 10YR 4-5/2), mostly medium- to very coarse-grained, subrounded, moderately to poorly sorted, and composed of volcanic grains with 25-30% sanidine + quartz. Channel-fill sediment is loose, but floodplain deposits are well consolidated. Tread commonly lies 1-2 m above modern stream grade. Gravelly surfaces exhibit bar- and swale- relief and no to very weak clast varnishing. Sandy surfaces are relatively flat. Surface soils exhibit weak stage I calcic horizons. Possibly as much as 4 m thick.

Qahm Historical and subordinate modern alluvium, undivided (0 to ~600 years old)—Historical alluvium (Qah) and subordinate modern alluvium (Qam). See detailed descriptions of those individual units.

Qahy Historical alluvium and younger alluvium, undivided (~50 to 8,000 years old)—Historical alluvium (Qah) and subordinate younger alluvium (Qay). See detailed descriptions of those individual units.

Qar Recent alluvium (historical + modern)—Valley-floor sediment that includes subequal proportions of historical (Qah) and modern alluvium (Qam). See detailed descriptions of these individual units.

Qary Recent alluvium (historical + modern) and younger alluvium, undivided (0 to 10,000 years old)—Recent alluvium (Qah and Qam—grouped together as a "recent" deposit) and subordinate younger alluvium (Qay). See detailed descriptions of these individual units.

Qay Younger alluvium, undivided (middle to upper Holocene)—Brown, relatively fine sand interbedded with subequal to minor gravelly beds. Compared to Qah, bedding is slightly less distinct (because of infiltration of fines, bioturbation, weak cumulic soil development) and the deposit has more fine sand beds; its surface also has less bar-and-swale relief and exhibits weak clast varnishing. An overall fining-upward trend is observed locally. In small, steep canyons, sediment is generally a sandy gravel in laminated to medium, tabular to lenticular beds. The finer sand is brown (10YR 4-5/3) and in thin to thick, tabular to lenticular beds. This sand is mainly very fine- to medium-grained with minor (15-30%) coarse to very coarse sand and minor (1-20%) scattered pebbles; sand is subrounded (lesser subangular), moderately sorted, and its composition reflects the local source area. Typically, the finer sediment exhibits cumulative soil profiles characterized by moderate, fine to coarse, subangular blocky peds with faint evidence of clay illuviation (especially clay bridges); buried calcic horizons are not usually observed. Gravel are in very thin to thick, lenticular to tabular beds, clast- supported, and consist of gravel to cobbles. Clasts are subrounded, poorly sorted, and their composition reflects the local source area. Channel-fill sand is brown to light brown (7.5YR 5-6/3), fine- to very coarse-grained, subrounded, poorly sorted, and composed mostly of volcanic grains. Surface has very subdued bar-and-swale topography (<20 cm) together with weak clast varnish. Erosion typically results in poor top soil preservation and coarse lag gravel, but locally a stage I to stage I+ calcic horizon is observed. Along Greenhorn Arroyo and its tributaries, this map unit also locally includes a gravel-rich terrace deposit of similar composition to the channel-fill gravels and with similar soil development to the Qay sands. Younger sands correlative to Qay are inset against this gravel-rich terrace. Weakly consolidated and 1-4 m thick.

Qaym Younger alluvium and modern alluvium, undivided (0 to 800 years old)—Younger alluvium and subordinate active alluvium, the latter typically occupying an incised channel. See descriptions for Qay and Qam.

Qayh Younger alluvium and historic alluvium, undivided (50 to 8000 years old)—Younger alluvium and subordinate historic alluvium. See descriptions for Qay and Qah.

Qayr Younger alluvium and recent (historical + modern) alluvium, undivided (present to lower Holocene)—Younger alluvium (Qay) and subordinate historic and modern alluvium (Qah and Qam -- grouped together as a "recent" deposit). See descriptions for Qay and Qar.

HILLSLOPE AND VALLEY MARGIN DEPOSITS (QUATERNARY)

Hillslope units

Qco Older colluvium (Upper Pleistocene to Holocene?)—Sandy pebble-cobble gravel with a brown (7.5YR 5/3-4) matrix. Occurs in tabular, massive/unstratified to medium beds along Percha Creek in western part of quad. Gravel consist of 85- 95% pebbles and 5-15% cobbles that are matrix-supported, angular to subrounded, and poorly sorted. Pebbles commonly aligned in slope-parallel fabric, particularly in upper 1.5-2 m. Clast lithologies are mostly volcanics reworked from the Palomas Formation and upper Santa Fe Group beds. Sand is fine to very coarse, angular to subangular, very poorly to poorly sorted, and composed of 60% lithic (volcanic), 20% quartz, and 20% feldspar (plagioclase>K-spar) grains, with up to 1% clay chips. Bioturbated by fine to medium roots and burrows up to 25 cm across. Deposit is capped by a 15 cm A horizon and is graded to fine-grained valley fill atop Qtp1. Unconsolidated and up to 6 m thick.

Alluvial fan units

Qfam Modern alluvium in alluvial fans (0 to ~50 years old)—Unit is similar to that described in Qam but is found on alluvial fans. Very thin to thin beds and clast imbrication is common. Gravel consist of well-graded pebbles through boulders that are subrounded (minor rounded), moderately to poorly sorted within a bed, and volcanic. Sand is light brown to brown (7.5YR 5-6/3 to 5/-34), mostly medium- to very coarse-grained, subrounded (mostly) to subangular, poorly to moderately sorted, and a volcanic litharenite. Loose. No surface clast varnishing and no topsoil. 10-50 cm of surface relief due to channel forms, bars, and cobbly-bouldery sieve deposits. Weak to moderate vegetative cover, with larger shrubs and trees commonly showing signs of burial. Unit commonly progrades over historic valley- fill alluvium (i.e., Qah or Qahap). Probably less than 3 m thick.

Qfamh Modern and historic alluvium in alluvial fans, undivided (0 to ~600 years old)—Modern alluvium (Qfam) and subordinate historical alluvium (Qfah) deposited on alluvial fans. See descriptions of Qfam and Qfah. <3 m thick.

Qfah Historical alluvium in alluvial fans (0 to ~600 years old)—Sandy gravel with subordinate gravelly sand. Very thin to medium, tabular to lenticular beds; local concave-up channel-fills as much as 60 cm deep; minor cobbly, medium to thick beds. Beds slope away from fan axis. Gravel is clast- to matrix-supported, locally imbricated, subangular to rounded (mostly subrounded), poorly sorted, and comprised of pebbles and cobbles with 0-15% boulders. Clast lithologies generally consist of volcanic rocks reworked from Palomas Formation or Santa Fe Group gravels. Sand color ranges from grayish brown (10YR 4/3-5/2), light yellowish brown (10YR 6/4), brown to dark brown (7.5YR 3-4/4; 5/3), or light brown (7.5YR 6/3). Sand is fine- to very coarse- grained (minor very fine- to fine-grained sand), subrounded, moderately to poorly sorted, and composed of 65% lithic (volcanics), 20% quartz, and 15% feldspar (plagioclase>K-spar) grains. 1% thin-medium beds dominated by very fine- to medium-brained sand with 1-5% silt-clay. Surface exhibits up to 1 ft of bar-and-swale relief and is commonly cobbly. Soil development is not evident, or very weak and manifested by: 1) faint calcium carbonate precipitation around clasts; 2) accumulation of eolian silt-clay in upper ~10 cm exhibiting weak ped development. Weakly to moderate consolidated and non-cemented. 1-5(?) m thick.

Qfar Recent alluvium (modern + historic) in alluvial fans (0 to ~600 years old)—Alluvial fan sediment that includes subequal proportions of historical (Qah) and modern alluvium (Qam). See detailed descriptions of these individual units. <3 m thick.

Qfahm Historic and modern alluvium in alluvial fans, undivided (0 to ~600 years old)—Historic alluvium (Qfah) and subordinate modern alluvium (Qam) deposited on alluvial fans. See descriptions of Qfah and Qfam. <3 m thick.

Qfahy Historic and younger alluvium in alluvial fans, undivided (upper to lower Holocene)—Historic alluvium (Qfah) and subordinate younger alluvium (Qay) deposited on alluvial fans. See descriptions of Qfah and Qfay. <3 m thick.

Qfary Recent alluvium (historical + modern) and younger alluvium in alluvial fans, undivided (0 to ~600 years old)—Historic and modern alluvium (Qfah and Qfam, grouped together as a "recent" deposit) and subordinate younger alluvium (Qfay) deposited on alluvial fans. See descriptions of Qfah, Qfam, and Qfay. Up to ~5(?) m thick.

Qfay Younger alluvium in alluvial fans (Holocene)—In larger arroyos: interbedded sandy gravel with minor to subequal fine-dominated sand. At the mouths of small, steep gullies: gravely sand to sandy gravel (sand is mostly medium- to very coarse-grained), locally with 1-5% fines. On the whole, deposit is weakly consolidated and poorly sorted. Gravel is found in very thin to thin, tabular beds and thin to thick, lenticular beds. Gravel is comprised of very fine to very coarse pebbles and 10-20% cobbles that are mostly clast-supported. Clasts are subrounded (minor rounded), moderately to poorly sorted within a bed, and composed of volcanic rocks reflective of local source area. Sand in gravelly beds is brown (7.5YR 5/3-4), medium- to very coarse-grained, subrounded to subangular, moderately to poorly sorted, and a volcanic litharenite. Finer sediment is brown to light brown (7.5YR 5- 6/3), variably silty (1-5%), and composed of very fine- to medium-grained sand with minor, scattered coarser sand and 1-20% scattered pebbles. Sand is subrounded to subangular and moderately sorted. Surface is generally eroded and lacks a notable soil; erosion-related lag gravel is common (comprised of coarse pebbles or cobbles). Where a top soil is present, it generally manifests brown colors (7.5YR 4/2-5/3), weak to very weak ped development, and minor calcium carbonate accumulation (stage I carbonate morphology) up to 1 m thick; locally, illuviated clay horizons are found above the calcic horizons (with very few, faint, clay films as ped faces, grain coats, or bridges). Surface exhibits subdued to no bar and swale topography (≤20 cm relief), weak clast varnish, and a weak desert pavement. Surface clasts may have partial calcium carbonate coats. Where it flanks valley- bottom, historic alluvium (Qah or Qahap), the toe of the fan is commonly eroded (toe-cut), resulting in a 1-3 m tall scarp. Up to ~6 m thick.

Qfaym Younger alluvium and modern alluvium (upper to lower Holocene)—Younger alluvium (Qfay) and subordinate modern alluvium (Qam) deposited on alluvial fans. See descriptions of Qfay and Qfam. Up to ~6 m thick.

Qfayh Younger alluvium and historic alluvium (0 to ~800 years old)—Younger alluvium (Qfay) and subordinate historic alluvium (Qah) deposited on alluvial fans. See descriptions of Qfay and Qfah. Up to ~6 m thick.

Qfayr Younger alluvium and recent (modern + historic) alluvium in alluvial fans (0 to ~8000 years old)—Younger alluvium (Qfay) and subordinate recent alluvium (grouped modern and historical alluvium, Qam and Qah) deposited on alluvial fans. See descriptions of Qfay, Qfah, and Qfam. Up to ~6 m thick.

Qfao Older alluvium in alluvial fans, undivided (upper-middle Pleistocene to lower Holocene)—Alluvial fan sandy gravel and sand. Gravel is subrounded (mostly) to rounded, very poorly sorted, and consists of pebbles, cobbles, and ~25% boulders. Surface clasts are moderately to well varnished. 1-10(?) m thick.

Qfap1 Older alluvial fan deposit whose surface grades to the tread of terrace deposits Qtp1 and Qta1, (upper Pleistocene)—Alluvial fan sandy gravel and gravelly sand that have prograded over the treads of the lowest terraces in Animas and Percha Creeks (Qtp1 and Qta1). 1-4 m thick.

Qfap2 Older alluvial fan deposit whose surface grades to the tread of terrace deposits Qta2 and Qtp2, (uppermost middle to upper Pleistocene)—Sandy gravel (minor pebbly sand) in vague, thin to medium, lenticular to tabular beds. GSravel comprised of pebbles with 35-45% cobbles and 10-15% fine boulders. Clasts are subrounded (mostly) to rounded and volcanic. Matrix consists of brown (7.5YR 5/4), very fine- to very coarse-grained sand with 5-7% clay-silt. Subequal matrix vs. clast-supported (and imbricated) beds. Moderately consolidated. Surface is commonly eroded. 1-3 m thick.

Qfp3 Older alluvial fan deposit whose surface grades to the tread of terrace deposits Qtp3, (middle Pleistocene)—

Slightly calcareous, clayey sand and gravel. Light reddish brown (5YR 6/4). Occurs in thin to thick, tabular, massive beds. Gravel consist of 45-60% pebbles, 45-55% cobbles, and 0-10% boulders that are matrix-supported, subangular to subrounded and poorly sorted. Clast lithologies generally consist of volcanic rocks reworked from Palomas Formation or Santa Fe Group gravels. Sand is very fine to coarse, angular to subrounded, very poorly to poorly sorted, and composed of 70% lithic (volcanics), 20% feldspar, and 10% quartz grains. In places, deposit overlies massive buried soil with stage II+ carbonate morphology (Bk to K horizon). Unconsolidated and 2-4 m thick.

Qfa3 Older alluvial fan deposits whose surfaces grade to the tread of terrace deposit Qta3, (middle Pleistocene)—Sandy gravel that was not exposed. A few meters thick.

Qfa4 Older alluvial fan deposits whose surfaces grade to the treads of terrace deposit Qta4, (middle Pleistocene)—A relatively widespread alluvial fan deposit along Animas Creek that consists of sandy gravel and pebbly sand, commonly coarsening upward; it also is characterized by a paleosol developed on lower, finer strata. Sandy gravel are generally clast-supported and occur in medium to thick, lenticular beds and very thin to medium, tabular beds; also locally massive, slightly clayey, and matrix-supported (debris flow deposits). Gravel consist of pebbles with minor cobbles and 0-25% boulders. Gravel are subrounded to rounded and poorly sorted. Sand is brown to light brown to strong brown (7.5YR 4-6/4; 4-5/6), very fine- to very coarse-grained (mostly medium- to very coarse-grained), subrounded (lesser subangular), poorly sorted, and dominated by volcanics; ≤5% clay. Pebbly sand tends to be massive; sand is light brown (7.5YR 6/4), clayey-silty (mostly silty), very fine- to fine-grained (with 15-20% medium- to very coarse-grained sand and ~10% scattered pebbles). Lowest 1-2 m of deposit commonly is a massive, very fine- to fine-grained sand, with 5-10% clay-silt, that is light brown to light reddish brown (5-7.5YR 6/4) and contains minor scattered coarser sand and pebbles. The lower 1-2 m of the deposit, albeit fines or pebbly sand, is generally overprinted by a paleosol. This paleosol is commonly cumulic and characterized by ped development, illuviated clay, and calcium carbonate precipitation (stage I to III+ morphology, most commonly stage II to II+); locally abundant root traces 1 mm wide. Surface gravel are moderately varnished and locally spallated. Moderately consolidated. 2-6 m thick.

Qfp4 Older alluvial fan deposit whose surface grades to the tread of terrace deposit Qtp4, (middle Pleistocene)—Sandy gravel and pebbly sand of an alluvial fan deposit that has prograded over terrace Qtp4 in Percha Creek. ~4 m thick.

Qft4 Older alluvial fan deposit whose surface grades to the tread of terrace deposit Qtt4, (middle Pleistocene)—Sandy gravel and pebbly sand of an alluvial fan deposit that has prograded over terrace Qtt4 in Trujillo Canyon. 2-3 m thick.

Terrace deposits

Terrace deposits associated with Animas Creek

Qtau Undifferentiated Animas Creek terrace deposit (Pleistocene)—Sandy gravel terrace deposit that was not correlated. 1-2 m thick.

Qta1 Lowest Animas Creek terrace deposit (upper Pleistocene)—Basal 80 cm has abundant cobbles and boulders that are very poorly sorted, subrounded, and volcanic. Overlying sediment is a brownish pebbly sand. Tread lies 7 m above the valley floor. 2 m thick.

Qta2 Lower middle Animas Creek terrace deposit (uppermost middle to upper Pleistocene) –Surface gravel are moderately to well varnished. Locally divided into three subunits: Qta2a, Qta2b, Qta2c (lower to highest), which are described separately below. Mostly 1-2 m thick.

Qta2a: Sandy gravel in vague, medium to thick beds. Clast-supported, subrounded to rounded, poorly to very poorly sorted, and comprised of 30-40% pebbles, 30-40% cobbles, and 15-30% boulders. Sand is brown to strong brown (7.5YR 4/4-6), medium- to very coarse-grained, subrounded, and moderately sorted. Topsoil has some clay illuvation but no strong calcic horizon. Treads are ~13 m above the valley floor. ~ 1 m thick.

Qta2b: Sandy gravel; gravel is clast-supported, imbricated, and consists of well- graded pebbles through cobbles with 15-30% boulders. Beds are thin to thick (mostly thin and medium) and lenticular to tabular. Clasts are subrounded to rounded, very poorly sorted, and composed of rhyolite with minor andesite; ~5% basalt clasts. Matrix consists of brown to strong brown (7.5YR 4/4-6), fine- to very coarse-grained sand (mostly coarse to very coarse) that is subrounded to subangular (coarser grains are more rounded), poorly sorted, and moderately consolidated. <0.5% clay and no obvious clay argillans. Tread lies 18-21 m above the valley floor. Loose to moderately consolidated. 1-3 m thick.

Qta2c: Sandy gravel in thin to thick, lenticular beds and very thin to medium, tabular beds. Very minor laminated to very thin, lenticular beds of pebbly sand. 60-75% of strata are clast-supported and imbricated vs. 25-40% matrix- supported, the latter probably being debris flow deposits. Gravel include pebbles, cobbles, and boulders that are subrounded (lesser rounded), very poorly sorted, and consist of volcanic rocks (5-6% basalts). Lower 1 m has abundant boulders. Sand is reddish brown to brown (5-7.5YR 4-5/4), mostly medium- to very coarse-grained, and composed mostly of subrounded volcanic detritus (but fine- to medium-grained sand has abundant subangular quartz and feldspar grains). 3-5% clay in the matrix. Very minor interbeds of fine-grained pinkish gray (7.5YR 7/2), fine-grained sediment dominated by silt and very fine- to fine-grained sand. Tread lies 23-27 m above the valley floor. 1-8 m thick. Weakly to moderately consolidated and non-cemented.

Qta3 Middle Animas Creek terrace deposit (middle Pleistocene)—Sandy gravel and gravelly sand. Mostly clast-supported in vague, thin to thick, lenticular beds. Gravel includes 30-50% very fine to very coarse pebbles, 30-40% cobbles, and 15-35% boulders. Gravel are subrounded to rounded, very poorly to moderately sorted within a bed, and composed of volcanics that include 10-15% aphinitic basalt. Sand is strong brown to dark brown to brown (7.5YR 5/4-6; 7.5YR 3/3), mostly medium- to very coarse-grained (minor fine-grained), subrounded to subangular, moderate to poorly sorted, dominated by volcanic grains, and has 1-5% clay in the matrix. Mangenese oxide stains are present on clasts. Surface clasts are moderately to well-varnished and cobbly to bouldery. Can be subdivided into three subunits with slightly different strath and tread heights, but these are lumped together consistent with a 1:24000 map scale. The three tread heights lie 29-31 m above the valley floor. Each subunit is 1.5-3 m thick

Qta4 Upper-middle Animas Creek terrace deposit (middle Pleistocene)– Sandy gravel in very thin to thick, tabular to lenticular beds. Local lateral accretion cross-stratification 1 m thick (foresets are medium-bedded). Gravel is clast- to matrix-supported, well-imbricated, and contains 35-50% pebbles, 30-40% cobbles, and 15-35% boulders. Commonly coarsest at its base. Clasts are subrounded (mostly) to rounded, poorly to very poorly sorted, and volcanic (including 5-10% fine-grained basalt). Sand is pinkish gray (7.5YR 6/2) to brown (7.5YR 4/4), locally yellowish brown (10YR 5/4) or strong brown (7.5YR 5/6), fine- to very coarse-grained (mostly medium- to very coarse-grained), subrounded (mostly) to subangular, poorly to moderately sorted, and consists of volcanic detritus with 5- 25% feldspar+lesser quartz grains. 0-3% clay in the matrix. Locally overprinted by an argillic soil horizon [strong brown (7.5YR 4/6), moderate to strong ped development, common, distinctive to prominent clay films on ped faces] and/or a strong calcic horizon (stage III to IV morphology)]. Locally in middle of deposit is a thick bed of tan, silty very fine- to fine-grained sand or sandy silt (minor scattered medium to very coarse sand and 7% scattered pebbles) that is bioturbated and massive (overprinted by a mottled, stage II to III+ calcic horizon). Clasts locally coated by manganese oxides. Weakly cemented by clay and well consolidated. Tread lies 42-35 m above the valley floor, decreasing in height downstream. 1-4 m thick (mostly ~2 m).

Qta5 Uppermost Animas Creek terrace deposit (middle Pleistocene)—A sandy gravel in vague, medium to thick beds. Its gravel fraction is clast-supported, commonly imbricated, and consists of volcanic, well-graded pebbles through boulders composed of subequal intermediate volcanic rocks vs. rhyolites in addition to 10-15% tuffs, and 10-20% basalt clasts. Clasts commonly coated by MnO. Local intervals, about 1 m thick, dominated by pinkish gray to pink (7.5YR 7/2-3), bioturbated silt and very fine- to fine-grained sand mixed with 1-5% scattered pebbles. Surface is commonly covered by slopewash (mostly Holocene). Topsoil commonly has a stage III+ to IV calcic soil horizon. Lower contact is scoured (50-60cm of relief). Tread lies 52-44 m above the valley floor, decreasing in height downstream. 0.5-3 m thick.

Terrace deposits associated with Percha Creek (Quaternary)

Qtp1 Lower Percha Creek terrace deposit (upper Pleistocene)—Sandy to bouldery pebble-cobble gravel. Matrix consists of reddish brown (5YR 4-5/4), subrounded, poorly sorted, silty, very fine- to medium-grained sand with ≥50% lithic (mostly volcanic) grains. Clast-supported gravel occur in thick, tabular to broadly lenticular beds, and consist of 40-45% pebbles, 35-45% cobbles, and ≤15% boulders of tuff, flow-banded rhyolite, and andesite with minor limestone and dolostone derived from the eastern Black Range and Animas Hills. Clasts are well imbricated, subrounded to well rounded, and poorly sorted. Varnish is observed on ≤45% of clasts at the surface. Overbank sediments are typically not preserved and no significant soil formation is observed. Deposit constitutes a fill terrace with no base observed in the western part of the quad; basal strath is up to 3 m above modern grade downstream. Unconsolidated and 2 to ≥8 m thick.

Qtp2 Lower-middle Percha Creek terrace deposit (uppermost middle to upper Pleistocene)—Sandy pebble-cobble-boulder gravel comprising thin strath terrace deposits. Matrix consists of yellowish red (5YR 4-5/6), subrounded, poorly sorted, fine- to coarse-grained sand with ≥50% lithic (mostly volcanic) grains; 10- 15% reddish clay films are also present. Clast-supported gravel occur in thick, tabular to broadly lenticular beds, and consist of 55-60% pebbles, 35% cobbles, and 5-10% boulders of tuff, flow-banded rhyolite, and andesite with subordinate limestone, dolostone, and granite derived from the eastern Black Range and Animas Hills. Clasts are well imbricated, subrounded to well rounded, and poorly sorted. Varnish is observed on 10-15% of clasts at the surface. Overbank sediments and soils are typically not preserved, though stage I carbonate morphology (≥50% of clasts partially coated by calcite) may be observed. Locally subdivided into two deposits: Qtp2a and Qtp2b. Unconsolidated and 2-6 m thick.

Qtp2a: Basal strath lies 5-8 m above modern grade. It is inset 4-6 m into unit Qtp2b.

Qtp2b: Basal strath lies 11-12 m above modern grade.

Qtp3 Middle Percha Creek terrace deposit (middle Pleistocene)—Sandy pebble-cobble gravel comprising thin strath terrace deposits. Matrix consists of reddish brown (5YR 4/3-4), non-calcareous, subrounded, poorly sorted, very fine- to coarse-grained sand with 45-50% lithic (mostly volcanic), 30-40% quartz, and 10-25% feldspar grains; 15-25% reddish clay films are also present. Clast- supported gravel occur in poorly stratified to thick (70-100 cm), tabular beds, and consist of 45-50% pebbles, 40-50% cobbles, and 5-10% boulders of andesite, dacite, and tuff with subordinate conglomerate, jasperoid, and granite derived from the eastern Black Range and Animas Hills. Clasts are well imbricated, subrounded to well rounded, and very poorly sorted. Varnish is observed on ≤70% of clasts at the surface. Overbank sediments are typically not preserved, though weak soil development and stage I+ carbonate morphology (30-70% of clasts coated by calcite) may be observed in places; these are often discontinuous. In the easternmost part of the quad, the treads of Qtp3 and Qtp4 converge, with Qtp3 inset 6-8 m into Qtp4. Basal strath is 14-21 m above modern grade. Unconsolidated and 1-4 m thick.

Qtp4 Upper middle Percha Creek terrace deposit (middle Pleistocene)—Sandy to bouldery pebble-cobble gravel comprising thin strath to somewhat thick fill terrace deposits. Matrix consists of yellowish red (5YR 4/6), subangular to rounded, poorly to moderately sorted, very fine- to coarse-grained sand with 50- 65% lithic (mostly volcanic), 25-35% quartz, and 5-15% feldspar grains; 5-20% reddish clay films may also be present. Sandy lenses are trough to planar-cross stratified with foresets 12-15 cm thick. Clast-supported gravel occur in thick, tabular beds, and consist of 30-90% pebbles, 10-60% cobbles, and 0-10% boulders of rhyolite and andesite, with subordinate conglomerate and granite derived from the eastern Black Range and Animas Hills. Clasts are well imbricated, subrounded to well rounded, and very poorly to moderately sorted. Deposit is commonly capped by continuous stage II carbonate horizons and discontinuous Btk horizons up to 35 cm thick. In the easternmost part of the quad, the treads of Qtp3 and Qtp4 converge, with Qtp3 inset 6-8 m into Qtp4. Locally subdivided into two inset deposits: Qtp4a and Qtp4b. Unconsolidated and 2-9 m thick.

Qtp4a: Basal strath lies 19-21 m above modern grade. It is inset 3-4 m into Qtp4b.

Qtp4b: Basal strath lies 25-29 m above modern grade.

Qtp5 Upper Percha Creek terrace deposit (middle Pleistocene)—Sandy pebble-cobble gravel comprising strath terrace deposits. Matrix consists of yellowish red (5YR 4/6), weakly to strongly calcareous, subangular to rounded, very poorly sorted, fine- to coarse-grained sand with 60% lithic (volcanic), 20% clay chips and films, and 20% total quartz and feldspar grains. Clast-supported gravel occur in thick to very thick (70-110 cm), tabular to broadly lenticular beds, and consist of ~50% pebbles, ~40% cobbles, and ~10% boulders of andesite, rhyolite, and tuff with subordinate conglomerate and jasperoid derived from the eastern Black Range and Animas Hills. Clasts are well imbricated, subrounded to well rounded, and very poorly to poorly sorted. Occasionally, beds are planar cross- stratified over 8-10 m with foresets up to 70 cm thick. Varnish is observed on 75- 90% of clasts at the surface. Overbank sediments are typically not preserved. Cambic horizons may be observed in the upper 20 cm, whereas the lower 1 m of the deposit may feature stage III carbonate development with carbonate plugs atop intra-deposit scour surfaces. Bioturbated by fine to very coarse roots in the upper 0.5 m. Locally subdivided into two inset deposits: Qtp5a and Qtp5b. Weakly consolidated and 2-8 m thick.

Qtp5a: Basal strath lies 32-34 m above modern grade. It is inset 4-14 m into Qtp5b.

Qtp5b: Basal strath lies 35-47 m above modern grade.

Terrace deposits associated with Trujillo Canyon

Qtt1 Lower Trujillo Canyon terrace deposit (upper Pleistocene)—Sandy gravel; not described in detail. Tread is about 5 m above the valley floor. Probably 1- 3 m thick.

Qtt2 Lower-middle Trujillo Creek terrace deposit (uppermost middle to upper Pleistocene)—Cobble-rich sandy gravel that locally fines upward from boulder-dominated to pebble-dominated. Gravel are rounded to subrounded, poorly sorted, and composed of relatively dark volcanic rocks. Clasts on tread are well-varnished. Tread lies 11-12 m above the valley floor. 1-2 m thick.

Qtt3 Middle Trujillo Creek terrace deposit (middle Pleistocene)–Clast-supported sandy gravel in very thin to medium, tabular to lenticular beds; minor planar cross-stratification up to 60 cm thick. Local lateral accretion cross- stratification up to 1.5 m thick. Gravel consists of 40% pebbles, 35-45% cobbles, and 15-25% fine to coarse boulders. Gravel are subrounded to rounded, poorly sorted, and composed of crystal-poor rhyolite, 10-20% gray limestone, 5-10% greenish Cretaceous andesite, 25% other intermediate volcanic rocks, 15% dark gray basalt, 5-7% reddish vesicular basalt, and 5% tuffs. Sand is mainly medium- to very coarse- grained, subrounded (minor subangular), poorly sorted, and composed of subequal potassium feldspar, volcanic grains, plagioclase, and quartz. Trace clay. Preserved top soil exhibits a sufficient calcium carbonate accumulation to be stage III morphology. Near the western quadrangle boundary, a lower 1.0-1.2 m-thick gravel layer is overlain by 1.5 m of pink (7.5YR 7/3). massive silt containing calcium carbonate nodules. Tread is 20-27 m above the valley floor, increasing in height downstream. 5-6 m thick.

Qtt4 Upper Trujillo Creek terrace deposit (middle Pleistocene)–Sandy gravel. Bedding is well-defined to poor. Gravel fraction consists of very fine to very coarse pebbles, 30-40% cobbles, and 15-30% boulders. Particularly large boulders are found near the western quadrangle border (b axis of 30-60 cm). Clasts are rounded to subrounded and poorly sorted. Estimated clast composition of the gravel: 50-70% dacite-andesites, 30% crystal-poor rhyolite, 5-6% dark, vesicular basalts, 5% tuffs, 3% Paleozoic limestone. Sand is reddish brown to light reddish brown (5YR 5-6/4), medium- to very coarse-grained, subrounded (lesser subangular), moderately to poorly sorted, and dominated by volcanic grains. Where not covered by Holocene slopewash, the surface clasts are strongly varnished and rubified. Moderate clast armor but no Av peds on surface. Lower contact is scoured, with about 10-20 cm of scour relief. Tread lies 21-30 m above the valley floor, increasing in height downstream. 1-3 m thick.

Qtt5 Upper Trujillo Creek terrace deposit (middle Pleistocene)–Sandy gravel with 25-35% pebbly sand. Latter is in laminated to very thin, tabular beds. Sandy gravel is in very thin to medium, tabular to lenticular beds. Gravel is generally clast-supported and comprised of pebbles, 30-40% cobbles, and 3-30% boulders. Clasts are subrounded to rounded, poorly to very poorly sorted, commonly imbricated, and composed of: 40-50% crystal-poor rhyolite, 35-40% andesites-dacites (plagioclase, hornblende, pyroxene phenocrysts), 5-10% pyroxene-phyric basaltic andesites (excluding Cretaceous andesites), 3% Cretaceous andesites, 1-5% tuffs, 1% limestone, 1% vesicular basalt. Sand is reddish brown to brown (5-7.5YR 5/4), mostly medium- to very coarse-grained, subrounded, moderately sorted, and composed mostly of volcanic grains. Lower contact is scoured. Weakly cemented by clay and moderately consolidated. Surface clasts are strongly varnished. Moderate clast armor but no Av peds. Locally overlain by thick, Holocene slopewash deposits. Tread is 35-

40 m above the valley floor, increasing perpendicularly away from the drainage axis due to southward slope. 1-6 m thick.

Terrace deposits flanking smaller canyons

Qtgl Lower terrace deposit associated with smaller canyons (upper Pleistocene)—Sandy gravel and lesser pebbly sand. Sandy gravel is in thin to thick, lenticular beds; very minor lateral accretion cross-stratification up to 0.5 m thick. Pebbly sand forms laminated to very thin beds. Gravel includes pebble, cobbles, and sparse to abundant boulders that are poorly to very poorly sorted, subrounded, and volcanic. Sand is mostly medium- to very coarse-grained, subrounded, poorly sorted (because of 10% very fine- to fine-grained sand), volcanic, and has 3-5% clay in the matrix. Well consolidated and weakly cemented by clay. Where observed, top soil has notable illuviated clay horizon(s) but only weak calcium carbonate accumulation (stage I morphology). Strath lies 0-2 m above the modern stream, with treads being 2-4 m above the modern stream. Inset into both Qtg2 and Qtguh. Up to 2 m thick.

Qtg2 Middle terrace deposit associated with smaller canyons (middle to upper Pleistocene)—Sandy gravel consisting of very fine pebbles to cobbles and minor fine boulders. Deposits are 70-90% gravel that consist of subrounded (lesser subangular), poorly to moderately sorted very fine pebbles to sparse small boulders. Bedding ranges from massive to very thin to medium, tabular to lenticular; local cross-stratification ≤ 30 cm thick. Matrix material is reddish brown (5YR 4/4 to 4/6 observed) to light reddish brown to pinkish gray (7.5YR 7/2-6/3), clayey fine to coarse sands, with common clay films bridging sand grains and coating gravel. The base of the deposit is channelized, with gravel channels inset up to 1 m into underlying Palomas gravels in outcrop. Strath heights are 2-5 m above the modern channel; tread heights are 3-8 m above the channel and inset into Qtguh treads. Deposits are 0.5 to 4 meters thick.

Qtguh High-level terrace deposit associated with smaller canyons, undivided (middle Pleistocene)–Poorly sorted sandy gravels with sparse interbedded sandy silts and clays. 70-90% gravel that consist of subrounded (lesser subangular) very fine pebbles to sparse small boulders in massive to medium tabular beds. Matrix material is reddish brown (5YR 4/6 observed) clayey fine to coarse sands, with common clay films bridging sand grains and coating gravel. Sandy silts and clays are found along the margins of valleys; these consist of reddish brown (75-7.5YR 5/4), medium or massive beds with sparse to locally common, matrix-supported fine pebbles. Clay films bridging grains and coating gravel are common, and locally up to stage II carbonate horizon morphology is found (visible CaCO3 accumulation has not been observed in gravel beds). Due to limited outcrop, restricted lateral extents, and stripped soils, correlation of Qtguh deposits as mapped between arroyos is not certain. Strath heights are over 5 m above the local channel; tread heights are 5-12 m above the channel. Deposits are 0.75 to 1.5 meters thick.

Qtgu Terrace deposit associated with smaller canyons, undivided (middle to upper Pleistocene)—Poorly sorted sandy gravels. Commonly used in upstream reaches of small tributary drainages, where terrace tread and strath heights converge and the above map units become indistinguishable. Also applied to what appears to be erosion-related, thin gravel deposits in the southeastern corner of the quadrangle (which commonly have a concave-up profile).

SANTA FE GROUP BASIN-FILL OF PALOMAS BASIN, WESTERN PIEDMONT FACIES (EARLY MIOCENE-EARLY PLEISTOCENE)

Palomas Formation

QTpuc Palomas Formation, upper coarse unit (lower Pleistocene)—A subunit of QTpu, where the proportion of gravelly channel fills clearly dominates (>65%) compared to finer-grained extra-channel-sediment. Especially noteworthy is the unit's westward onlap onto older Santa Fe Group strata. Upper 2-6 m of unit contains paleosols. In Percha Creek, these are 2-2.5 m thick and consist of strongly developed calcic horizons (stage III to IV morphology). In western Trujillo Creek, there is up to 6 m of stacked stacked illuviated-clay and calcic horizons (stage III). The coarse sediment consists of sandy gravel and subordinate gravelly sand. This unit typically overlies QTpu; the lower contact is sharp, scoured, and conformable. Eastward, this unit interfingers with QTpu. Matrix clay imparts a distinct orangish color to gravel, facilitating differentiation from browner Quaternary terrace deposits. Sandy gravel is in thin to thick, lenticular to tabular beds; pebbly sand tends to be in laminated to very thin, horizontal-planar beds; sparse cross-stratified beds (commonly low-angle, also exhibiting planar foresets up to 40 cm thick). Bedding becomes less distinct and clast size increases westward. Along Animas Creek, this unit grades westward into a relatively massive to vaguely bedded, clast- to matrix-supported sediment interpreted to largely reflect debris flow deposition. Gravel is generally clast-supported, commonly imbricated, and consists of very fine to very coarse pebbles with 30-50% cobbles and 10-30% boulders -- coarsening to the west. Gravel are subrounded to rounded, poorly to very poorly sorted, and composed of rhyolites (mostly crystal-poor varieties), 20-40% andesite-dacites (phenocrysts include plagioclase +/- pyroxene +/- hornblende; this bin excludes Cretaceous andesites), 2-5% greenish, plagioclase-phyric Cretaceous andesites (not noted in Animas Creek), 5-7% basaltic andesites, 1-7% tuffs, 0.5-3% Paleozoic limestone, and 0.5-4% basalt, locally as much as 10% (dark gray, aphinitic, and variably vesicular). Some clasts are notably decomposed. Sand is mostly reddish brown to light reddish brown to reddish yellow (5YR 5-6/4; 6/6), with lesser brown to light brown (7.5YR 5-6/4) or yellowish red (5YR 5/6), mostly medium- to very coarse-grained, subrounded to subangular, poorly (lesser moderately) sorted, and composed of volcanic grains, subordinate feldspar [plagioclase and potassium feldspar, and roughly 10% quartz. In the matrix, there is 1-20% clay as sand-size flakes and clast coatings. Weakly cemented by clay; moderately to well consolidated. Extra-channel sediment generally consists of reddish brown, thick, tabular (internally massive) beds of very fine- to medium-grained sand with minor, scattered coarse to very coarse sand and pebbles; locally overprinted by paleosols showing clay illuviation and ped development. These beds are well consolidated and weakly cemented by clay. As thick as 90 m the northern quadrangle; in southern quadrangle, thins west and east to 1-3 m.

QTpu Palomas Formation, upper unit (lower Pleistocene)—Light reddish brown extra-channel-sediment interbedded with laterally extensive (100s of meters), coarse channel-fill complexes 1-3 m thick (locally as much as 5 m thick). The coarse channel-fills do not exceed 60% of unit volume and are comprised of sandy gravel and subordinate pebbly sand. Extra-channel sediment consists of medium to thick, tabular (internally massive) beds composed of two sediment types associated with two depositional processes: 1) poorly sorted sediment deposited by debris flows to hyperconcentrated flows consisting of very fine- to medium-grained sand to clayey-silty very fine- to medium-grained sand, with minor, scattered medium-upper to very coarse sand and <20% pebbles; and 2) well-sorted overbank sediment of silt and very fine- to fine-grained sand. The proportion of the latter increases down-section. Color of extra-channel sediment is a function of clay content, with: 1) clay-rich beds being yellowish red (5YR 5/6) to light reddish brown (5YR 6/4) to light brown (7.5YR 6/4); 2) overbank, well-sorted, silty beds being light brown, pink, pinkish gray, or very pale brown to (7.5YR 6/4; 7/2-3; 10YR 7/3). The extra-channel beds are well consolidated and weakly cemented by clay. The coarse channel-fills have scoured bases and abrupt tops. Bedding for sandy gravel is very thin to medium and lenticular to tabular, with local cross-stratification of two types: 1) planar foresets likely related to gravel bars (up to 30 cm thick, with very thin beds); 2) lateral accretion sets (up to 1 m thick). Bedding for pebbly sand is laminated to very thin, horizontal-planar or low-angle cross-stratified. Gravel consists of pebbles, 30-50% cobbles, and 10-15% fine to coarse boulders. Gravel is subrounded (lesser rounded), poorly to moderately sorted (within a bed), and composed of: 25-40% felsites, mostly crystal-poor rhyolites; 25-40% dacite- andesites (excluding Cretaceous andesites) that are: 1) medium to dark gray plagioclase-pyroxene-phyric or 2) light gray and plagioclase-hornblende phyric; 5- 10% tuffs (Sugarlump Tuff is common and generally exceeds Kneeling Nun Tuff in abundance); 5-10% basaltic andesite (mostly aphinitic, with 5% pyroxene phenocrysts <= 1 mm long); 1-5% Cretaceous andesites (greenish and plagioclase-phyric); 1-5% Paleozoic limestone, and 0.5-2% basalt (mostly black, aphinitic, and slightly to non-vesicular; some reddish brown). Channel-fill sand is pinkish gray to light brown (7.5YR 6-/2-4; 7/2), medium- to very coarse-grained, subrounded, poorly sorted, and composed of volcanic and feldspar grains (volcanic ≥feldspar) with 10-15% quartz grains. In the matrix, there is 0-15% clay as sand-size flakes and clast coatings. Weakly cemented by clay and well consolidated. 15-41 m thick, pinching out to west.

QTpui Palomas Formation, fine-grained tongue of the upper unit within the upper coarse unit (QTpuc) (lower Pleistocene)—Light reddish brown extra- channel-sediment interbedded with minor gravelly channel-fill complexes 1-3 m thick, as described in unit QTpu. Forms mappable tongues in the upper coarse unit (QTpuc) in lower Greenhorn Arroyo. 4-25 m thick.

QTput Palomas Formation, transition at base of upper unit (upper Pliocene to lower Pleistocene)—Reddish brown to brown or gray, interbedded extra-channel sand/silt and channel-fill gravel, deposited by hyperconcentrated flows, in stream channels, or in overbank settings. Progressively becomes less red down-section. Coarse channel-fills constitute 35-65% of unit volume and can be traced over ~150 m. Brown to pinkish gray (7.5YR 5/4 to 7/2) gravel is in medium to very thick, broadly lenticular beds, and is weakly to moderately imbricated. Clast lithologies include ≤50% Eocene tuff (mostly Kneeling Nun Tuff) and aphanitic rhyolite, ≤40% basaltic to plagioclase-phyric andesite, andesites, ≤10% miscellaneous lithologies including Pliocene basalt, Miocene conglomerate, Cretaceous andesite, and Paleozoic sedimentary rocks. Rare sand lenses interbedded with channel-fill gravel feature planar cross-stratification with foresets ≤20 cm thick. Finer-grained extra- channel deposits constitute 35-65% of unit volume and can be traced 80-100 m. These beds are reddish brown to light reddish brown (5YR 5-6/3) or light brown to pink (7.5YR 6-7/3), thin to very thick, tabular to broadly lenticular, and massive to (less commonly) horizontally laminated or ripple cross-laminated. Sand is very fine- to medium-grained, angular to rounded, poorly to moderately well sorted, and composed of 40-65% lithic (felsite+chert>intermediate volcanics), 25-45% feldspar (plagioclase>K-spar), and 10-20% quartz grains. Matrix clay is rare and pebbles are scattered throughout beds. Occasional gravel lenses up to 1.5 m thick enveloped by massive sand/silt beds feature planar cross-stratification with foresets ≤30 cm thick. Weakly to moderately cemented by carbonate and unconsolidated (fine- grained beds) to moderately consolidated (gravel beds). 9-52 m thick, pinching out to west.

QTpm Palomas Formation, middle unit (middle part of Pliocene)—Silt and very fine- to fine-grained sandstone; 10-20% interbedded gravelly channel-fills near eastern quad border but these increase to 30-50% in the middle of the quad. Fine- grained beds are thin to thick, tabular, and mostly internally massive; very minor scattered medium to very coarse sand grains, 0-5% scattered pebbles, and 0-5% very thin, lenticular sandy pebble lenses. Their color ranges from very pale brown (10YR 7-8/3) to light brown (7.5YR 6/4) to pink (5-7.5YR 7-8/3) to pinkish gray (7.5YR 7/2). Silty sand beds display vague trough cross-stratification in places. Stage II carbonate morphology (common carbonate nodules) occasionally observed in silty beds. Minor calcium carbonate nodules up to 30 cm wide. Coarse channel- fills are typically ribbon-like (thin- to medium, lenticular beds that commonly fine- upward); minor (5-15%) 1-3 m-thick, tabular coarse channel-fill complexes; these channel-fill complexes have tabular, very thin beds (pebbly sand) to thin to medium, lenticular beds (coarse pebbles and cobbles); also local trough cross-stratification. Gravelly sediment is gray to dark gray (7.5YR 4-5/1) and comprised of >80% pebbles, 1-20% cobbles, and 1-10% boulders that are mainly clast-supported. Clasts are subrounded, poorly to moderately sorted, and composed of crystal-poor rhyolite, 20-35% dacite-andesites, 10-20% tuffs (particularly common are the Sugarlump and Kneeling Nun Tuffs), 10-15% platy Oligocene basaltic andesites, 0- 1% Paleozoic limestone, 2-3% green Cretaceous andesites, and 1-3% gray, vesicular basalt. Sand is very fine- to medium-grained, subangular to well rounded, and moderately to moderately well sorted. In eastern Trujillo Canyon, this unit likely correlates to the lower part of what is mapped as QTput, but was not differentiated because it was relatively indistinct or obscurred by poor exposure. Moderately to well consolidated and weakly cemented, with the coarse channel fills being locally strongly cemented. 5-35 m thick and pinches out to the west.

QTpl Palomas Formation, lower unit (lower Pliocene)—Sandy gravel and pebbly sand interbedded with minor silt and fine sand beds. Sandy gravel is in very thin to medium beds that are tabular to lenticular; local lateral accretion sets (up to 100 cm thick and with very thin to thin foresets). Pebbly sand is typically in laminated to very thin, horizontal-planar beds or cross-stratified (<30 cm thick, typically planar foresets). Gravel comprised of pebbles, 5-40% cobbles, and 0-15% boulders that are mainly clast-supported (minor matrix-supported). Clasts are subrounded (minor rounded), poorly to moderately sorted in a bed, and composed of rhyolite (mostly crystal-poor varieties), 30-40% dacite-andesites (excluding Cretaceous andesites) that have phenocyrsts of plagioclase and lesser pyroxene +/- hornblende +/- biotite (light gray, hornblende-phyric dacite noted), 2-5 (locally up to 10%) Cretaceous andesites (yellow-green and plagioclase-phyric), 5-10% tuffs (particularly common are the Sugarlump Tuff and Kneeling Nun Tuff), 3-5% platy Oligocene basaltic andesites, 1-5% (locally up to 8%) Paleozoic limestone, and trace to 2% black to very dark gray, aphinitic basalt (0-1% pyroxene or olivine phenocrysts). Typical sand colors include pinkish gray to light brownish gray (7.5- 10YR 6/2) and light brown to light yellowish brown 7.5-10YR 6/4; 7.5YR 6/3). Sand is fine to very coarse-grained (mostly medium- to very coarse-grained), subrounded, poorly to moderately sorted, and composed of volcanic grains, subordinate feldspar grains, and ~15% quartz; matrix is relatively clean, with ≤1% silt-clay. Minor (1-20%) 1-3 m-thick intervals of very pale brown silt (10YR 7/4) with 5% calcium carbonate cementation (irregular masses to stringers). Moderately to weakly consolidated and non- to weakly cemented. In Trujillo Canyon, this unit has a distinctive, well-developed calcic soil in its upper 1-12 m (stage III to V carbonate morphology, mostly III+), increasing in thickness to the west. 1-155 m thick, pinching out to the west.

QTplt Palomas Formation, transitional base of lower unit (lower Pliocene)—Reddish, transitional zone at the base of the lower unit of the Palomas Formation. Composed of pebbly sandstone and subordinate sandy gravel (which locally occurs as 2-10 m-thick intervals) that contains trace to 1% dark gray, vesicular basalt clasts. Pebbly sand beds are laminated to thin and horizontal-planar, with very minor cross-stratification <20 cm thick. Sandy pebbles are typically in very thin to medium, lenticular (lesser tabular) beds. Gravel are comprised of pebbles, 5-30% cobbles, and 0-3% boulders -- coarsening to the west. Clasts are subrounded, moderately to poorly sorted within a bed, and composed of rhyolite (mostly crystal- poor varieties), 25-40% dacite-andesites excluding the Cretaceous andesites (mostly plagioclase-phyric +/- pyroxene +/- hornblende), 7-25% tuffs (particularly common are the Sugarloaf Mountain and Kneeling Nun Tuffs) 5-10% platy Oligocene basaltic andesites, 1-8% Paleozoic limestone, 1-7% Cretaceous andesites (yellow-green and plagioclase-phyric), and trace-1% (locally as much as 2% basalts) including: 1) dark to very dark gray, aphinitic, vesicular basalt; 2) maroon and splotchy basalt; 3) reddish brown, vesicular basalt. Sand color ranges from light reddish brown to reddish yellow (5YR 6/4-6) to light brown (7.5YR 6/4) to pink (7.5YR (7/3) to light brownish gray (10YR 6/2). Sand is fine- to very coarse-grained (mostly medium- to very coarse-grained), poorly (lesser moderate) sorted, subrounded (lesser subangular), and rich in volcanic grains. 0.5-5% clay present in matrix, giving the unit its reddish color. Moderately consolidated and weakly cemented by clay or calcium carbonate, with 1-20% zones of moderate to strong cement (by calcium carbonate), commonly as thin layers that are micritic and dense; local nodules of calcium carbonate. In Trujillo Canyon, a well-developed calcic soil is preserved on top of this unit to the west (1-2 m thick and a stage III+ morphology). Unit pinches out to the west, and near its pinch-out the upper soil zone, comprised of cumulic and strongly developed calcic soil horizons, thickens to several meters. Its base is relatively sharp and planar (locally scoured) and appears to be conformable. In the Percha well, this unit is correlated to a 192 ft-thick interval of pebbly sand with subordinate interbeds of sandy to gravelly clay or silt (520-712 ft depths; James Witcher, unpublished data). 1-60 m thick.

Basin-fill that underlies the Palomas Formation

Tsu Santa Fe Group, upper unit of pre-Palomas Formation basin-fill (upper Miocene)—Reddish pebbly sandstone interbedded with minor sandy pebbles that tends to be a slope-former; estimated 10-15% coarse intervals where sandy gravel is about subequal to gravelly sandstone. Probably equivalent to the Rincon Valley Formation of Seager et al. (1971). Mainly reddish brown to light reddish brown to reddish yellow to yellowish r (5YR 5-6/4-6), with lesser light brown (7.5YR 6/3-4). Pebbly sandstone beds are laminated to thin and tabular. 5-40% very thin to medium, lenticular (lesser tabular) beds composed of sandy gravel. The sandy gravel beds are clast- to matrix-supported, with the latter probably being deposited by debris flows; cobbles are generally restricted to the lenticular beds. 10-15% cross-stratification, typically with low-angle, laminated to very thin foreset beds. Gravel are predominately pebbles, with only 1-15% cobbles and trace-1% boulders [15-35% cobbles and 1-5% boulders in the aforementioned 10-15% coarse intervals]. Clasts are subrounded, moderately to poorly sorted within a bed, and composed of rhyolite (mostly crystal-poor varieties) that decreases in abundance northwards (from 30-50% to 5-10%), 15-35% dacite-andesites that are mostly plagioclase- +/- hornblende-phyric (of which there is 0 to 3% Cretaceous andesites, increasing up-section), 5-25% tuffs (dominated by Kneeling Nun Tuff, but Sugarlump Tuff becomes more common up-section), 10-15% platy Oligocene basaltic andesites, and 1-3% reddish brown (minor very dark gray), vesicular basalt cobbles and boulders that gradually decrease and then disappear up-section; Paleozoic clasts are only seen near the upper contact, where they are as much as 5%. Sand is very fine to very coarse-grained (mostly medium to very coarse), subrounded (lesser subangular), poorly sorted, and dominated by volcanic grains. 1- 5% (minor 5-10%) clay-dominated fines present in matrix, giving the unit its reddish color. Weakly cemented by clay or calcium carbonate, with 1-15% zones of moderate to strong cementation (by calcium carbonate). Lower contact is gradational over 2-30 m; where mappable, this gradation zone is mapped separately (Tsut). Correlated to a fine-grained, reddish interval in the lower part of the Percha well (712-1000 ft depths). 100-300 m thick, thinning to west.

Tsut Transitional zone at the base of the upper unit of pre-Palomas Formation basin-fill (upper Miocene)—Transitional zone between the upper and middle units of pre-Palomas Formation basin fill that is pervasively moderately to strongly cemented but still reddish in color. Strata consist of pebbly sandstone with 5-25% thin to medium, lenticular sandy pebble-cobble beds. Pebbly sandstone is in very thin to thin, tabular beds or cross-stratified (tangential- and low-angle to trough-cross-stratified). Gravel is dominated by pebbles with 10-15% cobbles and 1-5% boulders. Clasts are subrounded to subangular and composed of fine-grained rhyolite (decreasing in abundance to the north), 20% tuff (mostly Kneeling Nun Tuff), 25% andesite-dacites, 20% light gray basaltic andesites; no Cretaceous andesites and very dark gray basalts, although reddish brown, vesicular basalts are locally present. Sand is pink (5-7.5YR 7/3-4) to pinkish gray to light reddish brown (5YR 6/4-7/2) to light brown (7.5YR 6/4), fine- to very coarse-grained (mostly medium- to very coarse-grained), subrounded to subangular, moderately to poorly sorted, and mostly composed of volcanic grains. Estimate 3% clay in the matrix. Pervasively moderately to strongly cemented by silica or calcium carbonate. Subsumed into the lowest part of unit Tsu in Percha Creek. Generally 10-30 m thick.

Tsm Santa Fe Group, middl unit of pre-Palomas Formation basin-fill (middle Miocene)—Well-cemented, light reddish brown (2.5YR 7/3) sandy conglomerate, conglomeratic sandstone, and subordinate sandy siltstone. Forms local ledges and cliffs that are not as prominent as those associated with Tslc. Differentiated only in western Percha Creek. Beds are medium to very thick and tabular. Gravel fraction is dominated by pebbles, with lesser cobbles and very minor boulders. Gravel are mainly clast-supported, subangular to subrounded, poorly sorted, and composed of 5-10% crystal-poor rhyolite, 30-40% intermediate volcanic rocks, 10-35% tuffs (particularly crystal-rich Kneeling Nun tuff), and 10-25% Oligocene basaltic andesite. Sand is mostly medium to very coarse-grained, subrounded to subangular, poorly to moderately sorted, and a volcanic-lithic arenite. Siltstone beds are typically light reddish brown (2.5YR 7/3), medium to thick, tabular, and internally massive. These beds are non-calcareous in places, but may contain paleosols with Btk horizons elsewhere. Cemented by silica and calcium carbonate. 50-60 m thick.

Tsml Santa Fe Group, middle-lower unit of pre-Palomas Formation basin-fill, undivided (lower to middle Miocene)—Well-cemented conglomeratic sandstone coarsening westward or down-section to sandy conglomerate. Forms ledges and cliffs, particularly towards the west. Mapped south of Percha Creek. Widespread clast-supported, imbricated gravels suggests deposition was dominated by stream flow processes, but debris flow-dominated intervals (1-10 m thick) increase westwards (down-section), where they comprise 10-40% of the strata. Debris flows are interpreted for strata exhibiting thin to thick, tabular beds that are internally massive, matrix-supported, and have minor clay-silt mixed with very fine to very coarse sand. Pink to light brown to pinkish gray to pinkish white (7.5YR 6-7/4; 7/2- 3; 8/1-2), but locally redder (5YR 7/2-3) where silty-clayey due to debris flows or argillic paleosol horizons. Pebbly sandstone is in laminated to ~20 cm-thick, tabular beds and also locally cross-stratified (especially in the upper part of unit, where planar to tangential foresets are present). Sandy conglomerate is in very thin to medium, lenticular and minor tabular beds. Gravel contains pebbles with 10-35% cobbles and 1-5% boulders (with clast size increasing westward or down-section). Gravel are mainly clast-supported, subrounded, poorly to moderately sorted within a bed, and composed of crystal-poor rhyolite, 10-35% plagioclase-phyric (+/- hornblende or pyroxene) intermediate volcanic rocks (with common light gray, plagioclase-hornblende dacite), 10-15% Oligocene basaltic andesite, 5-30% tuffs (dominated by Kneeling Nun Tuff), and trace basalt (generally reddish brown and vesicular) observed only near the southern quad border (increasing up-section to 0.5-1%). Sand is mostly medium to very coarse-grained, subrounded (lesser subangular), poorly sorted, and a volcanic-lithic arenite. Although up to 3% clay is found in the sand matrix near the top of the unit, it quickly decreases westward/downsection to be <1%. Very minor paleosols characterized by 10-30 cm-thick, light reddish brown to pink (2.5YR 6/4 to 5YR 7/3) argillic horizons (>30% ped coverage by distinct clay films). Well-cemented by silica and calcium carbonate, with the degree of cementation and the proportion of silica cementation increasing down-section. Basal contact not observed. Upper part of unit, which is finer-grained and more cross-stratified, may correlate to the Rincon Valley Formation. However, most of unit correlates to the Hayner Ranch Formation (both formations introduced in Seager et al., 1971). 550-1100 m thick.

Tslc Lower coarse unit of pre-Palomas Formation basin-fill (lower to middle Miocene)—Strongly cemented sandy conglomerate and pebbly sandstone comprising the base of the Santa Fe Group; forms prominent ledges and cliffs. Mapped only in western Percha Creek. Conglomerate beds are light gray (7.5-10YR 7/1) to light reddish brown (5YR 6/3) and thin- to thick-bedded, tabular to lenticular, and massive to planar or trough cross-stratified in foresets 25-50 cm thick; beds are grayer and feature thicker foresets up-section. Gravel are commonly imbricated and consist of subangular to rounded, very poorly to moderately sorted pebbles (50-90%) and cobbles (10-50%), with minor boulders (≤3%). Clast lithologies are dominated by Tertiary volcanics, with up to 60% basaltic andesite in some beds. More commonly, clasts are 20-45% basaltic andesite, 10-20% tuffs, 10- 15% aphanitic rhyolite, 5-10% dacite, and ≤5% each of chert and volcaniclastic lithologies. Finer-grained beds are pebbly sandstones that are gray to pinkish gray (5YR 6/1-2), tabular to lenticular, and commonly planar to trough cross-stratified; planar cross-stratification dominates (~65% of beds). Sand matrix is very fine- to coarse-grained, subangular to subrounded, and poorly to moderately sorted. Grains are composed of >60% lithics (volcanics), 25-40% quartz, 5-25% feldspar. Clay occasionally occurs as ≤5% films in sandy beds. Unit is primarily cemented by silica, although rare beds feature crystalline calcite that replaces fine matrix sand. Unit is likely correlative to Hayner Ranch Formation of Seager et al. (1971). Local exposures exceed 75 m in thickness; total thickness ~300 m based on correlation to exposures in Hillsboro quad to west.

Mafic Flows, Fissures, and Dikes (Pliocene)

Tb Basalt flows (Lower Pliocene)—Aphanitic basalt that is ledge-forming, dense and mostly non-vesicular. Very dark gray (10YR 3/1 to N3/), weathering—medium tannish to brownish gray to reddish brown. Locally weathers hackly (especially the lower 3 m north of Greyback Arroyo) or into 0.5-1.0 cm-thick plates (plates are particularly common south of County Road B027 along the north boundary of Section 6). Phenocrysts include 1-4% total olivine and pyroxene (0.25- 1 mm, mostly anhedral; commonly weathered to Fe-oxide minerals). The southernmost Tb unit contains 10% olivine phenocrysts (0.1-1.0 mm long) and 1% pyroxene phenocrysts (up to 2 mm long), both of which are euhedral. Groundmass has abundant plagioclase laths (≤0.1 m long). North of Greyback Arroyo, there are occasional ramp structures (implying obstructions to flow), local brecciated intervals, and the unit grades upward into slightly vesicular basalt capped by scoria/cinder. North of Greyback Arroyo, entire flow package may be up to ~30 m (~100 ft) thick and the unit is divided into an upper (Tbu) and lower (Tbl) flow, separated based on an inferred flow break. or local intervening sediment. South of County Road B027 (leading to the Copper Flat Mine), the basalt fills paleovalleys and is less than 2 m thick. Non-basaltic gravel does not overlie the flows. Flow in Greyback Arroyo at intersection of Highway NM-152 was dated at 4.5 ± 0.10 Ma using K/Ar methods (Seager et al., 1984).

Tbu: Upper flow subunit of Tb north of Greyback Arroyo. Grades upward into slightly vesicular basalt. See unit Tb description.

Tbl: Lower flow subunit of Tb south of Greyback Arroyo. Dated at 4.5 ±0.10 Ma using K/Ar methods (Seager et al., 1984). See unit Tb description.

Tmi Mafic intrusions in dike geometries (Lower Pliocene)—Very dark gray (10YR 3/1) to black (N 2.5/) weathering pale to very pale brown (10YR 6-7/3), dense to vesicular, fine- to medium-grained, aphanitic to aphanitic-porphyritic basalt occurring as dikes east of Wicks Gulch. Vesicles are tightly packed and ≤3mm long where present; they may be partially or wholly filled by silica and/or zeolites. Phenocrysts include 2-8% olivine (≤ 3 mm, anhedral to subhedral; commonly cumulophyric), trace to 4% pyroxene (≤1.5 mm, commonly altered to Fe-oxide minerals), and 1-2% plagioclase (≤0.5 cm, anhedral). Occurs along fissure that sourced aphanitic to aphanitic-porphyritic basalt with up to 8% olivine and lower intervals of hydromagmatic deposits. Locally, mafic material rests on or intrudes hydromagmatic deposits (subsumed into unit) that are 0.4-2.1 m thick, reddish gray (5YR 5/2) to reddish yellow (7.5YR 7/6), weakly to strongly cemented (iron oxide or silica), clast- to matrix-supported, tabular to lenticular, and massive/unstratified. These beds contain angular to subrounded, very poorly to poorly sorted pebble- cobble conglomerates consisting of tuff, aphanitic rhyolite, and andesite transitioning upward to ~50% aphanitic basalt, 35% scoria, and 15% older volcanics. Gravel consist of 35-45% pebbles, 55-65% cobbles, and ≤3% boulders, with the latter boulders composed exclusively of intrusive basalt; larger cobbles tend to be basalt as well. Matrix consists of fine- to very coarse grained sand that is subrounded and poorly to moderately sorted; this sand is mostly replaced by cement but including ≥60% ferromagnesian minerals in the upper parts of hydromagmatic deposits. Dikes inferred to have fed Tb flows and to be of similar age (4.5 Ma; Seager et al., 1984).

Subsurface units

Tv Volcanic rocks, undivided (Eocene-Oligocene)—Includes upper and lower andesites of Trujillo Peak, which are a dark-gray to purplish-brown, aphanitic to aphanitic-porphyritic, fine- to medium-grained andesite (Jochems et al., 2014). Other rocks may include rhyolites, dacite, andesites, basaltic andesites, tuffs (i.e., Kneeling Nun and Sugarlump Tuffs), and volcaniclastic sediment (including the Rubio Peak Fm). Poorly constrained thickness of ~180 m.

Pz Paleozoic rocks, undivided (upper Cambrian through Permian)—Paleozoic strata dominated by limestones and dolomites, with lesser shales and sandstones. Jochems et al. (2014) describes these strata in detail. Poorly constrained thickness of 600-650 m.

XYu Proterozoic rocks, undivided (Paleo- to Mesoproterozoic?)—Includes granite, gneiss, and schist.

Description of Map Units References

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APPENDIX C

TABLE OF CLAST TYPE AND DIAMETER FOR UNIT Tslc

Table C-5. Clast Type and Diameter (cm) for Unit Tslc

Date: Aug. 6, 2014

UTM Location[a]: 3645803N, 266588E

	basaltic andesite	plagioclase-phyric andesite	aphanitic, flow-banded rhyolite	dacite	quartz-phyric (≤10%) tuff	Sugarlump tuff	chert	Kneeling Nun tuff	volcaniclastic
measured diameters (cm)	4	3	2.5	6	2.5	4	2	4.5	4.5
	2	5.5	3	5	4.5	2.5			
	4	3.5							
	1.5								
	3								
	4								
	10								
	3.5								
	5								
	2.5								
	2.5								
mean diameter (cm)	3.8	4.0	2.8	5.5	3.5	3.3	2.0	4.5	4.5
n	11	3	2	2	2	2	1	1	1
% total	44	12	8	8	8	8	4	4	4

[a]UTM coordinates in NAD83, zone 13S.
Conducted by Andy Jochems

APPENDIX D

DESCRIPTION OF CUTTINGS FROM PERCHA CREEK WATER WELL

Appendix D. Description of cuttings from Percha Creek water well																								
Examined by Daniel Koning and Andy Jocehms on February 5, 2016, and June 4, 2016. (drilled by Rodgers-Hatch; located at SE1/4NE1/4 sec. 20, T16S, R5W)																								
														Percentages of key lithic grains										
Interval (ft)	unit	General lithology	Color	Percent Clay-silt	Subord sand size	Dominant sand size	% pbles	Pebble size (mm)	Roundness (m-vc sand & pbles)	Sorting (whole deposit)	%L[a]	%F[a]	%Q[a]	Basalt	Tsf ss	Bas. Andesite	Tuffs	K andesite	Pz chert, lm	%xtalline $CaCO_3$	%$CaCO_3$ coats[b]	%clay coats[b]	effervesence	remarks[c]
Unit QTpl																								
Cuttings subunit 1: Light gray, coarse, slightly more angular volcanic detritus																								
205-210	1	Fine-pebbly sand	White to lt gray (N8/ to 10YR 8/1	0		cL-vcU		2-4 mm	subround-subang	moderate	60-65	20-30	10-15			25	45		tr-2	5-7	35-40	N/A		Lithic grains include: 45% Tkn, 25-30% dac+epa+rhy, 25-30% Tb+Tba, trace-2% pCg, and trace-2% Pz jasperoid/chert+carbonate. Feldspar grains include 60% plag and 40% K-spar.
215-220	1	Fine-pebbly sand	White (N8/; 7.5-10YR 8/1	0.5%		cU-vcU		8 mm	subrnd-subang	mod to poor	--	--	--							--	--	--		Interval not examined.
225-230	1	Fine-pebbly sand	Gray-light gray (7.5YR 6-7/1)	0		cU-vcU		2-10 mm		poor	60-70	20-25	5-15			15	35		5	< 3	20	N/A		Lithic grains include: 35% Tkn, 25% dac+rhy, 20% epa, 15% Tb+Tba, 5% Pz jasperoid/chert, and trace pCg. Feldspar grains include 55% plag and 45% K-spar. 1x massive azurite observed.
235-240	1	Fine-pebbly sand	Gray-light gray (7.5YR 6-7/1)			cL-vcU			subang-subrnd	moderate	--	--	--							--	5	--		Interval not examined.
Cuttings subunit 2: Browner, more rounded, and more heterolithic volcanic detritus than above																								
245-250	2	Pebbly sand	Gray to pinkish gray (7.5YR 5/1-7/2)	0		cU-vcU	30-50%	2-8, local 10	subrnd	moderate	70-75	10-15	10-20				35		15	0-trace	< 10	N/A		Lithic grains include: 35% Tkn+Ts, 20% dac+epa+rhy, 15% Pz jasperoid/chert+carbonate (possibly +Pa), and trace pCg. Feldspar grains include 75% plag and 25% K-spar.
255-260	2	Sandy pebbles	Gray to pinkish gray (7.5YR 6/1-7/2)	0.5-1%	10-15% vfL-mL	cL-vcU	50-60%	2-6 mm	subrnd	poor	--	--	--							--	--	--		Interval not examined.
265-270	2	Sandy fine pebbles	Lt gray to pinkish gray (5-7.5YR 7/1-2	0.5-1%		cU-vcU		2-8 mm	subrnd-subang	poor	--	--	--							--	--	--		Interval not examined.
275-280	2	Sandy fine pebbles, slightly coarser than above	Lt gray to pinkish gray (5-7.5YR 7/1-2	Trace							65-75	5-15	15-20		tr	20	50		10	0	< 8	N/A		Lithic grains include: 50% Tkn+Ts, 20%Tb+Tba, 10% epa, 10% dac+rhy, 10% Pz jasperoid/chert+carbonate, and trace Tsf sst. Feldspar grains include 65% plag and 35% K-spar.
285-290	3	Sandy fine pebbles	Lt gray to pinkish gray (5-7.5YR 7/1-2)	Tr-0.5%		cL-vcU		2-6	subrnd (v minor rnd)	poor	--	--	--							--	--	--		Interval not examined.
Cuttings subunit 3: Pebbly sand, coarser pebbles than above																								
295-300	3	Pebbles	Lt greenish gray (N7/1)					2-15	subrnd	poor	~100	N/A	N/A	5		25	50-55		5-10	N/A	N/A	N/A		Nearly all grains are small (<1.2 cm diameter) pebbles. Lithologies include: 50-55% Tkn, 25% Tba, 10% epa, 5-10% Pz jasperoid/chert, and 5% Tb. Tba pebbles are typically better rounded.
305-310	3	Pebbles interbedded with muddy sand	Pinkish gray (7.5YR 7/2)	1-2% clay-silt	mU-c	vfL-mL; cU-vcU		2-15	subrnd (some broken pbles)	poor	--	--	--							--	--	--		Interval not examined.
315-320	3	Pebbles interbedded with muddy sand	Pinkish gray (7.5YR 7/2)	1-2% clay-silt	mU-c	vfL-mL; cU-vcU	50%	2-15	subrnd (some broken pbles)	poor	--	--	--							--	--	--		Interval not examined.
325-330	3	Pebbly sand	Gray (7.5-5YR 6/1)	trace				2-16	rnd-subrnd (some broken)	poor	75-80	10-15	5-10	tr-2%	3	20	60		7	0-trace	10-12	N/A		Lithic grains include: 60% Tkn+Ts, 20% Tba, 7% Pz jasperoid/chert, 5% dac, 5% epa, 3% Tsf sst, and trace-2% Tb. Feldspar grains include 85% plag and 15% K-spar. Tba grains are smaller and more angular.
335-340	3-4	**TRANSITION**									--	--	--							--	--	--		Interval not examined.
Cuttings subunit 4: Clayey-silty sandy pebbles																								
345-350	4	Sandy pebbles	Pinkish gray (5-7.5YR 7/2)	3-5%	mU-vcU	vfL-mL		2-20	subrnd (minor subang; pbles locally broken)	very poor	80	10	10			35	45-50		~5-7	0	30-35	45-55		Lithic grains include: 45-50% Tkn, 35% Tba, 10% dac+rhy, and 5-10% Pz jasperoid/chert+pCg+qz monz. Qz monz may be Cretaceous in age. 1x diorite pebble (1.8 cm diameter) observed. Feldspar grains include 90% plag and 10% K-spar.
355-360	4	Sandy pebbles	Pinkish gray (5-7.5YR 7/2)	3-5%	mU-vcU	vfL-mL		2-20	subrnd (minor subang; pbles locally broken)	very poor	--	--	--							--	--	--		Interval not examined.
Cuttings subunit 5: Clayey-silty sandy pebbles																								
370-375	5	Sand with minor fine pebbles	Gray to pinkish gray (7.5YR 6/1-2)	1%		cL-vcU	minor	2-5	subrounded	moderate	--	--	--							--	--	--		Interval not examined.
385-390	5	Sand with minor fine pebbles	Gray to pinkish gray (7.5YR 6/1-2)	2%		cL-vcU	minor	2-5	subrounded	moderate	55-60	20-25	15-25		tr-2	23	45		10%	0	25	30		Lithic grains include: 45% Tkn, 25% Tba, 20% dac+rhy, 10% Pz jasperoid/chert, trace-2% Tsf sst, and trace pCg±gneiss. Feldspar grains include 90% plag and 10% K-spar.

Appendix D. Description of cuttings from Percha Creek water well

Examined by Daniel Koning and Andy Jocehms on February 5, 2016, and June 4, 2016. (drilled by Rodgers-Hatch; located at SE1/4NE1/4 sec. 20, T16S, R5W)

														Percentages of key lithic grains										
Interval (ft)	unit	General lithology	Color	Percent Clay-silt	Subord sand size	Dominant sand size	% pbles	Pebble size (mm)	Roundness (m-vc sand & pbles)	Sorting (whole deposit)	%L[a]	%F[a]	%Q[a]	Basalt	Tsf ss	Bas. Andesite	Tuffs	K andesite	Pz chert, lm	%xtalline $CaCO_3$	%$CaCO_3$ coats[b]	%clay coats[b]	effervesence	remarks[c]
405-410	5	Fine-pebbly sand	Light gray to pinkish gray (7.5YR 7/1-2)	1%	10-15% fL-mU	cL-vcU	35%	2-10	subrnd (minor subang)	poor	60-65	20-25	10-20			30	40		7	trace-2	30-35	10-15		Lithic grains include: 30% Tba, 30% Tkn, 10% dac, 10% epa, 10% Ts, 7% Pz jasperoid/chert, and 3% pCg+qz monz. Qz monz may be Cretaceous in age. Feldspar grains include 55% plag and 45% K-spar.
415-420	5		Lt gray to pink gray to gray (7.5YR 7/1-2; 6/1)		5% vfL-fU	cU-vcU	40-50%	2-17 mm	subrnd (minor subang; some broken pbles)	poor	--	--	--							--	--	--		Interval not examined.
Cuttings subunit 6: Sandy pebbles with minor clayey sand (~2-3% clay-silt)																								
425-430	6	Slightly clayey, sandy med-pebbles		2-3%	5-15% vfL-mU	cL-vcU	50-60%	2-20	Sand: subrnd. Pbles: subrnd (minor subang; pbles may be broken)	poor	--	--	--							--	--	--		Interval not examined.
435-440	6	Slightly clayey, sandy med-pebbles		2-3%	5-15% vfL-mU	cL-vcU	50-60%	2-20	Sand: subrnd. Pbles: subrnd (minor subang; pbles may be broken)	poor	75-80	10-20	5-10			35	35		5	0	15-20	15-20		Lithic grains include: 35% Tba, 35% Tkn+Ts, 25% dac+rhy, 5% Pz jasperoid/chert+pCg+qz monz. Qz monz may be Cretaceous in age. Feldspar grains include 65% plag and 35% K-spar. Quartz grains are generally small (≤ 0.75 mm diameter).
Cuttings subunit 7: Pebbly sand with 125% clay-silt. Finer and less pebbly than above																								
445-450	7	Slightly muddy fine-pebbly sand	Lt gry to pinkish gray (7.5YR 7/1-2)	0.5%		cL-vcU	20%	2-10	subrnd (some pbles are broken)	moderate	--	--	--							--	--	--		Interval not examined.
455-460	7	Slightly muddy fine-pebbly sand	Pinkish gray (5-7.5YR 6-7/2); lt reddish brn (5YR 6/3)	1-2%	5-15% vfL-mU	cL-vcU	~20%	2-8	Sand: subrnd (minor subang). Pbles: subrnd	moderate to poor	70-75	15-20	10-15	1	5	40	35			3-5	10-15	5-10		Lithic grains include: 40% Tba, 35% Tkn+Ts, 15% dac, 5% rhy, and 5% Tsf sst+chert. Chert is lighter in color than dark maroon Pz jasperoid/chert. 1x Tb grain observed. Feldspar grains include 90% plag and 10% K-spar.
465-470	7	AS ABOVE									--	--	--							--	--	--		Interval not examined.
Cuttings subunit 8: Slightly muddy sand, subordinate sandy pebbles																								
485-490	8	Pebbly sand	Pinkish gray to lt red brn(5YR 6-7/2 & 6/3)	3-5%	fL-cU	vcL-vcU	~30%		Sand: subrnd-subang. Pbles: subrnd & broken.	poor	--	--	--							--	--	--		Interval not examined.
490-495	8	Sandy med-pebbles	Pinkish gray (5-7.5YR 6-7/2. Lt red brn: 5YR 6/3	2-3%	vfL-cU	vcL-vcU	50-60%	2-12 mm	Sand: subrnd-subang, Pbles: subrnd (minor subang or broken)	poor	75-80	15-20	0-10		~1%	25	55			trace	15-20	10-15		Lithic grains include: 55% Tkn+Ts, 25% Tba, 10% rhy, 5-10% dac, and ≤ 5% chert+Tsf sst (chert>>sst). Chert is lighter in color than dark maroon Pz jasperoid/chert. Color and phenocrysts of rhy suggest that it may be Tmr. Feldspar grains include 90% plag and 10% K-spar.
500-505	8	Sandy med-pebbles	Pinkish gray and pink (7.5YR 6-7/2; 7/3)	2-3%	10-25% fL-mU	cL-vcU	50-60%	2-5 (minor up to 13)	Sand: subrnd-subang. Pbles: subrnd or broken	poor	--	--	--							--	--	--		Interval not examined.
505-510	8	Muddy sand	Lt brn to pink (7.5YR 6-7/3)	5%	10-25% vfL-mL	cU-vcU	15%	2-11	Sand: subrnd-subang. Pebbles: subrnd or broken	poor	65-70	20-25	5-10	tr-2%		30	55			--	5-15	2-5	strong	Lithic grains include: 55% tuffs, 30% Tba, 5-10% rhy, 5-10% PA+HA, and trace-2% vTb. Feldspar grains include 70-80% plag and 20-30% K-spar. Tuffs and andesite are pebbles up to 2 cm across.
510-515	8	Slightly muddy sand	Pinkish gray (5-7.5YR 6-7/2. Lt red brn: 5YR 6/3	2-3%	<20% vfL-mL	mU-vcU	20%	2-12 mm	Sand: subrnd (minor subang). Pbles: subrnd (v few broken)	poor	--	--	--	XX						--	--	--		Interval not examined.
515-520	8	Sandy med-pebbles	Pinkish gray (5-7.5YR 6-7/2. Lt red brn: 5YR 6/3	2-3%	vfL-cU	vcL-vcU	50-60%	2-12 mm	Sand: subrnd-subang, Pbles: subrnd (minor subang or broken)	poor	N/A	N/A	N/A		~1%	35	55			N/A	N/A	N/A		Similar to interval 490-495' but with up to 35% Tba grains.
520-525	8	Slightly muddy sand	Pinkish gray to pink (7.5YR 7/2-3); lt red brn (5YR 6/3).	2-5%	<15% vfL-fU	mL-vcU	15%	2-13	Sand: subrnd-subang. Pbles: subrnd (minor subang or broken)	poor	75-85	10-20	5	tr		55-60	25-30			--	5-10	--	moderately strong	Lithic grains include: 55-60% Tba, 25-30% tuffs, 10-15% PA, trace Pa, trace vTb. Feldspar grains include 85-90% plag and 10-15% K-spar. 1x massive azurite observed.
Unit QTplt																								
Cuttings subunit 9: Muddy sand, subordinate sandy pebbles.																								

Appendix D. Description of cuttings from Percha Creek water well

Examined by Daniel Koning and Andy Jocehms on February 5, 2016, and June 4, 2016. (drilled by Rodgers-Hatch; located at SE1/4NE1/4 sec. 20, T16S, R5W)

Interval (ft)	unit	General lithology	Color	Percent Clay-silt	Subord sand size	Dominant sand size	% pbles	Pebble size (mm)	Roundness (m-vc sand & pbles)	Sorting (whole deposit)	%L[a]	%F[a]	%Q[a]	Percentages of key lithic grains: Basalt	Tsf ss	Bas. Andesite	Tuffs	K andesite	Pz chert, lm	%xtalline $CaCO_3$	%$CaCO_3$ coats[b]	%clay coats[b]	effervesence	remarks[c]
525-535	9	Silty-clayey coarse sand and pebbles	Lt brown to pink (7.5YR 6-7/3; lt red brn (5YR 6/3)	10-15%	30-35% vfL-cL	cU-vcU	15%	2-13	Sand: subrnd (minor subang). Pebles: subrnd-ang (or broken)	very poor	--	--	--							--	--	--		Interval not examined.
535-540	9	Slightly muddy sand		3-5%	<15% vfL-mU	cL-vcU	20%	2-12	Sand: subrnd-ang (most-least). Pebbles: subrnd-subang (1-5% broken)	very poor	70-80	15-20	5-10	tr-1%		45-55	40-45%			2-5	3-10	--	strong	Lithic grains include: 45-55% Tba, 40-45% tuffs; 5-15% PA, trace-1% bTb. Feldspar grains include 60-65% plag and 35-40% K-spar.
540-545	9	MISSING									--	--	--							--	--	--		*Interval missing.*
545-550	9	Sand with minor pebbles	Pinkish gray (5-7.5YR 6/2)	2-3%	Well-graded	fU-vcU	10-15%	2-15	Sand: subrnd-subang. Pebbles: rnd-ang (m subrnd-subang)	poor	60-65	30-35	0-5							--	2-3	--	moderate	Lithic grains include: 50-60% tuffs; 30% Tba, 10-20% PA+HA, trace bTb, trace Ka. Feldspar grains include 45% plag and 55% K-spar.
Cuttings subunit 10: Slightly reddish muddy sand. Notable left deflection in resistivity curves at 525-539 ft. Cs channel-fill at 550-563 ft. Carbonate fragments noted.																								
550-555	10	Reddish muddy sand	Pinkish gray to ltreddish brn (5YR 6/2-3)	5%	<15% vfL-fL	fU-vcU	15%	2-9 mm	subrnd-subang		--	--	--							--	--	--		Interval not examined.
555-560	10	Reddish muddy sand	Pinkish gray to ltreddish brn (5YR 6/2-3)	5-10%	<15% vfL-fL	fU-vcU	15%	2-9 mm	subrnd-subang															
560-565	10	AS ABOVE									80-85	10-15	0-5				60-70%	TR-5%	TR	--	3-5	--	very strong	Lithic grains include: 60-70% tuffs, 30% PA>Tba, 3-5% carbonate fragments, trace-5% Ka, trace j/c. Feldspar grains include 40% plag and 60% K-spar. Ka grains up to 0.75 cm across.
565-570	10	Clayey-silty sand and f pebbles	Pinkish gray (5YR 6-7/2)	5-8%	vfL-mU	cL-vcU	15%	2-10	Sand: subrnd-subang (minor ang). Pbles: subrnd-ang	poor	--	--	--							--	--	--		Interval not examined.
570-575	10	Clayey-silty sandw/ pebbles	Pinkishg gray - lt red brown (5YR 6-7/2; 6/3)	10-13%	vfL-mU	vcL-vcU	10-15%	2-10	sunbrnd-subang	very poor	?	?	?			10-20	65-70	tr	tr	--	5-10	--	very strong	Lithic grains include: 65-70% tuffs, 20% Tba~PA, 10% carbonate fragments (20% of which are xtalline), 2-5% Td, trace j/c, trace Ka. Feldspar grains include 50% plag and 50% K-spar.
575-585		AS ABOVE																						Interval not examined.
Cuttings subunit 11: Reddish muddy sand (more red than above and lesser pebbles)																								
585-590	11	Slightly clayey-silty sand	Lt reddish brown (5YR 6/3-4)	3-5%		vfL-vcU	5-7%	2-8	Sand: subrnd-subang. Pbles: ang-subrnd	very poor	70-80	15-20	10-15			15-20	60-65			--	3-5	--	weak to moderate	Lithic grains include: 60-65% tuffs, 20-25% Tba>PA, 8-10% carbonate fragments (5-10% of which are xtalline). Feldspar grains include 35% plag and 65% K-spar. Carbonate fragments are up to 1.7 cm across.
590-600	11	Clayey-silty coarse sand w/ pebbles	Lt red brn to pink (5YR 6/3-4; 7.5YR 6/3)	10-15%	fL-cU	vcL-vcU	10-12%	2-9 (mostly 2-5)	subrnd-subang	Poor														Interval not examined.
600-605	11	Clayey-silty coarse sand w/ pebbles	Lt red brn to lt brn (5YR 6/3-4; 7.5YR 6/3)	10-15%	fL-cU	vcL-vcU	10-12%	2-9 (mostly 2-5)	subrnd-subang	Poor	70-75	15-20	5-10			35-40	45-50		1-3%	--	trace	--	moderately strong	Lithic grains include: 45-50% tuffs, 35-40% Tba, 10% PA>HA, ≤3% j/c, ≤3% Td, 3% carbonate fragments (none xtalline). Feldspar grains include 50% plag and 50% K-spar.
605-620	11	Slightly clayey-silty sand w/ pebbles	Lt reddish brown (5YR 6/3)	5-10%	fU-mL (<=10% of vfL-fL)	mU-vcU	10-15%	2-8	subrnd-subang	Poor	--	--	--							--	--	--		Interval not examined.
620-625	11	AS ABOVE									75-80	20-25	0-5			40-45	45	5	tr	--	0	--	moderate	Lithic grains include: 45% tuffs, 40-45% Tba>PA, 5% Ka, 5% Td, 2-3% rhy, trace Pzc. Feldspar grains include 65% plag and 35% K-spar.
625-630	11	AS ABOVE									--	--	--							--	--	--		Interval not examined.
630-635	11	Slightly silty sand	Lt red brn to pink (5YR 6-7/3; 5YR 6/4))	5-10%		vfL-vcU	5-7%	2-10	subrnd-subang	Poor														
635-640	11	AS ABOVE									75-85	10-20	5			35	45	1-2		--	<1	--	weak	Lithic grains include: 45% tuffs, 35% Tba, 15% epa, 1-2% Ka, trace Pzc. Feldspar grains include 50% plag and 50% K-spar.
640-660	11	Clayey silty sand w/ pebbles	Lt reddish brown (5YR 6/3-4)	15%		vfL-vcU	10-15%	2-7	subrnd-subang	Poor	--	--	--							--	--	--		Interval not examined.

Appendix D. Description of cuttings from Percha Creek water well

Examined by Daniel Koning and Andy Jocehms on February 5, 2016, and June 4, 2016. (drilled by Rodgers-Hatch; located at SE1/4NE1/4 sec. 20, T16S, R5W)

														Percentages of key lithic grains										
Interval (ft)	unit	General lithology	Color	Percent Clay-silt	Subord sand size	Dominant sand size	% pbles	Pebble size (mm)	Roundness (m-vc sand & pbles)	Sorting (whole deposit)	%L[a]	%F[a]	%Q[a]	Basalt	Tsf ss	Bas. Andesite	Tuffs	K andesite	Pz chert, lm	%xtalline $CaCO_3$	$\%CaCO_3$ coats[b]	%clay coats[b]	effervesence	remarks[c]
660-665	11		AS ABOVE								80-85	15	0-5							--	2-5	--	weak to moderate	Lithic grains include: 40% Tba, 35% tuffs, 20% PA>Td, 2-3% chert, trace-1% Pzc, trace Ka, trace gypsum (?). Feldspar grains include 55-60% plag and 40-45% K-spar. Pzc grains up to 0.7 cm across. Gypsum occurs as tiny, non-calcareous, somewhat translucent flakes.
Cuttings subunit 12: Reddish muddy sand (more clayey and slightly more red than above) -- right shift in gamma curve																								
665-675	12	Clayey-silty sand w/ pebbles	Lt reddish brown (5YR 6/3-4)	15-18%		vfL-vcU	10-15%	2-9	subrnd-subang	Poor	--	--	--							--	--	--		Interval not examined.
675-680	12		AS ABOVE								70-80	15-20	5-10	3 - djk		55	30-35		5-10	--	--	trace-1	weak	Lithic grains include: 55% Tba, 30-35% tuffs, 5% chert, 1-3% carbonate fragments (none xtalline), trace-3% greenish clay balls, trace-2% Pzc. Feldspar grains include 60% plag and 40% K-spar.
680-690	12	Clay-silt and fine sand	Lt reddish brown (5YR 6/3-4)	15-18%	mL-vcU	vfL-fU	1-3%	2-3			--	--	--	1 - djk						--	--	--		Interval not examined.
Cuttings subunit 13: Interbedded muddy sand and sand -- left shift in gamma curve																								
690-695	13	Slightly clayey-silty sand	Lt reddish brown (5YR 6/3-4)	10-12%	vfL-fL; vcL-vcU	fU-cU	1%	2-5	subrnd-subang	Poor	65-75	20-25	5-10			30	60		5	trace	--	--	strong	Lithic grains include: 60% tuffs, 30% Tba>>PA+Td, 5% carbonate fragments (none xtalline), 5% chert. Feldspar grains include 40-45% plag and 55-60% K-spar.
695-700		Missing																						
700-705	13	Clayey-silty sand	Lt reddish brown (5YR 6/3-4)	15-20%	fL-mU	vfL-vfU; cL-vcU	2-4%	2-4	subrnd-subang	Poor	--	--	--							--	--	--		Interval not examined.
705-710	13	Sand	Lt reddish brown (5YR 6/3-4)	2-5%	mL-mU	vfL-fU; cL-vcU	1-3%	2-5	subrnd-subang	Poor	60-70	20-25	5-15			40	30		tr-3%	--	--	trace	weak to moderate	Lithic grains include: 40% Tba, 35% tuffs, 10-15% epa~PA+Td, 5-10% light tan clay balls, trace-3% Pzc, trace j/c. Feldspar grains include 65% plag and 35% K-spar.
710-715	13	Slightly clayey-silty sand	Lt reddish brown	10-12%		vfL-vcU	0		subrnd (minor subang)	Poor	--	--	--							--	--	--		Interval not examined.
715-720	13	Slightly clayey-silty sand	Lt reddish brown	10-12%	vfL-mU	cL-vcU	0.5-1%	2-4			75-80	15-20	0-10			45-50	35-40		2-3	--	trace	--	moderately strong	Lithic grains include: 45-50% Tba>PA, 35-40% tuffs, 10-15% Td+HA, 2-3% light tan clay balls, 2-3% Pzc, trace Ka. Feldspar grains include 60% plag and 40% K-spar.
Unit Tsu																								
Cuttings subunit 14: Fining-upward interbedded clay & sand of basin floor facies -- Prominent left shift in neutron and resistivity curves, but they are still not at lowest values. Clay chips at top. Rio Grande lake or playa?																								
720-725	14	Clayey-silty sand w/ clay chips	Lt reddish brown (5YR 6/3-4)	15-18%		vfL-vcU	1-4%	2-4	subrnd-subang	Poor	--	--	--							--	--	--		Interval not examined.
725-730	14		AS ABOVE								80	15-20	0-5			20-25	45-55		tr-3%	--	1-2	--	weak	Lithic grains include: 45-55% tuffs, 20-25% Tba>PA, 15-20% reddish clay chips, trace-2% chert, trace-1% Pzc. Feldspar grains include 50% plag and 50% K-spar.
730-735	14		AS ABOVE																					Interval not examined.
735-750	14	Slightly clayey-silty cs sand	Lt reddish brown (5YR 6/3-4)	10-15%	vfL-mU	cL-vcU	5-10%	2-10	subrnd (minor subang)	Poor	--	--	--							--	--	--		Interval not examined.
750-755	14		AS ABOVE								80-85	10-15	0-5			35-40	45-50	tr-3%		--	--	5-10% films	weak	Lithic grains include: 45-50% tuffs, 35-40% Tba, 15-25% reddish clay chips, 3-5% HA+Td, trace-3% Ka. Feldspar grains include 40% plag and 60% K-spar.
755-760	14	Slightly clayey-silty sand w/ pebbles	Lt reddish brown (5YR 6/3-4)	10-13%	vfL-fU	mL-vcU	12-15%	2-9	subrnd-subang (minor ang)	Very poor	--	--	--							--	--	--		Interval not examined.
760-765	14		AS ABOVE								70-80	10-20	5-10			20-25	50	tr-2		--	2-5	5-15% films	weak	Lithic grains include: 50% tuffs, 20-25% Tba, 10% reddish clay chips, 5-10% PA (f-g), 5-10% HA+Td, trace-5% rhy, trace-2% Ka. Feldspar grains include 35-40% plag and 60-65% K-spar.
765-770	14	Coarse sand	Lt reddish brown to pink (5YR 6-7/3)	2%	vfU-fL	fU-vfU (much vcU)	20%	2-7	subrnd-subang	Poor	60-70	25-30	5-15			comb	35	5	tr-3%	--	5-10	trace-2	moderate	Lithic grains include: 45-55% Tba+PA, 35% tuffs, 5-10% Td, 5% Ka, trace-3% j/c, trace rhy, trace reddish clay chips. Feldspar grains include 50% plag and 50% K-spar.
770-775	14	Slightly clayey coarse sand	Lt reddish brown (6/3-4, mostly 6/3)	10%	VfL-mU	cL-vcU	15-20%	2-10	subrnd-subang	Poor	--	--	--							--	--	--	--	Interval not examined.
Cuttings subunit 15: Pebbly coarse sand -- correlate to 748-755 ft on all logs. It is a little washed out.																								
775-780	15	Pebbly coarse sand	Pinkish gray, lt brn, lt red brn (5-7.5YR 6/2-3)	2-3%	fL-mL	mU-vcU	10-15%	2-7	subrnd-subang	Poor														

Appendix D. Description of cuttings from Percha Creek water well

Examined by Daniel Koning and Andy Jocehms on February 5, 2016, and June 4, 2016. (drilled by Rodgers-Hatch; located at SE1/4NE1/4 sec. 20, T16S, R5W)

														Percentages of key lithic grains										
Interval (ft)	unit	General lithology	Color	Percent Clay-silt	Subord sand size	Dominant sand size	% pbles	Pebble size (mm)	Roundness (m-vc sand & pbles)	Sorting (whole deposit)	%L[a]	%F[a]	%Q[a]	Basalt	Tsf ss	Bas. Andesite	Tuffs	K andesite	Pz chert, lm	%xtalline $CaCO_3$	%$CaCO_3$ coats[b]	%clay coats[b]	effervesence	remarks[c]
780-785	15	AS ABOVE									65-70	20	10-15			20	55-65		3-10	--	trace-3	15-20	weak to moderate	Lithic grains include: 55-65% tuffs, 20% Tba, 3-10% j/c, 5% rhy, trace-5% PA. Feldspar grains include 30-40% plag and 60-70% K-spar.
785-790	15	Pebbly coarse sand	Pinkish gray, lt brn, lt red brn (5-7.5YR 6/2-3)	<1%		cL-vcU	15-20%	2-11	subrnd-subamg	Moderate	--	--	--							--	--	--	--	Interval not examined.
790-795	15	AS ABOVE									75-80	15-20	5-10							--	--	5-15	very weak	Lithic grains include: 50% tuffs, 30-35% Tba, 5-10% Ka, trace-3% chert. Feldspar grains include 50% plag and 50% K-spar. Tuff pebbles up to 0.8 cm across. Copper mineralization (including possible native Cu) on 3-5% of grains, particularly dark, poorly consolidated fragments.
795-800	15	Slightly clayey cs sand w/ pebbles	Pink gray to lt red brown (5YR 6/2-4)	3%	<2% vf-m	cL-vcU	10-13%	2-8			--	--	--							--	--	--	--	*Interval missing.*
Cuttings subunit 16: Marginal basin floor facies																								
800-845	16	Missing																						
845-850	16	Clayey sand and pebbles	Pinkish gray to lt brown (7.5YR 6/2-3)	15%	<25% vfL-mL (mostly fU)	mU-vcU	30%	2-14	Pebles: subrnd-ang (broken). Sand: subrnd-subang (minor ang)		60-65	25-30	5-10				45		2-5	--	trace	--	weak to moderate	Lithic grains include: 45% tuffs, 40-45% Tba+epa, 5% rhy, 2-5% Pzc, trace reddish clay chips. Feldspar grains include 50% plag and 50% K-spar. Gravelly interval w/ angular pebbles up to 2.3 cm across.
850-855	16	Sand and clay	Reddish brown (5YR 5/4) for clay	20-25%		cL-vcU	5-15%	2-13 (mostly 2-5)	Pbles: subrnd-ang (broken); sand: subrnd-subang		--	--	--							--	--	--	--	Interval not examined.
855-860	16	Clay and sand		50%		cL-vcU	5-15%	2-13 (mostly 2-5)	Pbles: subrnd-ang (broken); sand: subrnd-subang		--	--	--			20	15-20		6	--	--	--	weak to moderate	Lithic grains include: 45-50% reddish clay chips, 20% dark Tba, 15-20% tuffs, 3% chert, 3% Pzc, 3% Td. Feldspar grains include 65-70% plag and 30-35% K-spar.
860-865	16	Clay and sand		80-85%		cL-vcU	5-15%	2-13 (mostly 2-5)	Pbles: subrnd-ang (broken); sand: subrnd-subang		--	--	--							--	--	--	--	Interval not examined.
Cuttings subunit 17: Playa facies																								
865-875	17	Clay				10% mU-vcU	2-5%	2-4	subrnd-subang															
875-915	17	Clay	Reddish brown			10-15% cL-vcU	3%	2-8	subrnd-subang															
915-940	17	Clay	Reddish brown to lt reddish brown (5YR 5-6/3; 5/4)			<5% mU-vcU																		
940-955	17	Clay (bigger chips)	Lt brown (7.5YR 6/3-4)			<8% c-vc sand	<5%	2-6			--	--	--							--	--	--	--	Interval not examined.
955-960	17	Clay	5-7.5YR 6-7/3; 6-7/4			<5%																		
960-995	17	Clay	5YR 6/3-4; 5YR 5/4			<5% cL-vcU	tr-2%	2-8																
995-1000	17	Clay	5YR 5-6/4			1% clumps of vfL-vfU sand																		

[a]Grain lithology classes: L = lithic, F = feldspar, and Q = quartz.

[b]Defined as percentage of grains with ≥ 75% of surface coated by a given material.

APPENDIX E

ELECTRIC WELL LOG FOR CABALLO LAKE-PERCHA CREEK

FIELD AREA. WELL ID: HATCH WELL NO.1-DEEPEN

JET WEST GEOPHYSICAL SERVICES, LLC.

COMPANY	Rodgers & Co		
WELL ID	Hatch Well No.1-Deepen		
FIELD	Caballo Lake-Percha Creek		
COUNTY	Sierra	STATE	New Mexico
TYPE OF LOG:	Gamma Ray,Neutron	OTHER SERVICES	Electric Log
LOCATION			
SEC	TWP	RGE	Permit No.

NAD

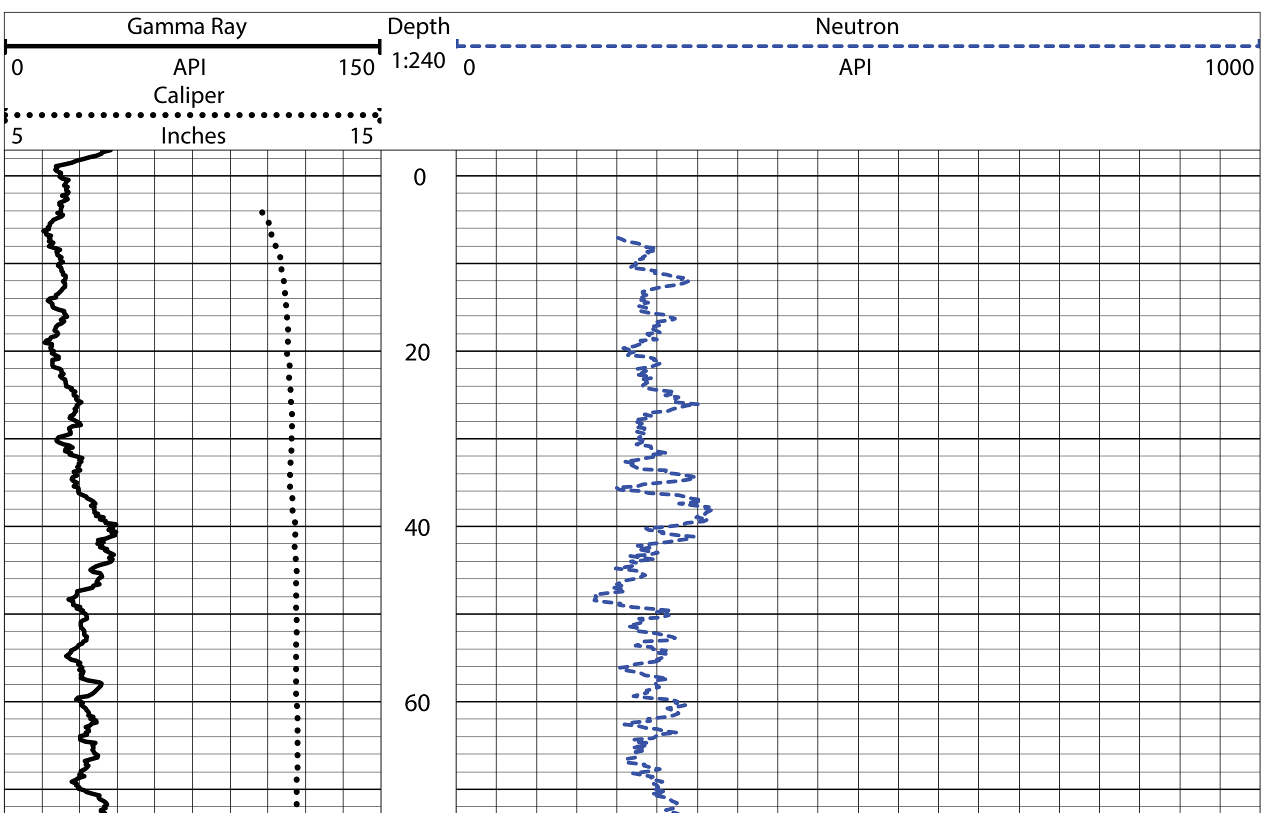
North:

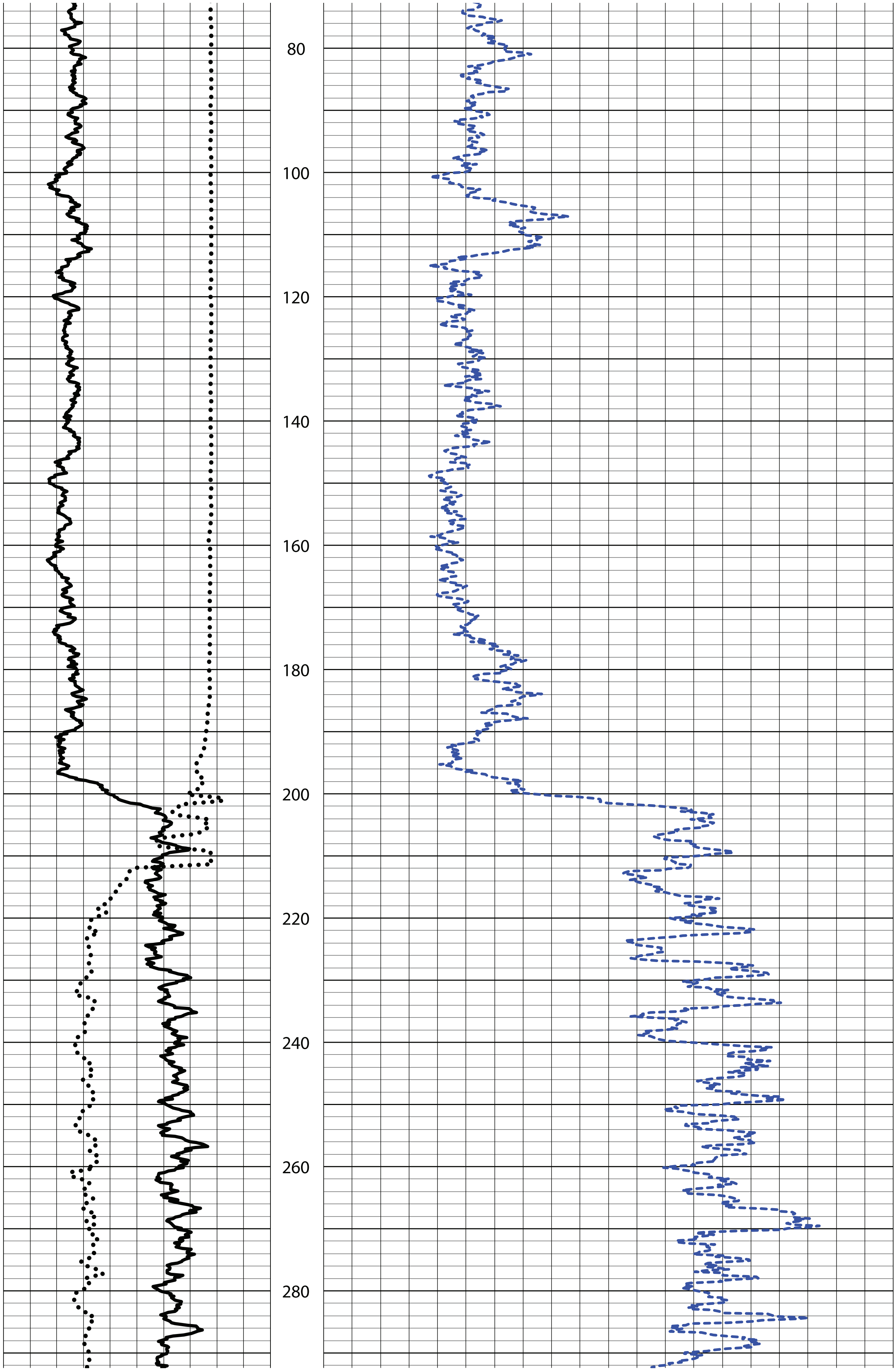
West:

PERMANENT DATUM	Ground Level	ELEVATION		K.B.	
LOG MEAS. FROM	Ground Level	ABOVE PERM. DATUM		T.O.C	
DRILLING MEAS. FROM	Ground Level			G.L.	
DATE	11-13-2014	TYPE FLUID IN HOLE		Drill Mud	
RUN No.	1	SALINITY			
TYPE LOG	GRN	DENSITY			
DEPTH-DRILLER	1000 ft.	LEVEL		Full	
DEPTH-LOGGER	996 ft.	MAX. REG. TEMP			
BTM LOGGED INTERVAL	996 ft.	DIGITIZE INTERVAL		0.2 ft.	
TOP LOGGED INTERVAL	Surface				
OPERATING RIG TIME					
RECORDED BY	A.Henderson				
WITNESSED BY	J.Witcher				

RUN	BOREHOLE RECORD			CASING RECORD			
NO.	BIT	FROM	TO	SIZE	WGT.	FROM	TO
1	7-7/8 in.	0 ft.	1000 ft.	16 in. OD	steel	0 ft.	200 ft.
2							
3							

REMARKS:

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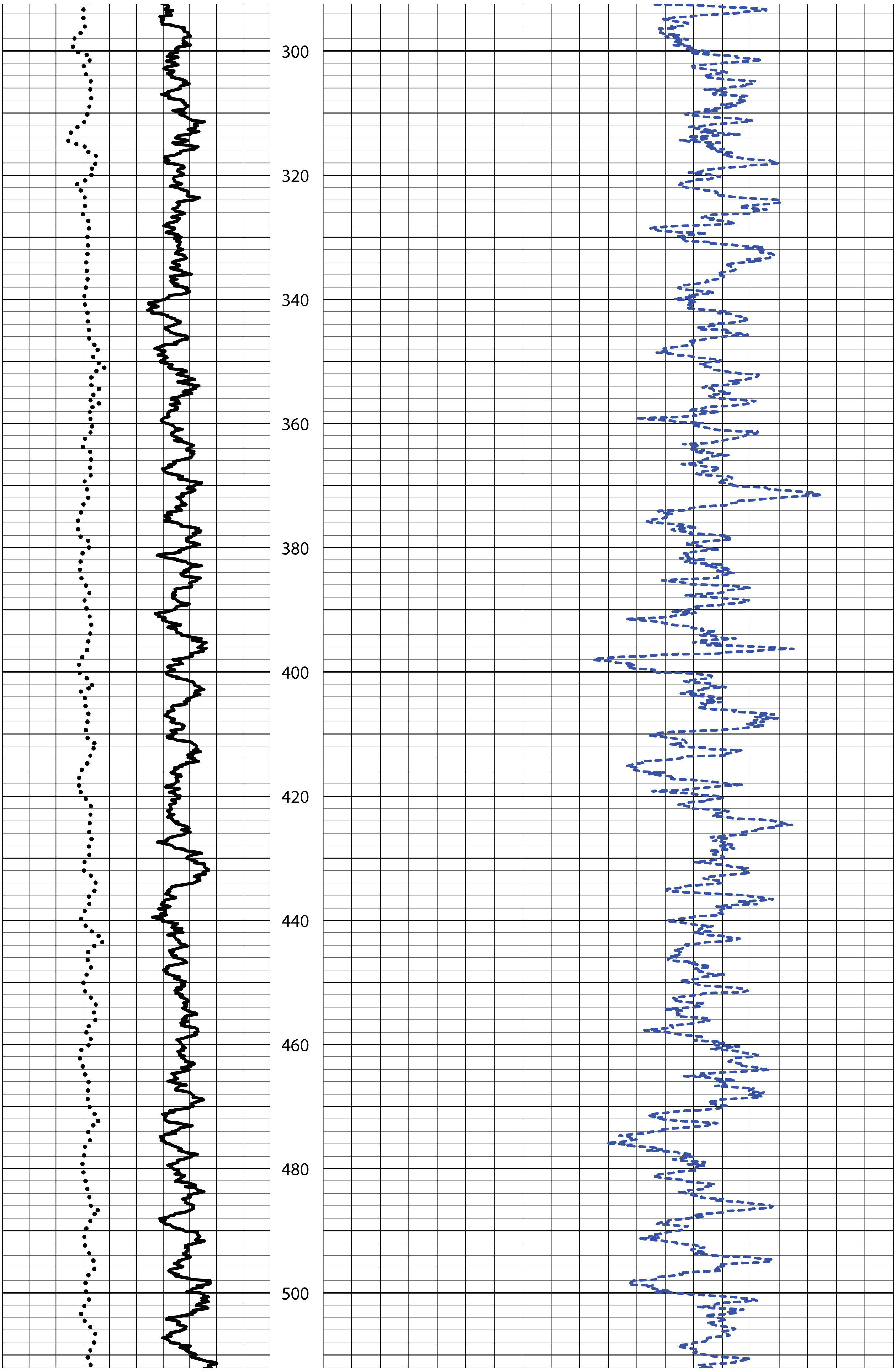

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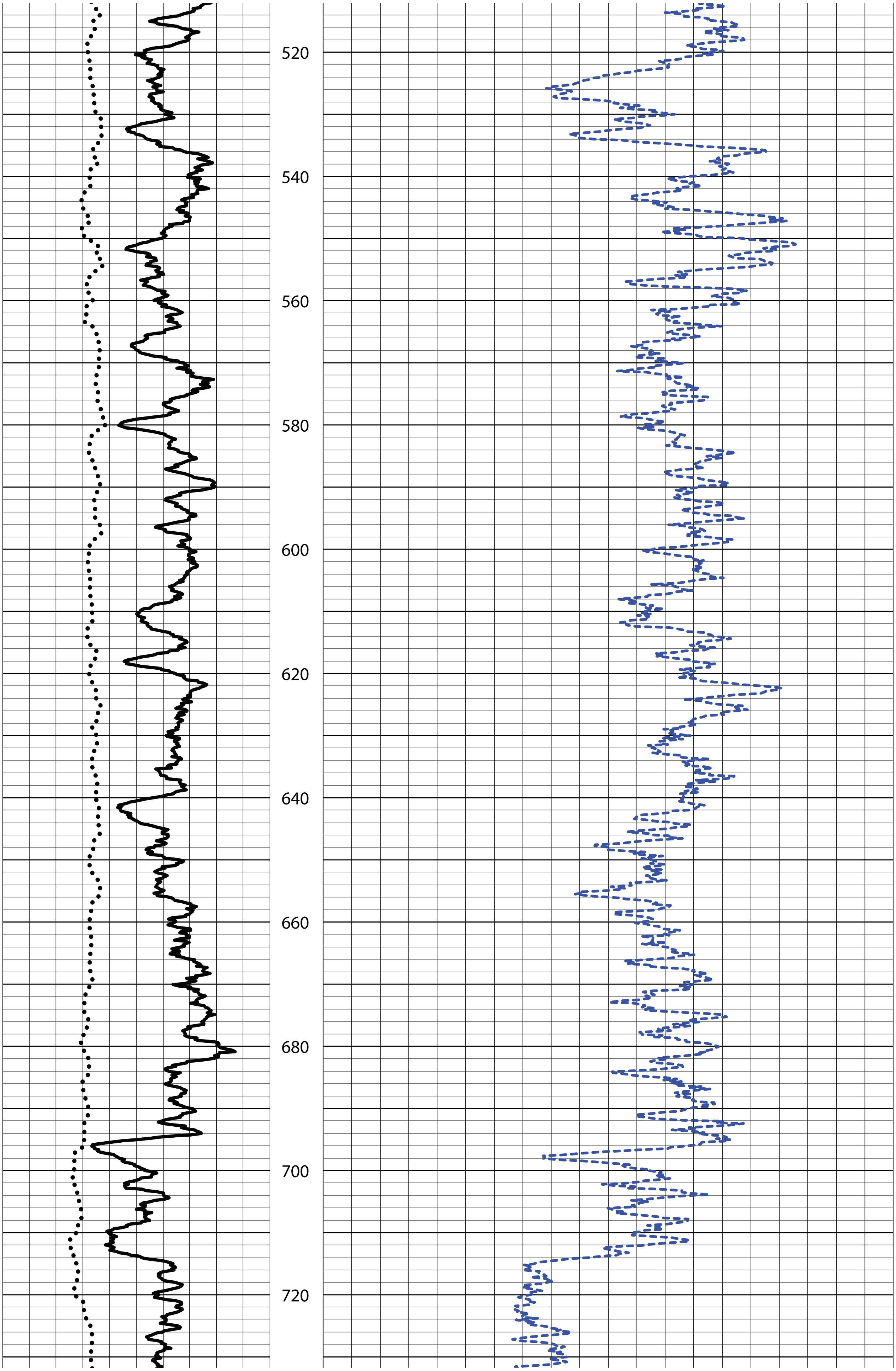
380
400
420
440
460
480
500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620
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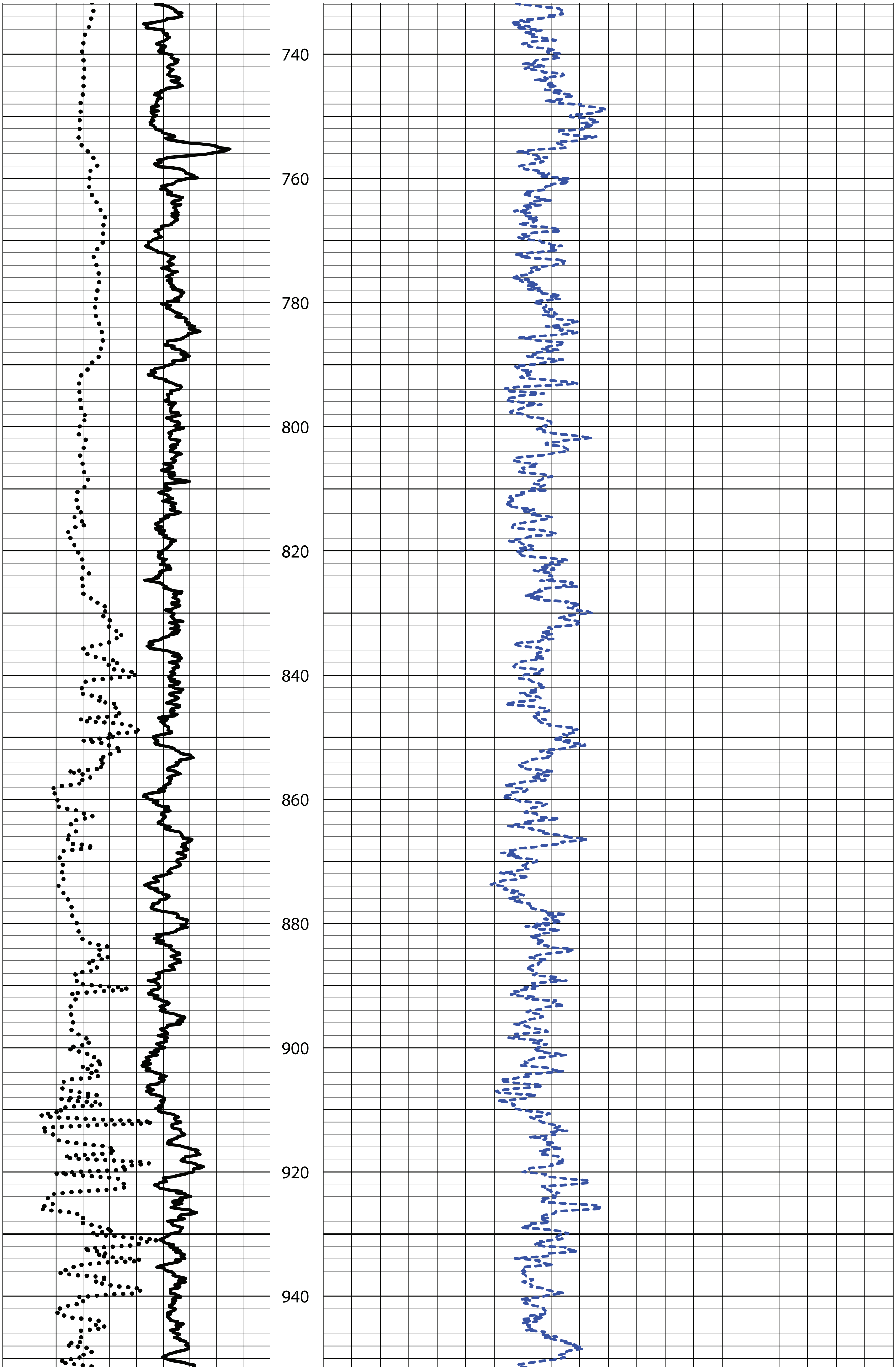
680
700
720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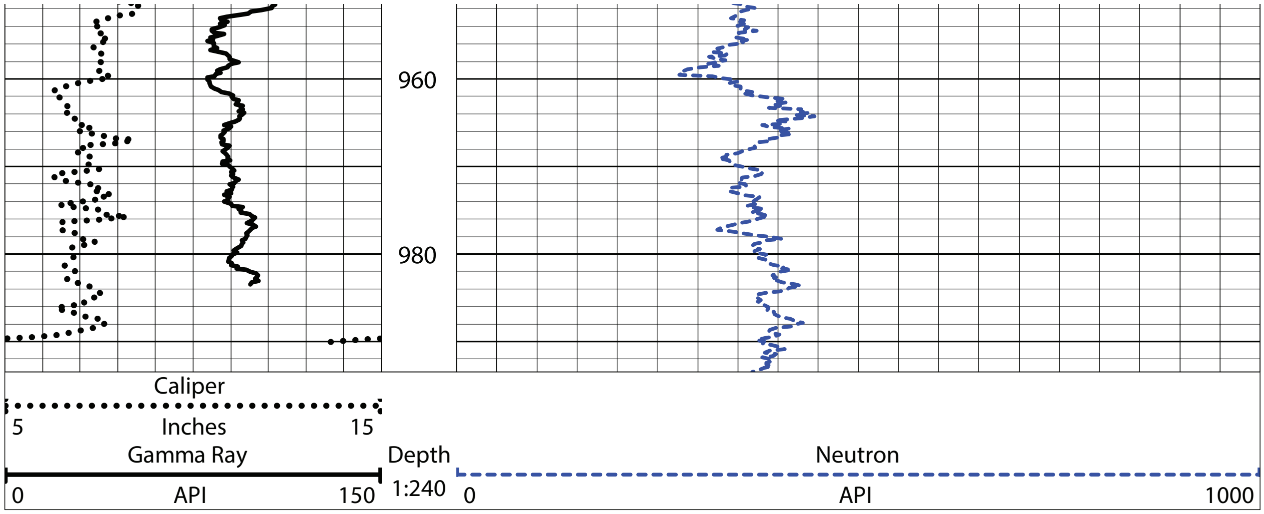
760
780
800
820
840
860
880
900
920
940


960
980
Caliper
5
Inches
15
Gamma Ray
0
API
150
Depth
1:240
Neutron
0
API
1000

APPENDIX F

TABLE OF MAXIMUM CLAST SIZES MEASURED IN THE NORTHERN HALF OF THE SKUTE STONE ARROYO QUADRANGLE

MAXIMUM CLAST SIZES MEASURED IN THE NORTHERN HALF OF THE SKUTE STONE ARROYO QUADRANGLE

QTppuc clast sizes		
Station	a axis (cm)	b axis (cm)
WS-332	47	32
	35	22
	38	28
	36	30
	37	28
	41	32
WS-350	37	20
	25	22
	38	25
	28	23
	45	21
WS-359	37	22
	23	18
	37	21
	24	15
	30	22
WS-375b	29	18
	26	20
	21	14
	29	20
	33	19
WS-403	30	22
	18	17
	27	20
	22	17
	33	15
	27	16
WS-426	30	15
	35	21
	25	15
	25	18
	22	15
WS-461c	41	30
	33	29
	29	17
	29	19
	27	25
	80	64
WS-464	45	29
	45	29
	38	29
	42	37
	42	37

Qta5 clast sizes		
Station	a axis (cm)	b axis (cm)
WS-375b	33	29
	41	20
	40	28
	39	29
	50	40

Qta4 clast sizes		
Station	a axis (cm)	b axis (cm)
WS-358	82	60
	40	34
	83	45
	56	35
	55	45
WS-399b	40	27
	54	25
	38	24
	47	29
	44	35
WS-462	80	43
	41	37
	44	38
	64	52
	46	32

Qta3c clast sizes		
Station	a axis (cm)	b axis (cm)
WS-340a	26	24
	28	24
	32	22
	34	25
	26	26
	60	32
WS-458a	30	24
	41	40
	34	30
	40	29
	41	35

MAXIMUM CLAST SIZES MEASURED IN THE NORTHERN HALF OF THE SKUTE STONE ARROYO QUADRANGLE

Qta2c clast sizes		
Station	**a axis (cm)**	**b axis (cm)**
WS-331a	41	36
	54	42
	35	34
	52	31
	35	32
WS-331e	65	43
	59	42
	61	37
	45	32
	46	43

Qt2a clast sizes		
Station	**a axis (cm)**	**b axis (cm)**
WS-411	33	26
	43	28
	45	26
	33	29
	54	45
	53	44
WS-417	47	30
	30	27
	31	21
	29	24

Qta3b clast sizes		
Station	**a axis (cm)**	**b axis (cm)**
WS-339	50	38
	50	35
	50	30
	51	45
	75	40
WS-336	36	28
	35	22
	37	28
	52	30
	39	28
	50	50

Qta2b clast sizes		
Station	**a axis (cm)**	**b axis (cm)**
WS-385	53	41
	45	30
	38	30
	53	41
	45	30
	43	29
WS-447a	41	15
	30	19
	37	36
	34	20
	44	30

Qahap clast sizes		
Station	**a axis (cm)**	**b axis (cm)**
WS-346	38	26
	20	15
	30	20
	25	13
	25	15

TABLE OF MAXIMUM CLAST SIZES MEASURED IN THE SOUTHERN HALF OF THE SKUTE STONE ARROYO QUADRANGLE

MAXIMUM CLAST SIZES MEASURED IN THE SOUTHERN HALF OF THE SKUTE STONE ARROYO QUADRANGLE

Tsu clast sizes		
Station	**a axis (cm)**	**b axis (cm)**
WS-523	26	14
	25	15
	32	19
	21	18
	22	17
	29	27
WS-530	25	23
	20	15
	26	23
	21	19
	30	21
WS-535	24	12
	20	13
	22	18
	28	19
	30	19
WS-537	30	20
	22	13
	20	15
	51	30
	27	25
WS-611	13	10
	14	11
	14	10
	13	11
	16	9
WS-614	14	8
	13	10
	30	26
	9	7
	9	6
	19	10
Average		16.03125
Median		15

QTpl clast sizes		
Station	**a axis (cm)**	**b axis (cm)**
WS-585	36	22
	37	25
	30	19
	58	20
	28	18
WS-592	34	22
	20	15
	24	13
	28	20
	22	19

Tsml clast sizes		
Station	**a axis (cm)**	**b axis (cm)**
WS-551	16	15
	15	14
	17	11
	16	15
	15	12
	17	11
WS-552	30	30
	>21	14
	15	10
	36	21
	22	14
WS-557	15	12
	>13	12
	18	11
	21	13
	15	12
Average		14.1875
Median		12.5

QTppuc clast sizes		
Station	**a axis (cm)**	**b axis (cm)**
WS-571	28	25
	28	15
	25	18
	30	28
	53	16

QTpu clast sizes		
Station	**a axis (cm)**	**b axis (cm)**
WS-579	26	15
	15	10
	21	15
	26	19
	30	20
	17	15

QTplt clast sizes		
Station	**a axis (cm)**	**b axis (cm)**
WS-609	13	12
	15	7
	25	13
	17	15
	16	11

MAXIMUM CLAST SIZES MEASURED IN THE SOUTHERN HALF OF THE SKUTE STONE ARROYO QUADRANGLE

Qtt5 clast sizes		
Station	**a axis (cm)**	**b axis (cm)**
WS-586	60	30
	43	31
	40	25
	55	41
	42	30
WS-728	35	23
	57	30
	24	15
	35	21
	24	14
	25	16

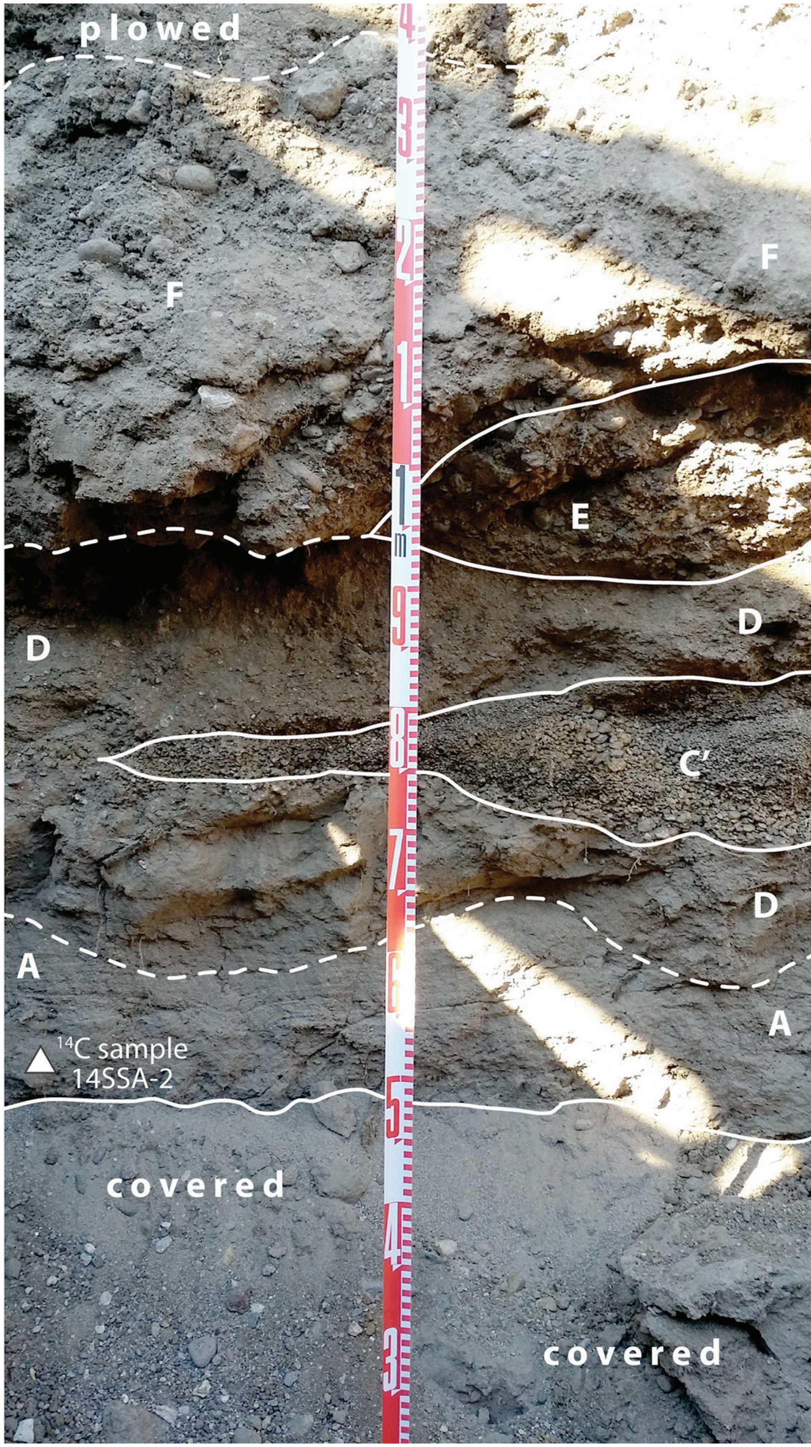
Qtt3 clast sizes		
Station	**a axis (cm)**	**b axis (cm)**
WS-536	35	35
	32	28
	25	15
	26	21
	25	21
WS-554	45	41
	35	23
	26	17
	30	23
	30	21

Qtt4 clast sizes		
Station	**a axis (cm)**	**b axis (cm)**
WS-556	51	45
	96	58
	51	41
	85	38
	55	34

Qtt2 clast sizes		
Station	**a axis (cm)**	**b axis (cm)**
WS-553	23	18
	20	18
	36	26
	32	27
	30	25
	24	22

APPENDIX G

ANNOTATED FIGURES OF SOIL PROFILE FOR LAS ANIMAS CREEK



Ap horizon

F) Sandy gravel: mostly matrix-supported with 80% pebbles and 20% cobbles. Clayey sand is vfL-cU, p sorted, and ang-subrnd. Locally preserves Bw soil horizon in upper 15 cm.

Sharp, locally scoured contact

E) Sandy gravel: clast- to matrix-supported with 90% pebbles and 10% cobbles. Sand is vfU-cU, p sorted, and ang-subrnd. Common manganese coats (up to 90% of clast surfaces). Non-calcareous.

Sharp, locally scoured contact

D) Pebbly sand: fL-cU, p sorted, subang-subrnd. 10% pebbles. Massive. Weakly calcareous, occasionally bioturbated.

C′) Granule-pebble gravel: clast-supported to open-framework. Well imbricated and cross-stratified with planar foresets up to 12 cm thick. Lenticular with abrupt contacts.

Sharp, pervasively scoured contact

A) Sandy silt to silty-clayey sand: Ripple laminated. Sand is fL-mU, mod-well sorted, and subrnd. Abundant charcoal and shells.

Disturbed, but has weak Bt soil horizon. Silty-clayey vf-f sand. 0.5% vf-f (mostly) to vc scattered pebbles and 1-3% scattered m-vc sand. Massive. Abundant charcoal

Subtle, gradual contact. 7 cm of wavy relief

Slightly disturbed and has weak Btk horizon. Fines upward from vf-mL sand to silt-vf sand. Massive.Strong HCl effervescence (stage I).

Sharp, scoured contact

Bk soil horizon with tract CaCO3 filaments. Silt and vf-f sand with 10-20% m-vc sand and 10% scattered vf-vc pebbles whose concentration increases downwards. Massive and bioturbated.

gradual contact over 3-5 cm and wavy

Sandy gravel: mostly clast-supported and consists of vf-vc pebbles and 5% cobbles. Sand is mostly mL-vcU, p sorted, and subrnd. ~20% faint clast coatings by CaCO3. Clast imbrication indicates 055° paleoflow.

Sharp, scoured contact

Fining-upward from clast-supported, sandy gravel (~050° paleoflow from clast imbrication) up to silty vfL-cL sand. Weak ped development at top but no to very weak HCl effervescence.

APPENDIX H

SUMMARY REPORT AND TABLE OF ^{40}AR/^{39}AR

$^{40}Ar/^{39}Ar$ Geochronology Results from the Skute Stone Arroyo Quadrangle

By

Lisa Peters

OCTOBER 23, 2015

Prepared for
Dan Koning
Bureau of Geology
801 Leroy Place
Socorro, NM, 87801

NEW MEXICO GEOCHRONOLOGY RESEARCH LABORATORY (NMGRL)

CO-DIRECTORS

DR. MATTHEW T. HEIZLER

DR. WILLIAM C. MCINTOSH

LABORATORY TECHNICIAN

LISA PETERS

Internal Report #: NMGRL-IR-881

Table 1. Summary of $^{40}Ar/^{39}Ar$ results and analytical methods

Sample	Lab #	Irradiation	mineral	age analysis	steps/analyses	Age	±2σ	MSWD	comments
140715A-SSA-A3	63599	276	groundmass concentrate	bulk step-heat	8	4.46	0.04	12.58	weighted mean
WS-112-140715-djk	63598	276	groundmass concentrate	bulk step-heat	8	4.46	0.03	7.16	weighted mean
WS-113b-14715-djk	63597	276	groundmass concentrate	bulk step-heat	7	4.58	0.07	5.00	weighted mean
140715B-SSA-A3	63600	276	groundmass concentrate	bulk step-heat	7	5.01	0.06	3.22	weighted mean
WS-103-140715-djk	63601	276	groundmass concentrate	bulk step-heat	8	5.18	0.08	2.21	weighted mean
P-13-djk	63596	276	groundmass concentrate	bulk step-heat	5	27.30	0.12	2.73	weighted mean

Sample preparation and irradiation:
Minerals separated with standard heavy liquid, Franz Magnetic and hand-picking techniques.
Samples in NM-276 irradiated in a machined Aluminum tray for 16 hours in C.T. position, USGS TRIGA, Denver, Colorado.
Neutron flux monitor Fish Canyon Tuff sanidine (FC-2). Assigned age = 28.201 Ma (Kuiper et al., 2008).

Instrumentation:
Total fusion monitor analyses performed on a Argus VI mass spectrometer on line with automated all-metal extraction system. System = Jan
Step-heat analyses performed on a Argus VI mass spectrometer on line with automated all-metal extraction system. System = Obama
Multi-collector configuration: 40Ar-H1, 39Ar-Ax, 38Ar-L1, 37Ar-L2, 36Ar-CDD
Flux monitors fused with a Photon Machines Inc. CO_2 laser. Groundmass concentrate and biotite step-heated with a Photon Machine Inc. Diode laser.

Analytical parameters:
Sensitivity for the Argus VI with the Diode laser (step-heated samples) is 9.84e-17 moles/fA.
Sensitivty for the Argus VI with the CO2 laser (fused monitors)is 4.62 e-17 moles/fA.
Typical system blank and background was 97.9, 0.39, 1.38, 8.17, 0.37 x 10^{-18} moles at masses 40, 39, 38, 37 and 36, respectively for the laser analyses.
J-factors determined by CO_2 laser-fusion of 6 single crystals from each of 8 radial positions around the irradiation tray.
Decay constants and isotopic abundances after Minn et al., (2000).

Table 2. ^{40}Ar/^{39}Ar analytical data.

	ID	Power (Watts)	^{40}Ar/^{39}Ar	^{37}Ar/^{39}Ar	^{36}Ar/^{39}Ar (x 10^{-3})	^{39}Ar$_K$ (x 10^{-15} mol)	K/Ca	^{40}Ar* (%)	^{39}Ar (%)	Age (Ma)	±1σ (Ma)
	P-13-djk, whole rock, 10.56 mg, J=0.0039383±0.02%, D=1±0, NM-276A, Lab#=63596-01										
X	A	1	194.0	0.3447	645.2	2.63	1.5	1.7	0.8	23.88	1.98
X	B	1	38.87	0.2387	121.3	5.58	2.1	7.8	2.5	21.79	0.46
X	C	1	24.47	0.2131	71.18	13.15	2.4	14.1	6.5	24.65	0.25
X	D	2	15.80	0.1385	41.12	17.79	3.7	23.1	11.8	26.13	0.14
X	E	2	10.52	0.0998	22.80	25.9	5.1	36.0	19.6	27.10	0.09
	F	2	8.593	0.1256	16.12	39.8	4.1	44.6	31.7	27.42	0.06
	G	3	10.38	0.1678	22.26	69.5	3.0	36.7	52.7	27.28	0.07
	H	5	12.39	0.1791	29.06	96.6	2.8	30.8	81.9	27.28	0.08
	I	7	14.20	0.1317	35.24	20.5	3.9	26.7	88.0	27.12	0.12
	J	10	17.52	0.1632	46.54	21.8	3.1	21.5	94.6	26.99	0.15
X	K	15	24.12	0.1941	68.46	17.77	2.6	16.2	100.0	27.89	0.20
	Integrated age ± 2σ			n=11		331.0	3.1		K2O=3.06	27.00	0.08
	Plateau ± 2σ		**steps F-J**	**n=5**	**MSWD=2.73**	**248.2**	**3.2 ±1.1**		**75.0**	**27.30**	**0.12**
	Isochron±2σ		steps A-K	n=11	MSWD=24.77		^{40}Ar/^{36}Ar=292.7±2.5			27.70	0.59
	WS-113b-14715-djk, whole rock, 10.7 mg, J=0.0039392±0.02%, D=1±0, NM-276A, Lab#=63597-01										
Xi	A	1	37.72	0.9826	122.3	1.227	0.52	4.4	0.9	11.84	0.83
X	B	1	4.936	0.7067	14.37	8.05	0.72	15.0	6.6	5.34	0.08
	C	1	1.434	0.6258	2.806	24.4	0.82	45.2	24.1	4.67	0.02
	D	2	1.278	0.7409	2.400	15.93	0.69	48.6	35.4	4.47	0.03
	E	2	1.350	1.192	2.732	10.97	0.43	46.8	43.3	4.55	0.03
	F	2	1.719	1.705	4.147	8.47	0.30	36.3	49.3	4.49	0.06
	G	3	3.320	2.690	9.803	16.92	0.19	19.1	61.4	4.56	0.06
	H	5	3.242	3.323	9.684	22.7	0.15	19.8	77.6	4.63	0.06
	I	7	3.503	3.602	10.62	12.51	0.14	18.5	86.5	4.67	0.07
X	J	10	5.927	3.453	18.64	12.72	0.15	11.6	95.6	4.97	0.10
X	K	15	5.075	4.134	15.93	6.15	0.12	13.7	100.0	5.02	0.12
	Integrated age ± 2σ			n=11		140.1	0.24		K2O=1.28	4.75	0.04
	Plateau ± 2σ		**steps C-I**	**n=7**	**MSWD=5.00**	**112.0**	**0.42 ±0.54**		**79.9**	**4.58**	**0.07**
	Isochron±2σ		steps B-K	n=10	MSWD=8.82		^{40}Ar/^{36}Ar=299.8±3.3			4.48	0.12
	WS-112-140715-djk, whole rock, 10.32 mg, J=0.0039339±0.02%, D=1±0, NM-276A, Lab#=63598-01										
Xi	A	1	5.089	0.9756	14.73	1.030	0.52	16.0	0.8	5.86	0.30
Xi	B	1	1.234	0.7592	1.891	5.15	0.67	59.2	4.9	5.26	0.05
Xi	C	1	0.7336	0.6786	0.4259	30.9	0.75	89.3	29.6	4.71	0.01
	D	2	0.6757	0.6647	0.3257	26.3	0.77	92.5	50.6	4.50	0.01
	E	2	0.6753	0.8219	0.4097	13.49	0.62	90.7	61.4	4.41	0.01
	F	2	0.7008	1.677	0.7271	9.85	0.30	87.5	69.2	4.42	0.02
	G	3	0.8297	3.992	1.795	16.58	0.13	73.9	82.5	4.42	0.03
	H	5	1.009	5.559	2.833	12.59	0.092	60.7	92.5	4.42	0.03
	I	7	0.8678	4.448	2.060	2.13	0.11	70.3	94.2	4.40	0.08
	J	10	0.8339	4.490	1.993	1.208	0.11	71.9	95.2	4.32	0.12
	K	15	0.9814	6.250	2.890	6.02	0.082	63.6	100.0	4.51	0.05
	Integrated age ± 2σ			n=11		125.2	0.25		K2O=1.18	4.56	0.02
	Plateau ± 2σ		**steps D-K**	**n=8**	**MSWD=7.16**	**88.2**	**0.41 ±0.54**		**70.4**	**4.46**	**0.03**
	Isochron±2σ		steps D-K	n=8	MSWD=7.83		^{40}Ar/^{36}Ar= 290±17			4.47	0.06

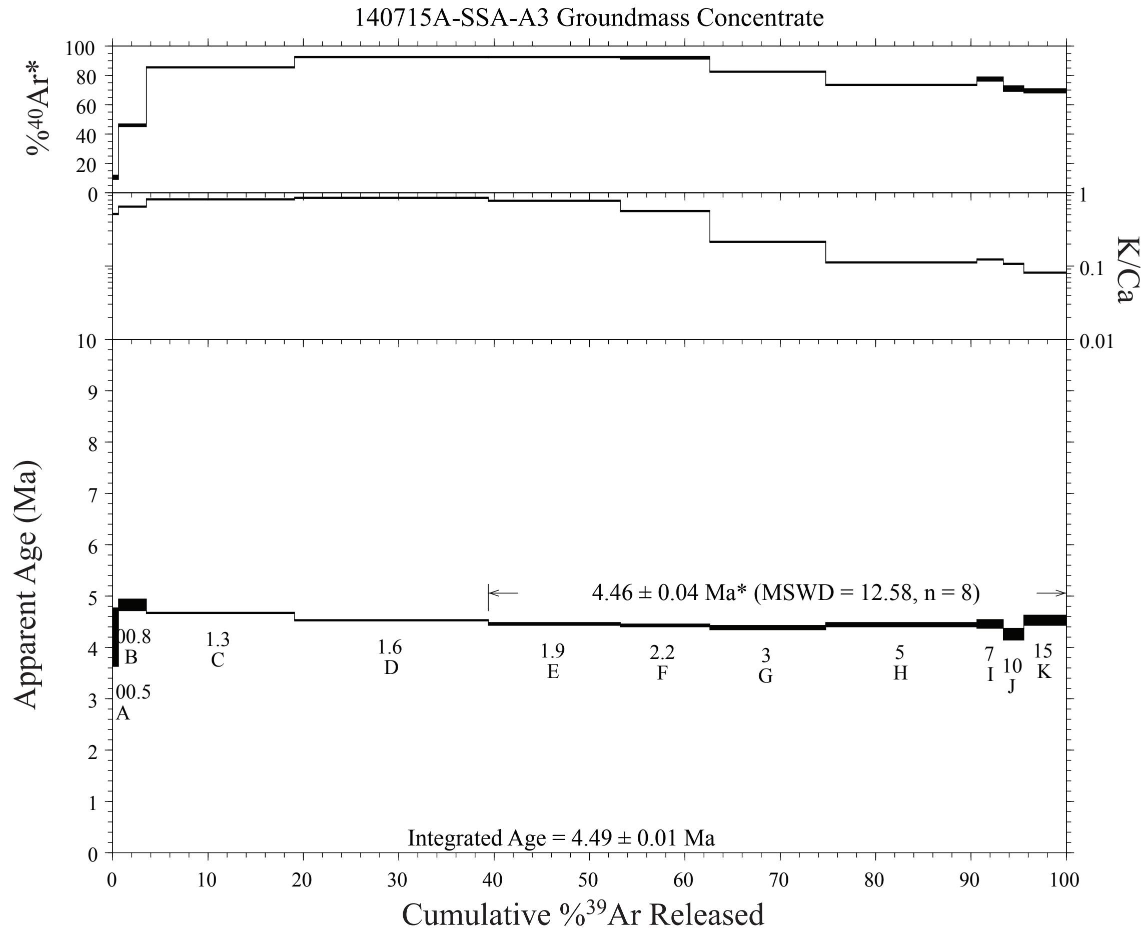
	ID	Power (Watts)	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$ (x 10^{-3})	$^{39}Ar_K$ (x 10^{-15} mol)	K/Ca	$^{40}Ar^*$ (%)	^{39}Ar (%)	Age (Ma)	±1σ (Ma)
	140715A-SSA-A3, whole rock, 12.67 mg, J=0.0039254±0.02%, D=1±0, NM-276A, Lab#=63599-01										
Xi	A	1	5.659	1.017	17.45	1.060	0.50	10.3	0.7	4.18	0.28
X	B	1	1.485	0.7781	2.944	4.65	0.66	45.2	3.7	4.82	0.06
X	C	1	0.7674	0.6361	0.5477	24.1	0.80	84.6	19.1	4.66	0.01
	D	2	0.6844	0.5888	0.3259	31.7	0.87	91.7	39.5	4.51	0.01
	E	2	0.6692	0.6600	0.3259	21.4	0.77	92.4	53.3	4.44	0.01
	F	2	0.6730	0.8966	0.4117	14.68	0.57	91.5	62.7	4.42	0.01
	G	3	0.7425	2.442	1.095	18.86	0.21	81.9	74.8	4.37	0.02
	H	5	0.8452	4.505	1.981	24.8	0.11	72.8	90.7	4.43	0.02
	I	7	0.7969	4.180	1.727	4.31	0.12	77.3	93.5	4.43	0.05
	J	10	0.8372	4.768	2.115	3.25	0.11	70.4	95.6	4.24	0.06
	K	15	0.9120	6.323	2.666	6.87	0.081	68.7	100.0	4.52	0.05
	Integrated age ± 2σ			n=11		155.6	0.26		K2O=1.20	4.49	0.01
	Plateau ± 2σ	**steps D-K**		**n=8**	**MSWD=12.58**	**125.8**	**0.48 ±0.66**		**80.9**	**4.46**	**0.04**
	Isochron±2σ	steps B-K		n=10	MSWD=40.04		$^{40}Ar/^{36}Ar$= 315±34			4.46	0.09
	140715B-SSA-A3, whole rock, 11.93 mg, J=0.0039187±0.01%, D=1±0, NM-276A, Lab#=63600-01										
X	A	1	102.7	1.167	347.1	0.743	0.44	0.2	0.5	1.22	1.57
X	B	1	47.63	0.9315	159.0	2.59	0.55	1.5	2.2	5.09	0.75
X	C	1	16.57	0.7451	53.96	8.78	0.68	4.1	8.0	4.88	0.22
X	D	2	5.531	0.7295	16.32	12.58	0.70	13.8	16.4	5.45	0.10
	E	2	3.212	0.7567	8.617	14.24	0.67	22.4	25.8	5.15	0.06
	F	2	2.409	0.8341	5.975	14.38	0.61	29.2	35.3	5.04	0.04
	G	3	1.746	1.747	4.010	27.1	0.29	39.8	53.3	4.98	0.03
	H	5	2.163	3.166	5.817	39.8	0.16	32.0	79.7	4.97	0.03
	I	7	2.231	3.266	6.033	5.31	0.16	31.5	83.2	5.05	0.09
	J	10	2.504	3.102	7.061	4.55	0.16	26.4	86.2	4.74	0.10
	K	15	2.875	3.842	8.362	20.8	0.13	24.6	100.0	5.08	0.05
	Integrated age ± 2σ			n=11		150.8	0.24		K2O=1.24	5.03	0.05
	Plateau ± 2σ	**steps E-K**		**n=7**	**MSWD=3.22**	**126.2**	**0.29 ±0.46**		**83.6**	**5.01**	**0.06**
	Isochron±2σ	steps A-K		n=11	MSWD=5.06		$^{40}Ar/^{36}Ar$=295.6±1.6			5.02	0.11
	WS-103-140715-djk, whole rock, 12.83 mg, J=0.0039177±0.01%, D=1±0, NM-276A, Lab#=63601-01										
X	A	1	151.2	0.9656	507.6	1.231	0.53	0.9	0.7	9.40	1.91
X	B	1	43.38	0.7132	144.7	3.78	0.72	1.5	2.6	4.77	0.56
X	C	1	18.05	0.5829	58.45	11.10	0.88	4.5	8.5	5.85	0.22
	D	2	8.634	0.6440	26.84	13.65	0.79	8.7	15.7	5.36	0.13
	E	2	5.903	0.7472	17.68	13.80	0.68	12.4	23.0	5.25	0.08
	F	2	4.661	0.8465	13.50	11.55	0.60	15.7	29.1	5.25	0.08
	G	3	4.883	1.466	14.51	32.5	0.35	14.5	46.3	5.06	0.06
	H	5	4.465	2.142	13.26	59.5	0.24	15.9	77.7	5.11	0.05
	I	7	4.618	3.172	14.03	24.4	0.16	15.6	90.6	5.16	0.06
	J	10	5.093	3.729	15.70	13.82	0.14	14.7	97.9	5.36	0.08
	K	15	5.087	4.036	15.79	3.97	0.13	14.5	100.0	5.30	0.13
	Integrated age ± 2σ			n=11		189.3	0.27		K2O=1.45	5.23	0.06
	Plateau ± 2σ	**steps D-K**		**n=8**	**MSWD=2.21**	**173.2**	**0.34 ±0.54**		**91.5**	**5.18**	**0.08**
	Isochron±2σ	steps A-K		n=11	MSWD=2.34		$^{40}Ar/^{36}Ar$=296.5±1.1			5.08	0.14

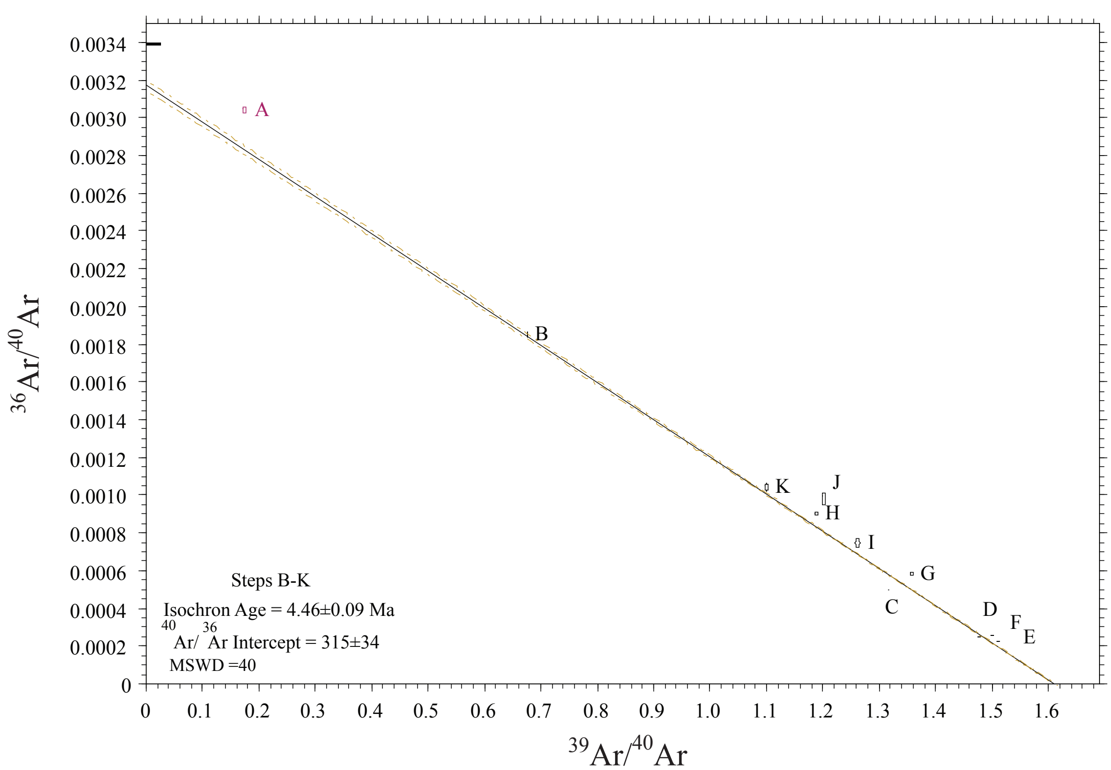
ID	Power (Watts)	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$ (x 10^{-3})	$^{39}Ar_K$ (x 10^{-15} mol)	K/Ca	$^{40}Ar^*$ (%)	^{39}Ar (%)	Age (Ma)	±1σ (Ma)

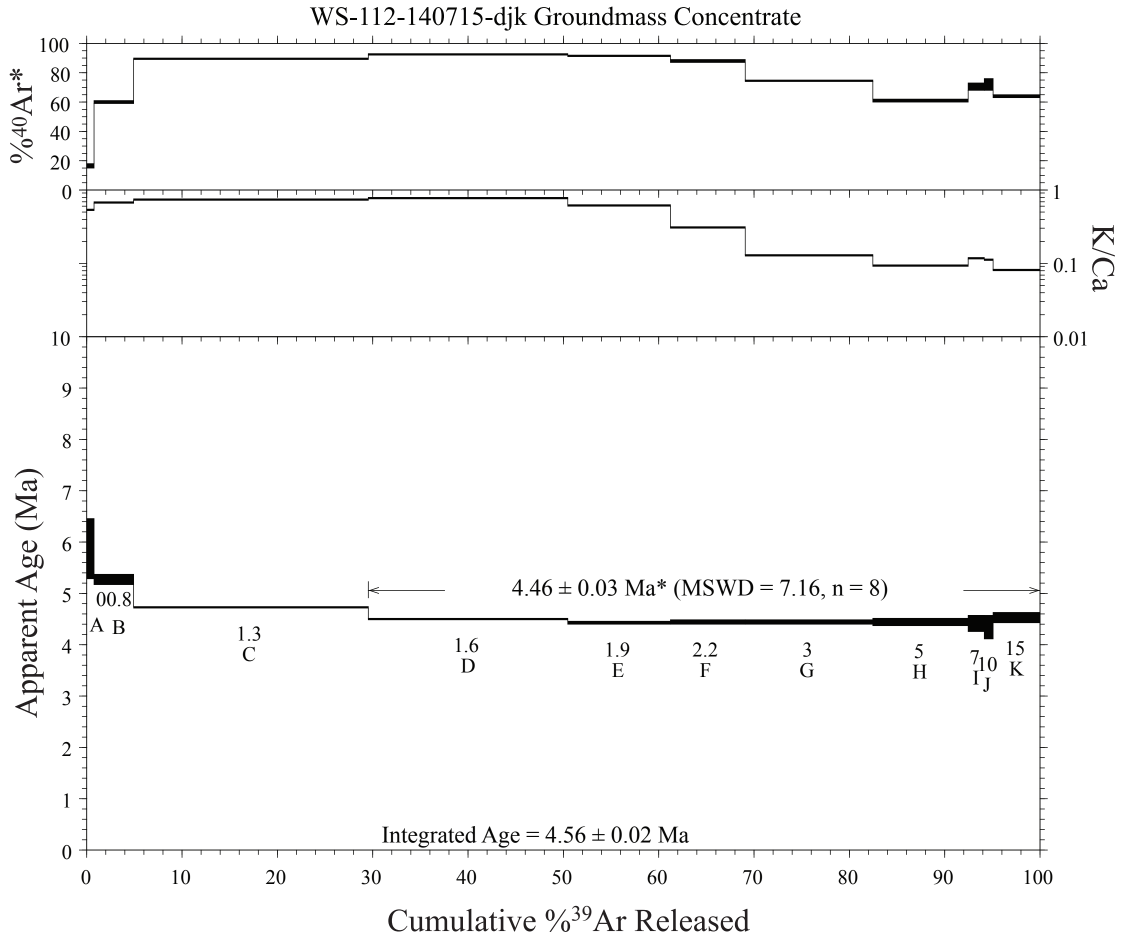
Notes:

Isotopic ratios corrected for blank, radioactive decay, and mass discrimination, not corrected for interfering reactions.
Errors quoted for individual analyses include analytical error only, without interfering reaction or J uncertainties.
Integrated age calculated by summing isotopic measurements of all steps.
Integrated age error calculated by quadratically combining errors of isotopic measurements of all steps.
Plateau age is inverse-variance-weighted mean of selected steps.
Plateau age error is inverse-variance-weighted mean error (Taylor, 1982) times root MSWD where MSWD>1.
Plateau error is weighted error of Taylor (1982).
Decay constants and isotopic abundances after Minn et al., (2000).
symbol preceding sample ID denotes analyses excluded from plateau age calculations.
Weight percent K_2O calculated from ^{39}Ar signal, sample weight, and instrument sensitivity.
Ages calculated relative to FC-2 Fish Canyon Tuff sanidine interlaboratory standard at 28.201 Ma
Decay Constant (LambdaK (total)) = 5.463e-10/a
Correction factors:

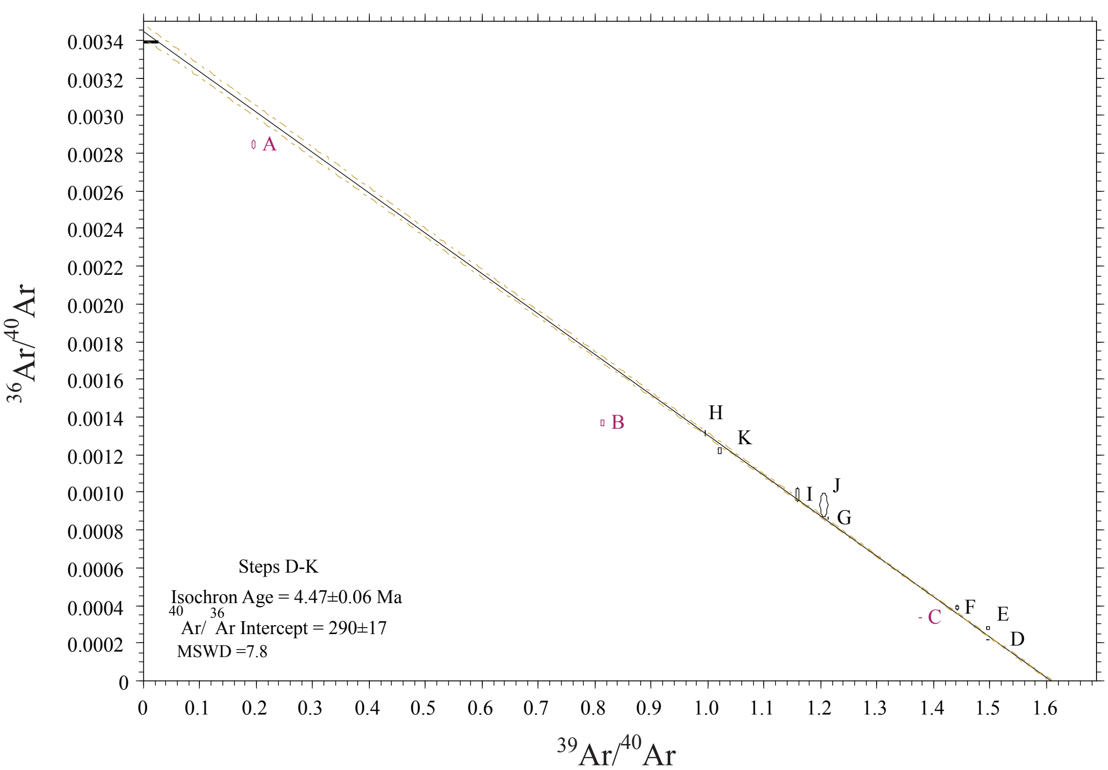
$(^{39}Ar/^{37}Ar)_{Ca}$ = 0.0007064 ± 4e-06
$(^{36}Ar/^{37}Ar)_{Ca}$ = 0.0002731 ± 0
$(^{38}Ar/^{39}Ar)_{K}$ = 0.01261
$(^{40}Ar/^{39}Ar)_{K}$ = 0.00808 ± 0.00041


140715A-SSA-A3 Groundmass Concentrate
%40Ar*
K/Ca
Apparent Age (Ma)
4.46 ± 0.04 Ma* (MSWD = 12.58, n = 8)
00.5 A
00.8 B
1.3 C
1.6 D
1.9 E
2.2 F
3 G
5 H
7 I
10 J
15 K
Integrated Age = 4.49 ± 0.01 Ma
Cumulative %39Ar Released

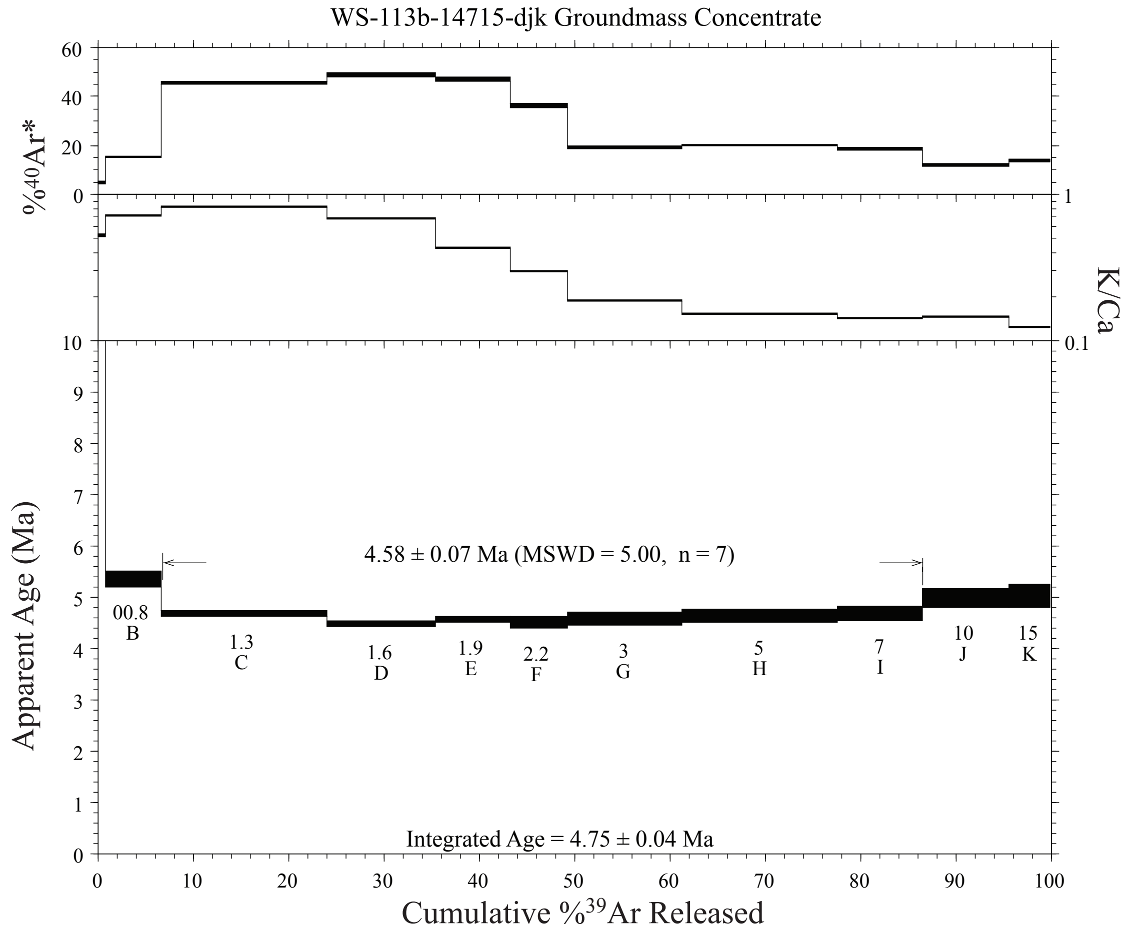

36Ar/40Ar
39Ar/40Ar
A
B
K
J
H
I
G
C
D
F
E
Steps B-K
Isochron Age = 4.46±0.09 Ma
40Ar/36Ar Intercept = 315±34
MSWD =40

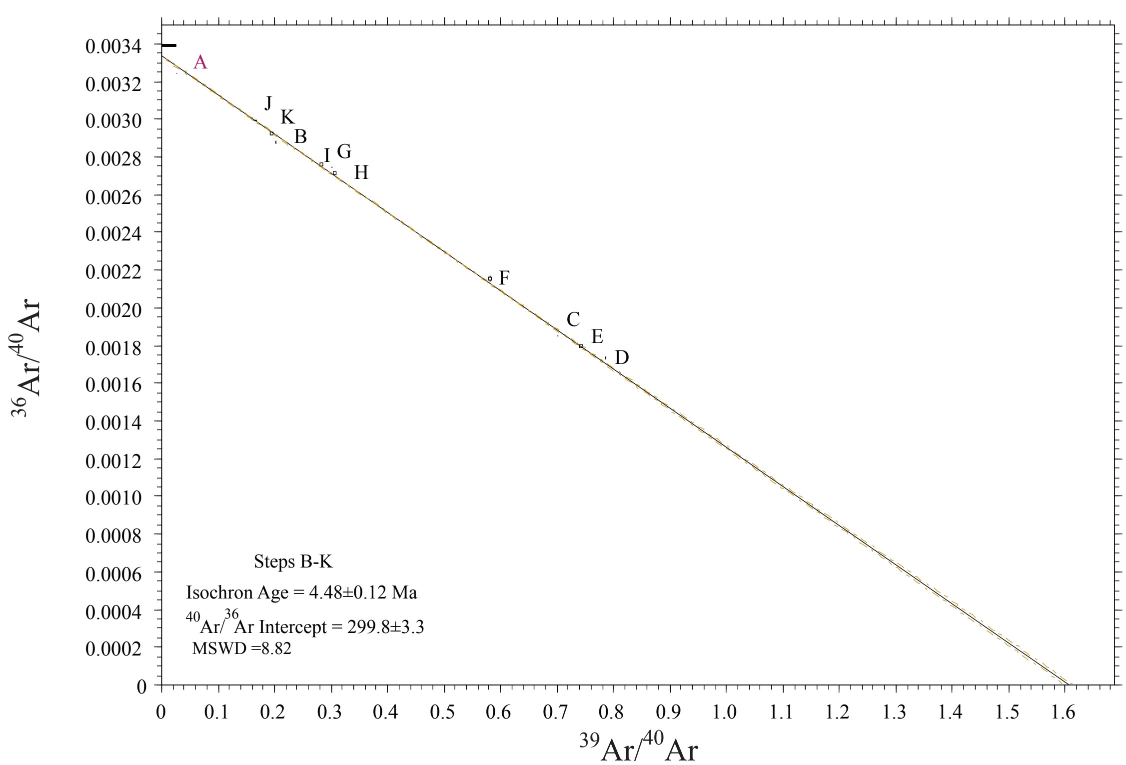


WS-112-140715-djk Groundmass Concentrate
%40Ar*
K/Ca
Apparent Age (Ma)
4.46 ± 0.03 Ma* (MSWD = 7.16, n = 8)
Integrated Age = 4.56 ± 0.02 Ma
Cumulative %39Ar Released

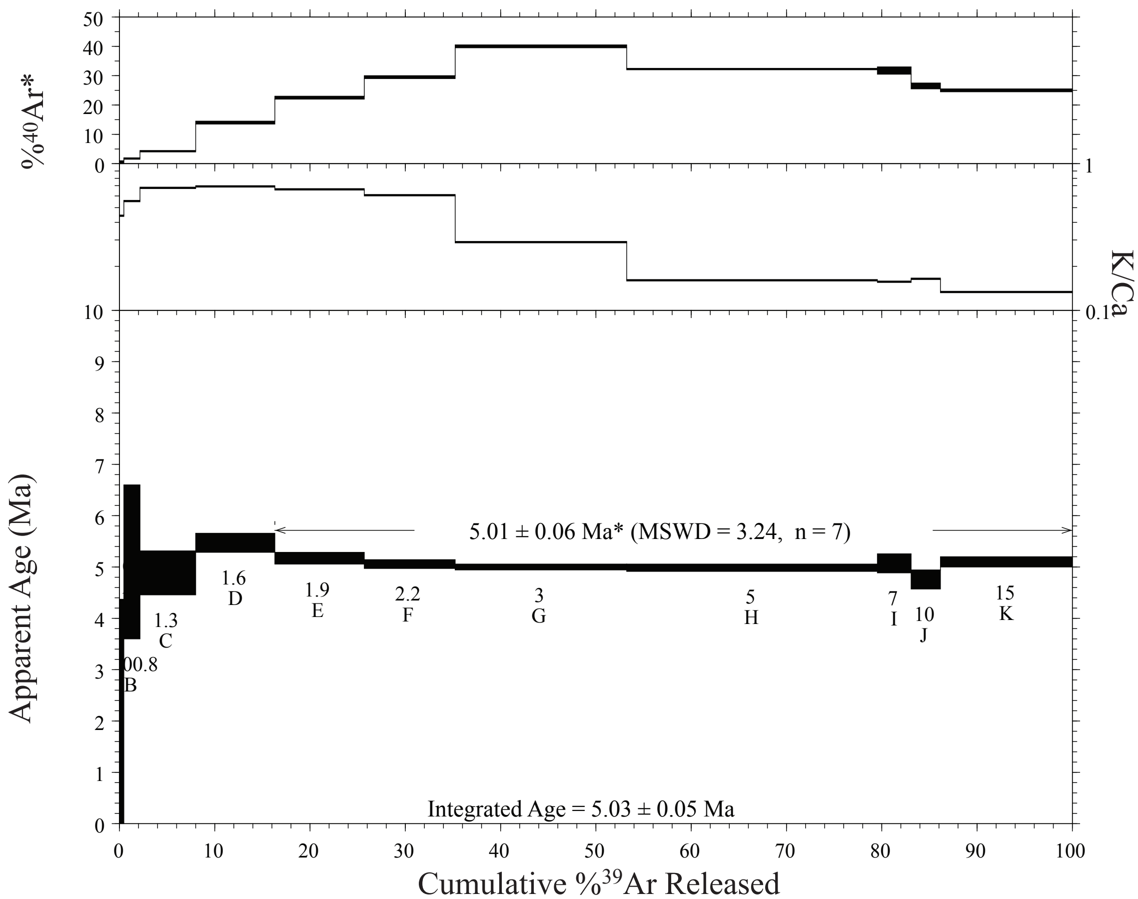


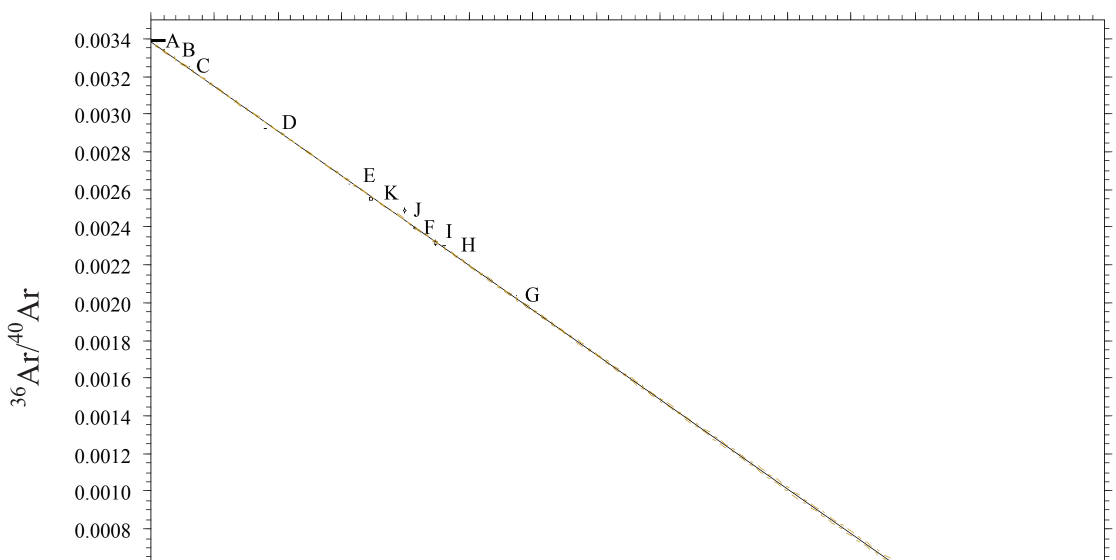
36Ar/40Ar
39Ar/40Ar
Steps D-K
Isochron Age = 4.47±0.06 Ma
40Ar/36Ar Intercept = 290±17
MSWD =7.8

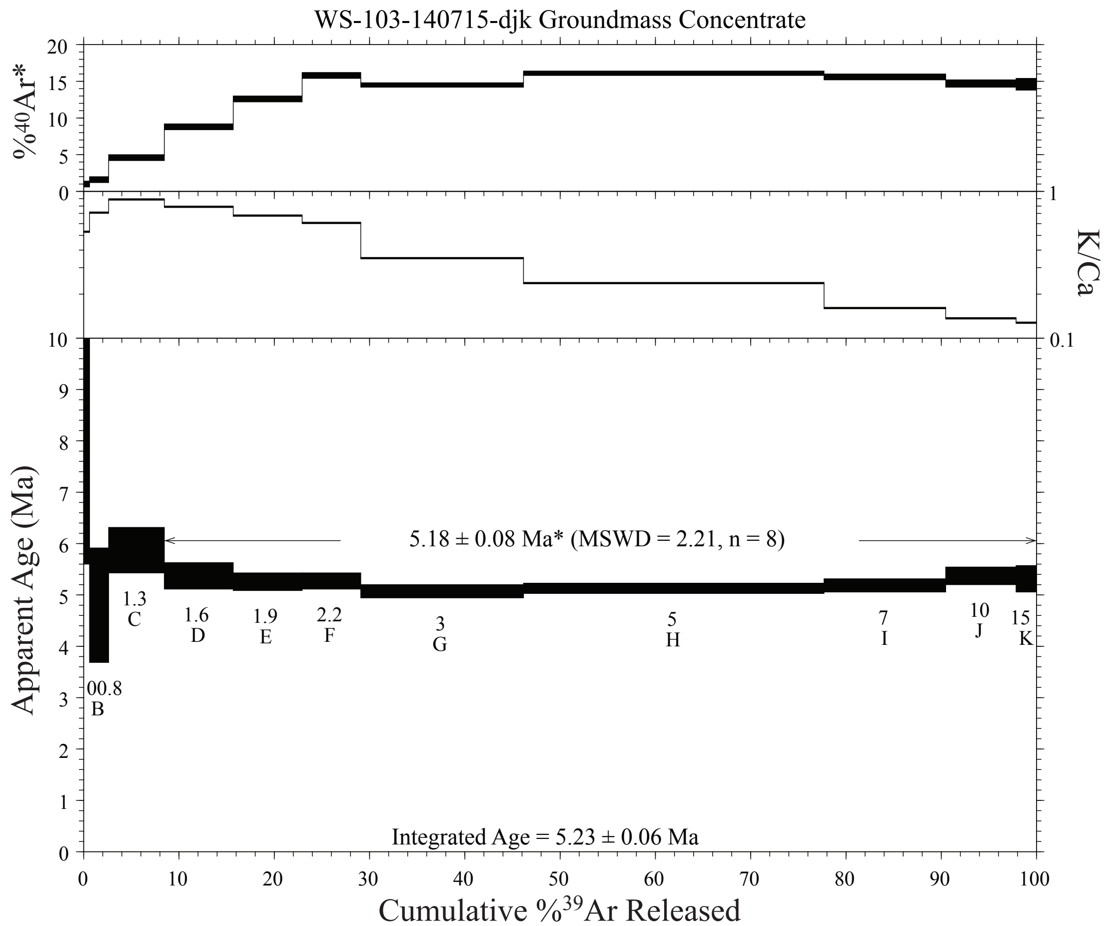

WS-113b-14715-djk Groundmass Concentrate
%40Ar*
K/Ca
Apparent Age (Ma)
4.58 ± 0.07 Ma (MSWD = 5.00, n = 7)
00.8
B
1.3
C
1.6
D
1.9
E
2.2
F
3
G
5
H
7
I
10
J
15
K
Integrated Age = 4.75 ± 0.04 Ma
Cumulative %39Ar Released

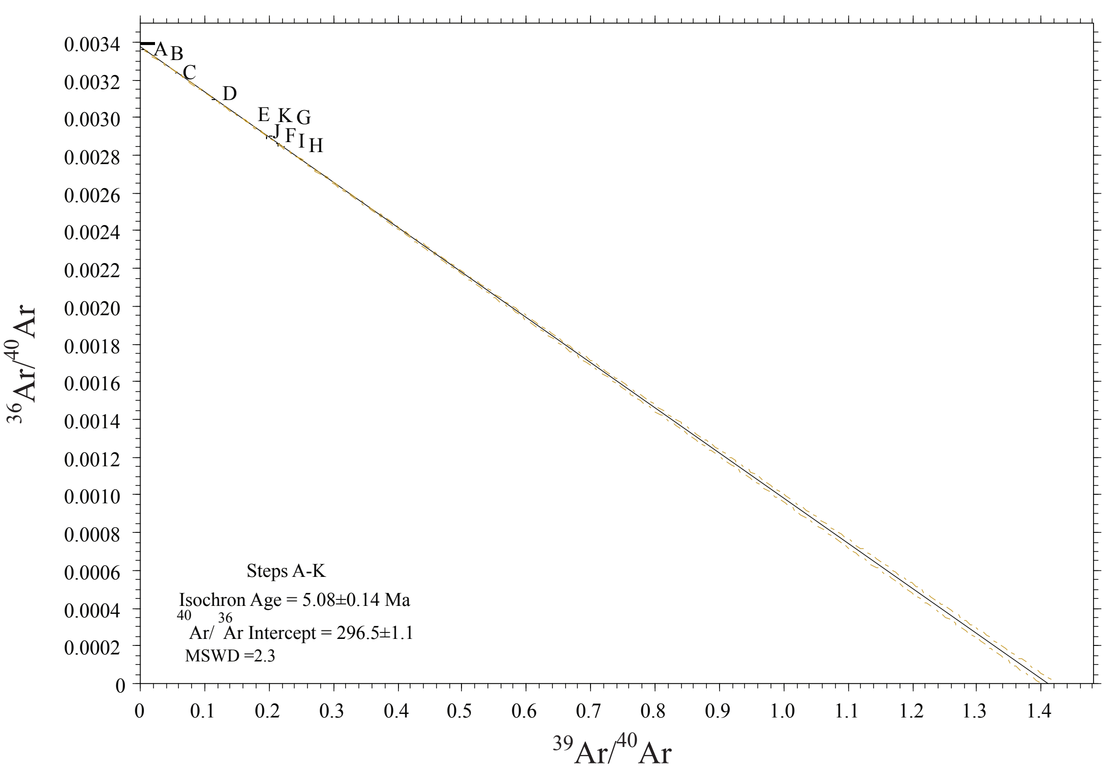

36Ar/40Ar
A
J
K
B
I
G
H
F
C
E
D
Steps B-K
Isochron Age = 4.48±0.12 Ma
40Ar/36Ar Intercept = 299.8±3.3
MSWD =8.82
39Ar/40Ar

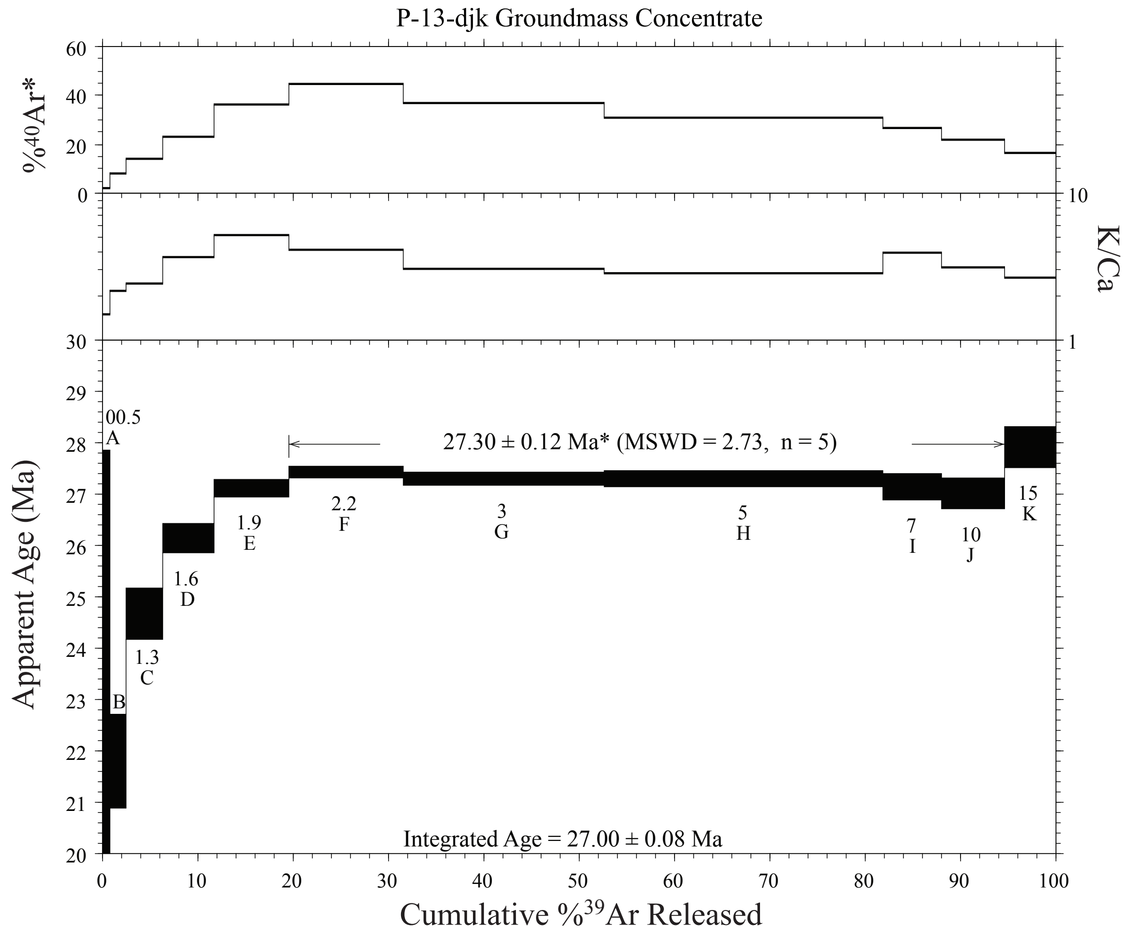
140715B-SSA-A3 Groundmass Concentrate



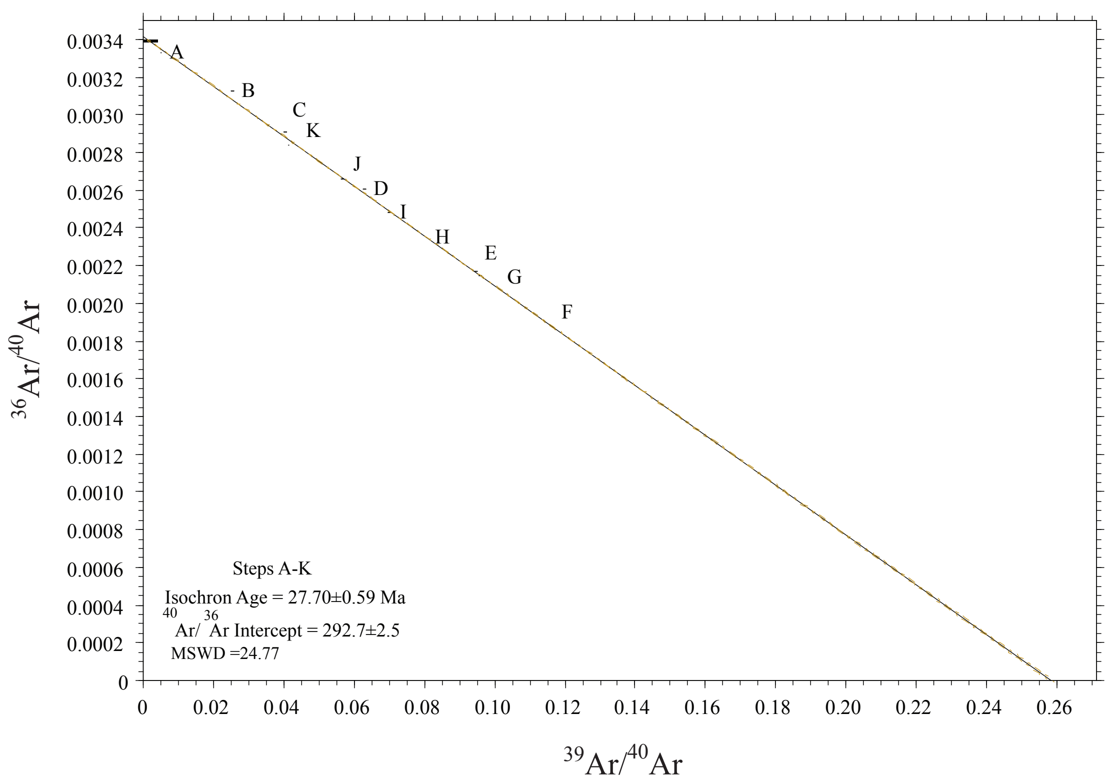



WS-103-140715-djk Groundmass Concentrate
%40Ar*
K/Ca
Apparent Age (Ma)
5.18 ± 0.08 Ma* (MSWD = 2.21, n = 8)
Integrated Age = 5.23 ± 0.06 Ma
Cumulative %39Ar Released


36Ar/40Ar
Steps A-K
Isochron Age = 5.08±0.14 Ma
40Ar/36Ar Intercept = 296.5±1.1
MSWD =2.3
39Ar/40Ar



P-13-djk Groundmass Concentrate
%40Ar*
K/Ca
Apparent Age (Ma)
00.5
A
B
1.3
C
1.6
D
1.9
E
2.2
F
3
G
5
H
7
I
10
J
15
K
27.30 ± 0.12 Ma* (MSWD = 2.73, n = 5)
Integrated Age = 27.00 ± 0.08 Ma
Cumulative %39Ar Released



36Ar/40Ar
A
B
C
K
J
D
I
H
E
G
F
Steps A-K
Isochron Age = 27.70±0.59 Ma
40Ar/36Ar Intercept = 292.7±2.5
MSWD =24.77
39Ar/40Ar

TABLE H-1. SUMMARY OF ^{40}AR/^{39}AR AGES FOR BASALTS ON SKUTE STONE ARROYO QUADRANGLE

Sample	Location in UTM coordinates, in meters (zone 13, NAD 83)	Location and map unit	Lab sample number	Heating steps	Age ± 2σ (Ma)	MSWD*	Comments
140715A-SSA-A3	268,503 E 3,650,379 N	Lower flow of northern basalt package (unit Tbl). Located at bottom of Greyback Arroyo 780 m upstream of where this arroyo is crossed by Highway 180.	63599	8	4.46 ± 0.04	12.58	Weighted mean
WS-112-140715-djk	268,683 E 3,649,414 N	Lower flow of southern basalt package (unit Tb). Located on south side of tributary to Greyback Arroyo, 660 m south of Highway 180 (measured from a point 580 m WSW of where this highway crosses Greyback Arroyo).	63598	8	4.46 ± 0.03	7.16	Weighted mean
WS-113b-140715-djk	268,690 E 3,649,476 N	Lower flow of southern basalt package (unit Tb). Located just above stream grade of tributary to Greyback arroyo, 600 m south of Highway 180 (measured from a point 580 m WSW of where this highway crosses Greyback Arroyo). Sample is a few meters stratigraphically lower than sample WS-112-140715-djk.	63597	7	4.58 ± 0.07	5.00	Weighted mean
140715B-SSA-A3	266,551 E 3,648,466 N	Mafic intrusion(Tmi) along north-south dike 230 m east of Wicks Gulch	63600	7	5.01 ± 0.06	3.22	Weighted mean
WS-103-140715-djk	266,725 E 3,646,972 N	Basalt flow plastering sides of a paleovally, at a location 170 m ENE of hill labeled "5292." Hill is located on inside of south-to-west curve of Highway 180 near western quadrangle border.	63601	8	5.18 ± 0.08	2.21	Weighted mean

Notes: Analyses performed at the New Mexico Geochronology Research Laboratory. Ages calculated relative to FC-2 Fish Canyon Tuff sanidine interlaboratory standard (28.201 Ma, Kuiper et al., 2008). Groundmass concentrate was step-heated with a Photon Machine Inc. Diode laser. Step-heat analyses performed on a Argus VI mass spectrometer on line with automated all-metal extraction system. See Internal Report NMGRL-IR-881 (included in Appendix H of this report) for more information regarding sample prepartion and irradiation, instrumentation, and analytical parameters.
* MSWD = Mean square weighted deviation.

APPENDIX I

REPORT OF RADIOCARBON DATING ANALYSES

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Darden Hood
President

Ronald Hatfield
Christopher Patrick
Deputy Directors

March 18, 2015

Mr. Daniel Koning
New Mexico Institute of Mining and Technology
New Mexico Bureau of Geology and Mineral Resources
801 Leroy Place
Socorro, NM 87801
USA

RE: Radiocarbon Dating Results For Samples WS-202-D#1, WS-204, 14-SSA-2, 14-SSA-5

Dear Mr. Koning:

Enclosed are the radiocarbon dating results for four samples recently sent to us. As usual, the method of analysis is listed on the report with the results and calibration data is provided where applicable. The Conventional Radiocarbon Ages have all been corrected for total fractionation effects and where applicable, calibration was performed using 2013 calibration databases (cited on the graph pages).

The web directory containing the table of results and PDF download also contains pictures, a cvs spreadsheet download option and a quality assurance report containing expected vs. measured values for 3-5 working standards analyzed simultaneously with your samples.

Reported results are accredited to ISO/IEC 17025:2005 Testing Accreditation PJLA #59423 standards and all chemistry was performed here in our laboratories and counted in our own accelerators here in Miami. Since Beta is not a teaching laboratory, only graduates trained to strict protocols of the ISO/IEC 17025:2005 Testing Accreditation PJLA #59423 program participated in the analyses.

As always Conventional Radiocarbon Ages and sigmas are rounded to the nearest 10 years per the conventions of the 1977 International Radiocarbon Conference. When counting statistics produce sigmas lower than +/- 30 years, a conservative +/- 30 BP is cited for the result.

When interpreting the results, please consider any communications you may have had with us regarding the samples. As always, your inquiries are most welcome. If you have any questions or would like further details of the analyses, please do not hesitate to contact us.

Our invoice will be emailed separately. Please, forward it to the appropriate officer or send VISA charge authorization. Thank you. As always, if you have any questions or would like to discuss the results, don't hesitate to contact me.

Sincerely,

Darden Hood
Digital signature on file

BETA ANALYTIC INC.
DR. M.A. TAMERS and MR. D.G. HOOD
4985 S.W. 74 COURT
MIAMI, FLORIDA, USA 33155
PH: 305-667-5167 FAX:305-663-0964
beta@radiocarbon.com

REPORT OF RADIOCARBON DATING ANALYSES

Mr. Daniel Koning — Report Date: 3/18/2015

New Mexico Institute of Mining and Technology — Material Received: 3/10/2015

Sample Data	Measured Radiocarbon Age	d13C	Conventional Radiocarbon Age(*)
Beta - 406473	9530 +/- 30 BP	-21.6 o/oo	9590 +/- 30 BP

SAMPLE : WS-202-D#1
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid
2 SIGMA CALIBRATION : Cal BC 9170 to 8810 (Cal BP 11120 to 10760)

Sample Data	Measured Radiocarbon Age	d13C	Conventional Radiocarbon Age(*)
Beta - 406474	310 +/- 30 BP	-10.8 o/oo	540 +/- 30 BP

SAMPLE : WS-204
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid
2 SIGMA CALIBRATION : Cal AD 1320 to 1350 (Cal BP 630 to 600) and Cal AD 1390 to 1435 (Cal BP 560 to 515)

Sample Data	Measured Radiocarbon Age	d13C	Conventional Radiocarbon Age(*)
Beta - 406475	180 +/- 30 BP	-24.7 o/oo	180 +/- 30 BP

SAMPLE : 14-SSA-2
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid
2 SIGMA CALIBRATION : Cal AD 1655 to 1695 (Cal BP 295 to 255) and Cal AD 1725 to 1815 (Cal BP 225 to 135) and Cal AD 1835 to 1840 (Cal BP 115 to 110) and Cal AD 1855 to 1865 (Cal BP 95 to 85) and Cal AD 1920 to Post 1950 (Cal BP 30 to Post 0)

Sample Data	Measured Radiocarbon Age	d13C	Conventional Radiocarbon Age(*)
Beta - 406476	130 +/- 30 BP	-26.3 o/oo	110 +/- 30 BP

SAMPLE : 14-SSA-5
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid
2 SIGMA CALIBRATION : Cal AD 1680 to 1765 (Cal BP 270 to 185) and Cal AD 1800 to 1940 (Cal BP 150 to 10) and Post AD 1950 (Post BP 0)

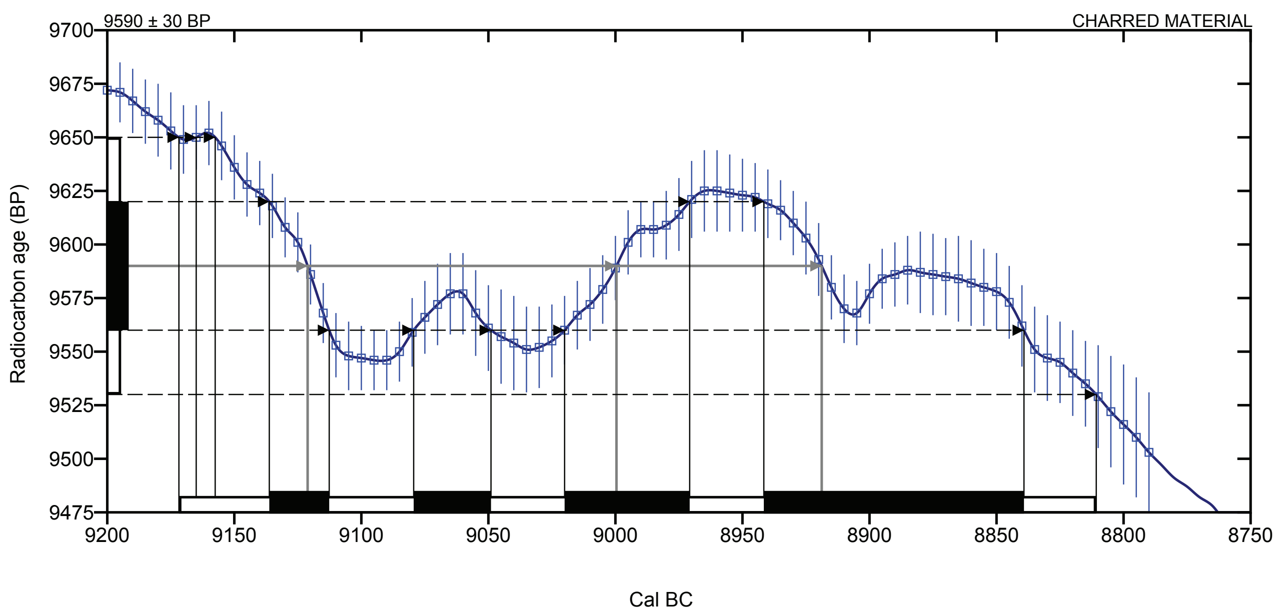
Dates are reported as RCYBP (radiocarbon years before present, "present" = AD 1950). By international convention, the modern reference standard was 95% the 14C activity of the National Institute of Standards and Technology (NIST) Oxalic Acid (SRM 4990C) and calculated using the Libby 14C half-life (5568 years). Quoted errors represent 1 relative standard deviation statistics (68% probability) counting errors based on the combined measurements of the sample, background, and modern reference standards. Measured 13C/12C ratios (delta 13C) were calculated relative to the PDB-1 standard.

The Conventional Radiocarbon Age represents the Measured Radiocarbon Age corrected for isotopic fractionation, calculated using the delta 13C. On rare occasion where the Conventional Radiocarbon Age was calculated using an assumed delta 13C, the ratio and the Conventional Radiocarbon Age will be followed by "*". The Conventional Radiocarbon Age is not calendar calibrated. When available, the Calendar Calibrated result is calculated from the Conventional Radiocarbon Age and is listed as the "Two Sigma Calibrated Result" for each sample.

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12 = -21.6 o/oo : lab. mult = 1)

Laboratory number	**Beta-406473**
Conventional radiocarbon age	**9590 ± 30 BP**
Calibrated Result (95% Probability)	**Cal BC 9170 to 8810 (Cal BP 11120 to 10760)**
Intercept of radiocarbon age with calibration curve	Cal BC 9120 (Cal BP 11070) Cal BC 9000 (Cal BP 10950) Cal BC 8920 (Cal BP 10870)
Calibrated Result (68% Probability)	Cal BC 9135 to 9115 (Cal BP 11085 to 11065) Cal BC 9080 to 9050 (Cal BP 11030 to 11000) Cal BC 9020 to 8970 (Cal BP 10970 to 10920) Cal BC 8940 to 8840 (Cal BP 10890 to 10790)



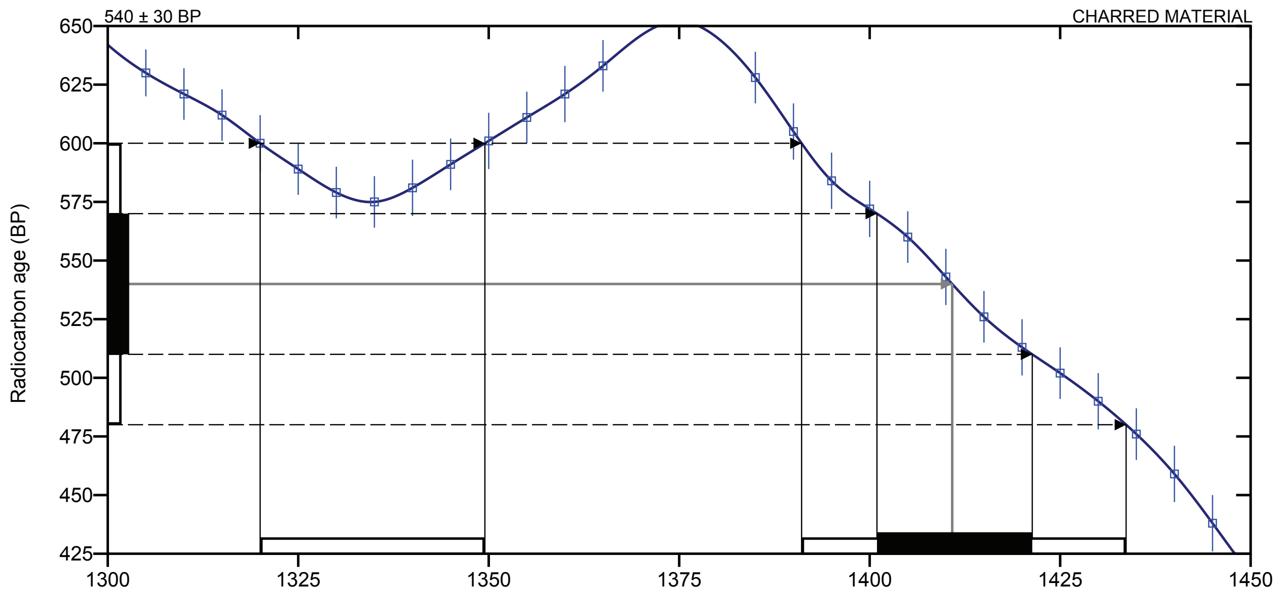
Database used
INTCAL13

References
Mathematics used for calibration scenario
A Simplified Approach to Calibrating C14 Dates, Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322
References to INTCAL13 database
Reimer PJ et al. IntCal13 and Marine13 radiocarbon age calibration curves 0– 50,000 years cal BP. Radiocarbon 55(4):1869– 1887., 2013.

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12 = -10.8 o/oo : lab. mult = 1)

Laboratory number	**Beta-406474**
Conventional radiocarbon age	**540 ± 30 BP**
Calibrated Result (95% Probability)	**Cal AD 1320 to 1350 (Cal BP 630 to 600)** **Cal AD 1390 to 1435 (Cal BP 560 to 515)**
Intercept of radiocarbon age with calibration curve	Cal AD 1410 (Cal BP 540)
Calibrated Result (68% Probability)	Cal AD 1400 to 1420 (Cal BP 550 to 530)



Database used

INTCAL13

References

Mathematics used for calibration scenario

A Simplified Approach to Calibrating C14 Dates, Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

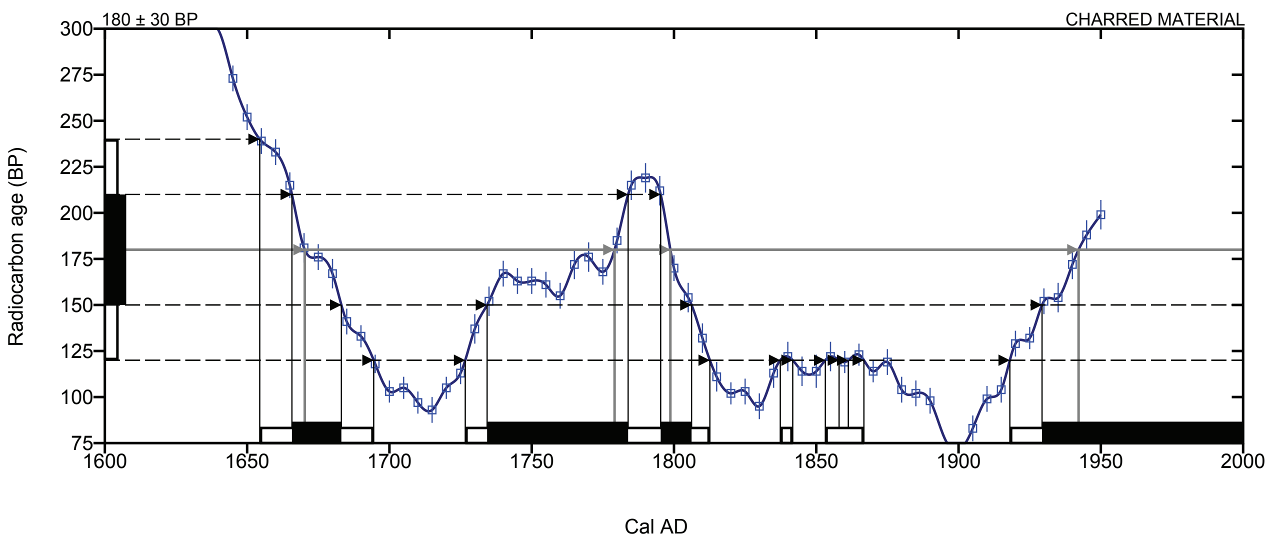
References to INTCAL13 database

Reimer PJ et al. IntCal13 and Marine13 radiocarbon age calibration curves 0– 50,000 years cal BP. Radiocarbon 55(4):1869– 1887., 2013.

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12 = -24.7 o/oo : lab. mult = 1)

Laboratory number	**Beta-406475**
Conventional radiocarbon age	**180 ± 30 BP**
Calibrated Result (95% Probability)	**Cal AD 1655 to 1695 (Cal BP 295 to 255)** **Cal AD 1725 to 1815 (Cal BP 225 to 135)** **Cal AD 1835 to 1840 (Cal BP 115 to 110)** **Cal AD 1855 to 1865 (Cal BP 95 to 85)** **Cal AD 1920 to Post 1950 (Cal BP 30 to Post 0)**
Intercept of radiocarbon age with calibration curve	Cal AD 1670 (Cal BP 280) Cal AD 1780 (Cal BP 170) Cal AD 1800 (Cal BP 150) Cal AD 1940 (Cal BP 10) Post AD 1950 (Post BP 0)
Calibrated Result (68% Probability)	Cal AD 1665 to 1685 (Cal BP 285 to 265) Cal AD 1735 to 1785 (Cal BP 215 to 165) Cal AD 1795 to 1805 (Cal BP 155 to 145) Cal AD 1930 to Post 1950 (Cal BP 20 to Post 0)



Database used

INTCAL13

References

Mathematics used for calibration scenario

A Simplified Approach to Calibrating C14 Dates, Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

References to INTCAL13 database

Reimer PJ et al. IntCal13 and Marine13 radiocarbon age calibration curves 0– 50,000 years cal BP. Radiocarbon 55(4):1869– 1887., 2013.

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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12 = -26.3 o/oo : lab. mult = 1)

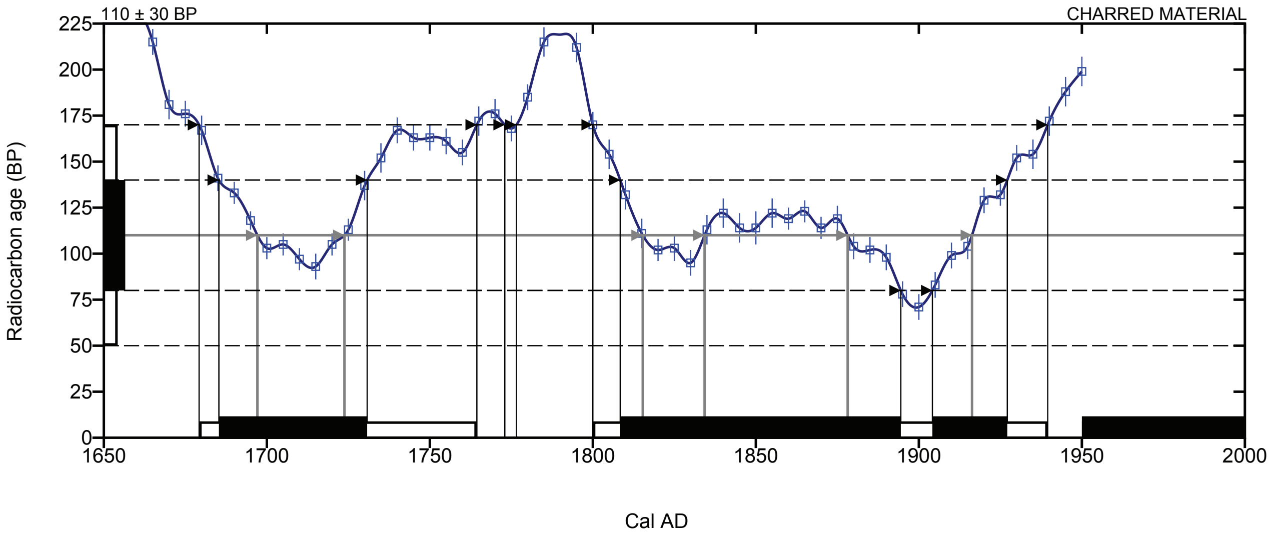
Laboratory number **Beta-406476**

Conventional radiocarbon age **110 ± 30 BP**

Calibrated Result (95% Probability) **Cal AD 1680 to 1765 (Cal BP 270 to 185)**
Cal AD 1800 to 1940 (Cal BP 150 to 10)
Post AD 1950 (Post BP 0)

Intercept of radiocarbon age with calibration curve
Cal AD 1695 (Cal BP 255)
Cal AD 1725 (Cal BP 225)
Cal AD 1815 (Cal BP 135)
Cal AD 1835 (Cal BP 115)
Cal AD 1880 (Cal BP 70)
Cal AD 1915 (Cal BP 35)
Post AD 1950 (Post BP 0)

Calibrated Result (68% Probability)
Cal AD 1685 to 1730 (Cal BP 265 to 220)
Cal AD 1810 to 1895 (Cal BP 140 to 55)
Cal AD 1905 to 1925 (Cal BP 45 to 25)
Post AD 1950 (Post BP 0)



Database used
INTCAL13

References
Mathematics used for calibration scenario
A Simplified Approach to Calibrating C14 Dates, Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322
References to INTCAL13 database
Reimer PJ et al. IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP. Radiocarbon 55(4):1869–1887., 2013.

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We thank James Witcher for sharing data from the Percha Creek well, which greatly assisted in construction of the cross section. We also thank various landowners for permission to access their properties, particularly Bill Bussmann, Harvey Chatfield, Twister Smith, Gene Thornton, and Nate Wolf. Greg Mack showed and discussed useful outcrops in Las Animas Creek. Leo Gabaldon drafted figure 25

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