



## ***An overview and delineation of the Cuchillo geomorphic surface, Engle and Palomas basins, New Mexico***

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# AN OVERVIEW AND DELINEATION OF THE CUCHILLO GEOMORPHIC SURFACE, ENGLE AND PALOMAS BASINS, NEW MEXICO

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**ABSTRACT**—The Cuchillo surface satisfactorily meets the defining criteria of a geomorphic surface, i.e., distinct landscape position, finite age, uniformity in degree of soil development, and defined geography within local rift basins. Its planar-concave-up surface formed at the cessation of Palomas Formation aggradational deposition at ~0.8 Ma, modern surface remnants generally slope only 1-2° (with few exceptions), and have a grade of ~90 m above the modern floodplain of the Rio Grande. It consistently exhibits mature soils with thick argillic Bt horizons overlying petrocalcic stage III-IV K horizons with depths commonly exceeding 1.5 m. As the overall distribution of the Cuchillo surface has never been adequately mapped, a proposed delineation using sophisticated digital mapping tools is presented here. The Cuchillo surface covers much of the Engle and Palomas basins, extending from just south of the San Jose Canyon fan to just north of Berrenda Creek and from the hanging wall margin of the Sierra Cuchillo and Black Range to the footwall escarpments of the Fra Cristobal Mountains and the Caballo Mountains, including paleofans above the Apache Valley.

## INTRODUCTION

The Engle and Palomas structural basins of the southern Rio Grande rift extend southwest and northwest of Truth or Consequences (T or C), New Mexico. At the surface of these basins, a broad, gently sloping, dissected plain lying west of the Rio Grande extends southward from the base of the southern San Mateo Mountains in the northern Engle basin past the Mud Springs Mountains (west of T or C) to the southern edge of the Palomas basin, and from the Fra Cristobal and Caballo Mountains east of the Rio Grande to the foothills of the Black Range and Sierra Cuchillo on the west sides of the Palomas and Engle basins (Fig. 1). This broad surface was initially referred to as the “Palomas surface” or the “Palomas-Cuchillo surface” (Kelley and Silver, 1952), or the “Cuchillo plain” (Hawley et al., 1978). Its currently preferred name, the “Cuchillo surface,” was established by Lozinsky (1986), Lozinsky and Hawley (1986a), and Maxwell



FIGURE 1. A typical view of the Cuchillo geomorphic surface with a well developed desert pavement. This is located on the North Alamosa remnant of the Cuchillo surface looking west towards the Sierra Cuchillo on the skyline with Sierras Mediano behind the inset Aragon Wash in the intermediate distance.

and Oakman (1990) in the mid 1980s, to avoid confusion with the antiquated “Palomas gravels,” derived from Gordon and Graton (1907) and Harley (1934), and the now formally named Palomas Formation of the Santa Fe Group (Lozinsky and Hawley, 1986a, b; Lozinsky, 1987). Unfortunately however, the “type locality” town of Cuchillo does not reside on the surface, but is inset in the Cuchillo Negro valley.

The Cuchillo surface satisfactorily meets the defining criteria for a *geomorphic surface* established by Ruhe (1956, 1969) as a time-stratigraphic unit with a known soil age and landscape position. The Cuchillo surface meets these criteria by exhibiting the following characteristics: a) a distinct and dominant landscape position; b) finite-age equivalency in a context of episodic processes and underlying stratigraphy; c) general uniformity in degree of soil development on stable (neither eroding nor aggrading) areas at the surface; and d) an aerially contiguous geographic extent and context. The Cuchillo surface is a planar to slightly concave-up surface of limited irregularities graded to the level at which the ancestral Rio Grande flowed at the termination of Palomas Formation aggradation in early Pleistocene time. Lozinsky (1986) and Lozinsky and Hawley (1986a) thus defined it as a largely constructional feature formed at the end of Palomas Formation deposition ~ 800 kyr ago, firmly established via three lines of chronologic evidence by Mack et al. (1993), Mack et al. (1998), Mack and Leeder (1999), Mack et al. (2006), and Mack et al. (2012, this guidebook). Since this time, the Rio Grande has incised its valley episodically, leading to tributary entrenchment into the surface, punctuated with climatically-driven, isolated episodes of minor backfilling of tributaries forming fill terraces (described in Davie and Spiegel, 1967; Lozinsky, 1986; Seager and Mack, 1991; McCraw and Williams, 2012, this guidebook) and alluvial fans (Mack and Leeder, 1999). This has resulted in isolated, relatively stable Cuchillo surface remnants, all containing petrocalcic stage III-IV horizons indicative of this age, found on both sides of the modern Rio Grande valley.

But where exactly are these surface remnants and what is their geographic extent? Specifically, does the Cuchillo surface have a “carte blanche extent” over the entire map area of the Palomas Formation, including the San Marcial Basin to the north, as Lozinsky and Hawley (1986a) defined it? Or could it extend even farther north to the Socorro basin (Palomas Formation applied to Pliocene strata at Arroyo de la Parida by Morgan et al., 2008; following Gordon and Graton, 1907). Where is its southern boundary? Hawley and Lozinsky (1986a, b) were purposely vague in establishing the southern extent of the Palomas Formation in the Derry area as Santa Fe Group nomenclature gradually shifts here to the Camp Rice Formation, with its defining constructional La Mesa surface found further south. Even the western and eastern margins, largely defined by the hanging and footwall uplifts of the Black Range / Sierra Cuchillo and the Caballo Mountains, respectively, have areas of complexity which could easily lead to differing interpretations of surface extent. In short, while numerous workers have described the Cuchillo surface in various specific localities, and all agree on its time-stratigraphic significance, its actual complete geographic extent has yet to be delineated. We do so here as a suggested proposal, in the hopes that it generates subsequent discussion and possible future refinements.

### PREVIOUS MAPPING

The reason no definitive comprehensive distribution of the Cuchillo surface exists is due to: a) regional geologic mapping has either not delineated geomorphic surfaces (e.g., New Mexico Bureau of Geology and Mineral Resources, 2003; Seager et al., 1982; Harrison et al., 1993; Hawley et al., 2005) or not differentiated the Cuchillo surface from other geomorphic surfaces (Kelley and Silver, 1952, fig. 21); or b) mappers who delineated it (Lozinsky, 1986; Maxwell and Oakman, 1990) were studying small subsets of its complete distribution. Kelley and Silver’s (1952, fig. 21) is the most comprehensive attempt at depicting all Cuchillo surface remnants (described as “Palomas and Engle surfaces”), although inaccuracies are common. However, considering they only had 1935-vintage SCS aerial photography and incomplete 1:62,500-scale topographic maps with 40-foot contour intervals to work with, their delineation of these surface distributions is admirable.

### METHODS

The distribution of the Cuchillo geomorphic surface was constructed in ArcGIS v. 10.2 utilizing 2009 NAIP four-band orthophotographic imagery, stereo imagery, and terrain (DEM, hillshade) data, with a resolution of 1-meter ground sample distance rectified to a horizontal accuracy of  $\pm 5$  meters. All previously described or mapped areas were examined to ascertain whether they met the characteristics described below and had the correct elevational range and grade above the modern Rio Grande floodplain using the digital orthophoto quarter-quadrangles (DOQQ; downloaded scales of 1:12,000 and 1:24,000) and digital elevation model (DEM) imagery and profiles (Figs. 2-4). Petrocalcic soil horizons were often clearly visible on the DOQQs. Polygonal

boundaries were refined using the stereo imagery, particularly in highly eroded terrain.

### DEFINING CHARACTERISTICS

The characteristics of the Cuchillo surface as a geomorphic surface were described in the introduction. The Cuchillo surface represents the top or maximum vertical extent of Quaternary deposition in the Engle and Palomas basins before the Rio Grande and tributaries began to entrench. Cuchillo surface remnants closest to the edge of the river valley have an average grade of  $\sim 90$  m above the modern Rio Grande floodplain, significantly higher than other Quaternary terraces and fan complexes except at basin margins (Figs. 2-4). Based upon similarities in surface elevations ( $\sim 90$ -95 m above the Rio Grande floodplain), soil development, and magnetostratigraphic ages, it is considered to be correlative to the lower La Mesa surface of the Camp Rice Formation to the south in the Mesilla basin (Gile et al., 1981; Seager and Mack, 1991, Mack et al, 1998), and to the Sunport surface of the Sierra Ladrones Formation to the north in the Albuquerque basin (Connell et al., 2007; Connell, 2010), and not the higher, older multiple surfaces of the Llano de Albuquerque, as previously suggested. The Llano de Manzano surfaces near the Rio Grande valley in the southern Albuquerque basin are lower than the Sunport surface and formed after the Rio Grande began entrenchment.

In the Socorro area, the maximum height of Rio Grande aggradation is about 90-105 m above the floodplain (Love et al., 2009), but deposits are commonly cut by normal faults and deposits are only preserved on the margins of the Rio Grande valley. Cikoski (2010) reported similar levels for the top of river deposits in the Bosque del Apache area. West of the Rio Grande valley the deposits are faulted and slightly tilted to the south.

The Cuchillo surface is comprised of both axial and piedmont facies sediments, whose clast content and size are determined by landscape position. Although largely constructional, coarse proximal piedmont facies do occur in predominantly erosional mountain-front / basin-margin settings (Fig. 2). The major parts of the surface lie west of the Rio Grande and generally slope 1-2° riverward through finer distal piedmont sediments into axial sands and clays adjacent to the present floodplain (Fig. 3). Smaller surface remnants capping paleofans flanking the Caballo Mountains east of the Rio Grande have similar westward slopes, although Mack and Leeder (1999) document several steeper fans sloping 3-4°, and attribute their increased slopes to smaller catchment areas and lithologically controlled coarser clast sizes relative to the other paleofans (Fig. 4). Quaternary faulting, both basin-bounding (Palomas Creek fault, Hot Springs fault, Caballo fault, Red Hills fault) and intrabasinal (Cuchillo Negro fault zone, Willow Draw fault, Mud Springs fault; Lozinsky, 1987; Machette, 1987; Seager and Mack, 2003), has offset surface profiles on both sides of the river. The most notable of these, the Caballo fault, with  $>30$  m of movement since middle Pleistocene (Mack and Leeder, 1999), has elevated footwall-surface segments accordingly.

A geomorphic surface can be used in a chronologic or stratigraphic context because of its finite episode of formation and ensuing stability, but its terminology should not be applied to the

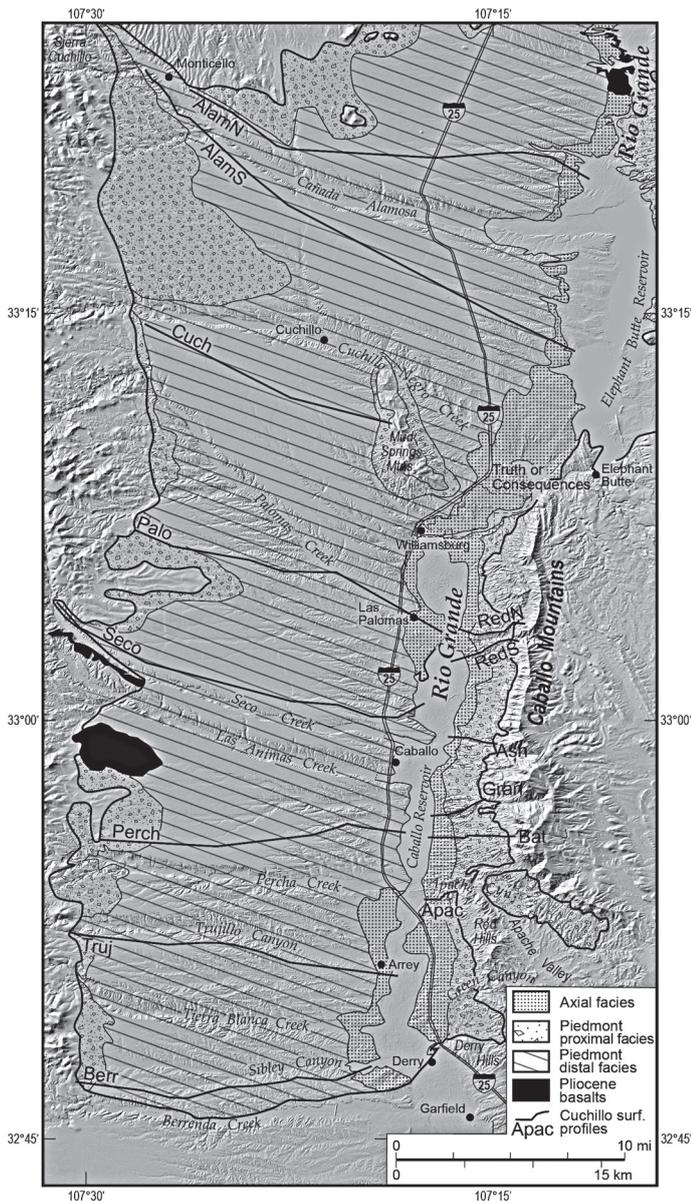


FIGURE 2. Distribution of the Palomas Formation in the Engle and Palomas basins modified from Lozinsky and Hawley (1986a, b) showing the locations of topographic profiles plotted in Figures 3 and 4. Hillshade base from 1-m 2009 NAIP DEM data.

underlying stratigraphic deposits, per se, which could result in misleading implications (Connell et al., 2007). Nevertheless, the depositional elements of a surface are necessarily the same age as the immediately underlying sediments, or where erosional, the surface is younger than the youngest geologic material it cuts, younger than any structure or landform it bevels (Daniels et al., 1971; Tonkin et al., 1981). Likewise, the magnitude of surface and shallow sub-surface alteration (e.g., soil development, degree of clast weathering, degree of desert pavement formation) are also equivalent among different surface remnants formed on varying geologic materials and landforms. These temporal and development criteria should be used to correlate surfaces in simi-

lar landscape positions and differentiate them from younger (usually lower) surfaces or older ones where confidence allows.

As Daniels et al. (1971) emphasized, a geomorphic surface must have a definite geographic extent and is likely to be contiguous at the time of formation, though it need not be. More importantly, the same causal formative factors must have operated at roughly the same rate within this defined geography. Within the Rio Grande rift, this finite formational period is necessarily time-transgressive, as initial axial Rio Grande entrenchment progressed up tributaries to marginal piedmont settings. The Cuchillo surface was thus formed within the coalescing Engle and Palomas basins at the end of Palomas Formation deposition after the initiation of incision by the Rio Grande within these basins, again at ~0.8 Ma. Stability has ensued in those high landscape positions which have not been buried by later deposits nor dissected by gullies or streams (if we assume deflation has been kept to a minimum), forming extensive desert pavements (Fig. 1) and well developed soils in these remnant areas; soils with argillic Bt horizons  $\geq 15$  cm thick overlying petrocalcic horizons with stage III – IV development accumulating to depths of  $\geq 1.5$  m (Fig. 5).

### PROPOSED DELINEATION

The proposed distribution of the Cuchillo geomorphic surface is depicted in Figure 6. We consider each of the parts of the surface and their characteristics below.

#### Northern and Western Areas

Lozinsky and Hawley (1986a, p. 242) stated, “the term Cuchillo is used here to designate Plio-Pleistocene surfaces that predate cutting of the Rio Grande valley in the Palomas, Engle, and San Marcial basins.” Although deposits similar to the Palomas Formation clearly extend northward into the San Marcial basin with a similar surface of maximum aggradation, at this point we decline to project the Cuchillo surface northward and restrict its northern boundary to south of the large, higher San Jose Canyon fan complex debouching eastward from the southern San Mateo Mountains. This is a convenient place to mark both the northern extent of the Engle basin and the Cuchillo surface. The eastward extension of volcanic rocks of the San Mateo Mountains and the Pliocene basalt flows west of the Proterozoic mountain front of the Fra Cristobal Range effectively constrict the valley here and act as a shallow bedrock sill between basins. The San Jose Canyon fan completely fills the Rio Grande valley west of the narrow floodplain. Partial burial of the Cuchillo surface by fan deposition, while possible, is unlikely. Fan soils are as well developed as those of the Cuchillo, implying a contemporaneous or older age. North of the San Jose fan, the dissected alluvial fans and piedmont aprons of Cuervo, Chaunte, and Nogal Canyons are disrupted by uplifted bedrock blocks and have multiple dissected surfaces and terraces that have yet to be traced and tied in to the maximum aggradation of the Rio Grande.

The physiography of the San Marcial basin farther north consists of broad piedmont aprons from the San Mateo and Magdalena Mountains with several large drainages crossing to the

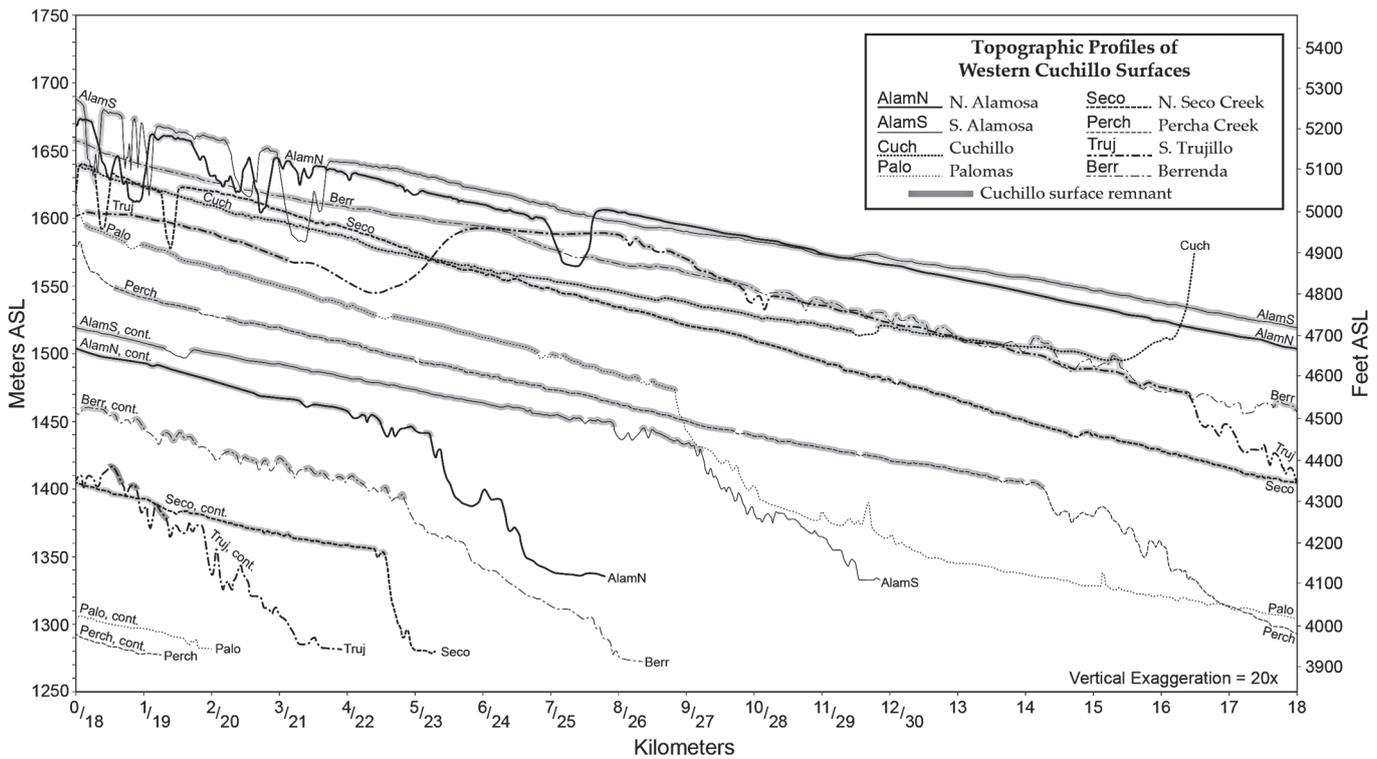


FIGURE 3. Selected topographic profiles of Cuchillo surface remnants west of the Rio Grande.

Rio Grande. The Milligan Gulch and Broken Tank subbasins have multiple levels of terrace treads graded to different levels of terraces of the Rio Grande that have yet to be studied. East of the Rio Grande is a broad plain of aggraded ancestral river deposits extending at least 20 km into the northern Jornada del Muerto basin. Until more investigation delineates different levels of aggradation and erosion in the greater San Marcial basin, we defer extending the Cuchillo surface into this area.

In the northern Engle basin, the Peñasco Canyon and Lumber Canyon fans are actually slightly inset into the Cuchillo surface (Fig. 6), while older higher surfaces occupy the Monticello graben on either side of Cañada Alamosa (Monticello Canyon). The highest of these west of Garcia Falls is the Burma surface, which is of sufficient height and antiquity (at least Pliocene; perhaps Miocene?), to put it most likely beyond base-level control of the Rio Grande in both time and space. Within Cañada Alamosa up canyon of the Engle basin, the Cuchillo surface actually grades into a terrace level, and is no longer at the top of Quaternary deposition as it is in the basin (McCraw and Williams, 2012, this guidebook).

South of Cañada Alamosa, the Willow Spring Draw fan complex flanking the Sierra Cuchillo is higher than the Cuchillo surface, and there are other multiple, higher, greatly dissected surfaces extending southward beyond Palomas Creek, such as those developed on the Miocene Rincon Valley Formation (Fig. 6; Seager et al., 1982).

**Southern and Eastern Areas**

South of both Seco Creek and Las Animas Creek, Pliocene volcanic rocks complicate the Palomas basin margin. These areas are not included in the Cuchillo surface distribution for clarity,

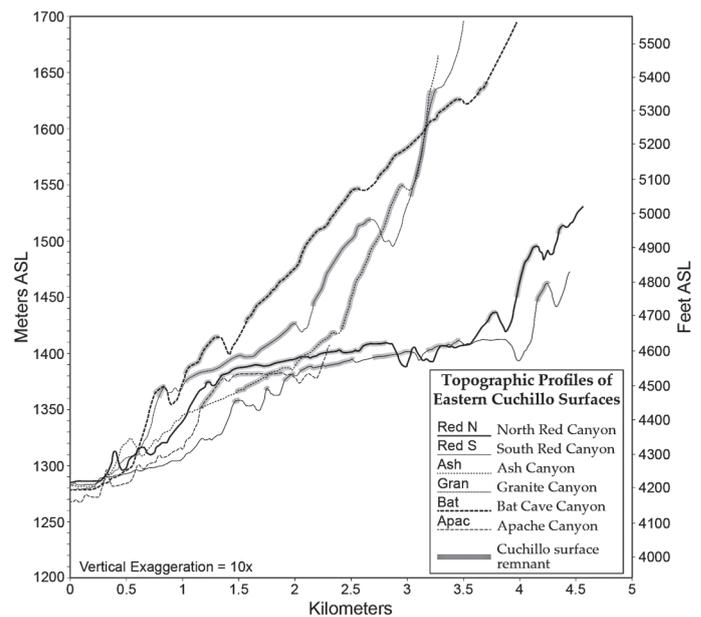


FIGURE 4. Selected topographic profiles of Cuchillo surface remnants east of the Rio Grande.

### Cuchillo Surface Soil Profile

Typic Paleorthids Nickel-Chamberino association (Neher, 1984)

Location: Southern bank cut of Aragon Wash; (UTM Zone 13S 286955 3692417; NE ¼, SE ¼, Sec. 18, T. 11 S., R. 4 W.)

Parent Material: Distal volcanoclastic fanglomerate, top of Palomas Formation

Elevation: 1,521m (4,990 ft) Aspect: North Slope: 0° Vegetation: Chihuahuan desertscrub

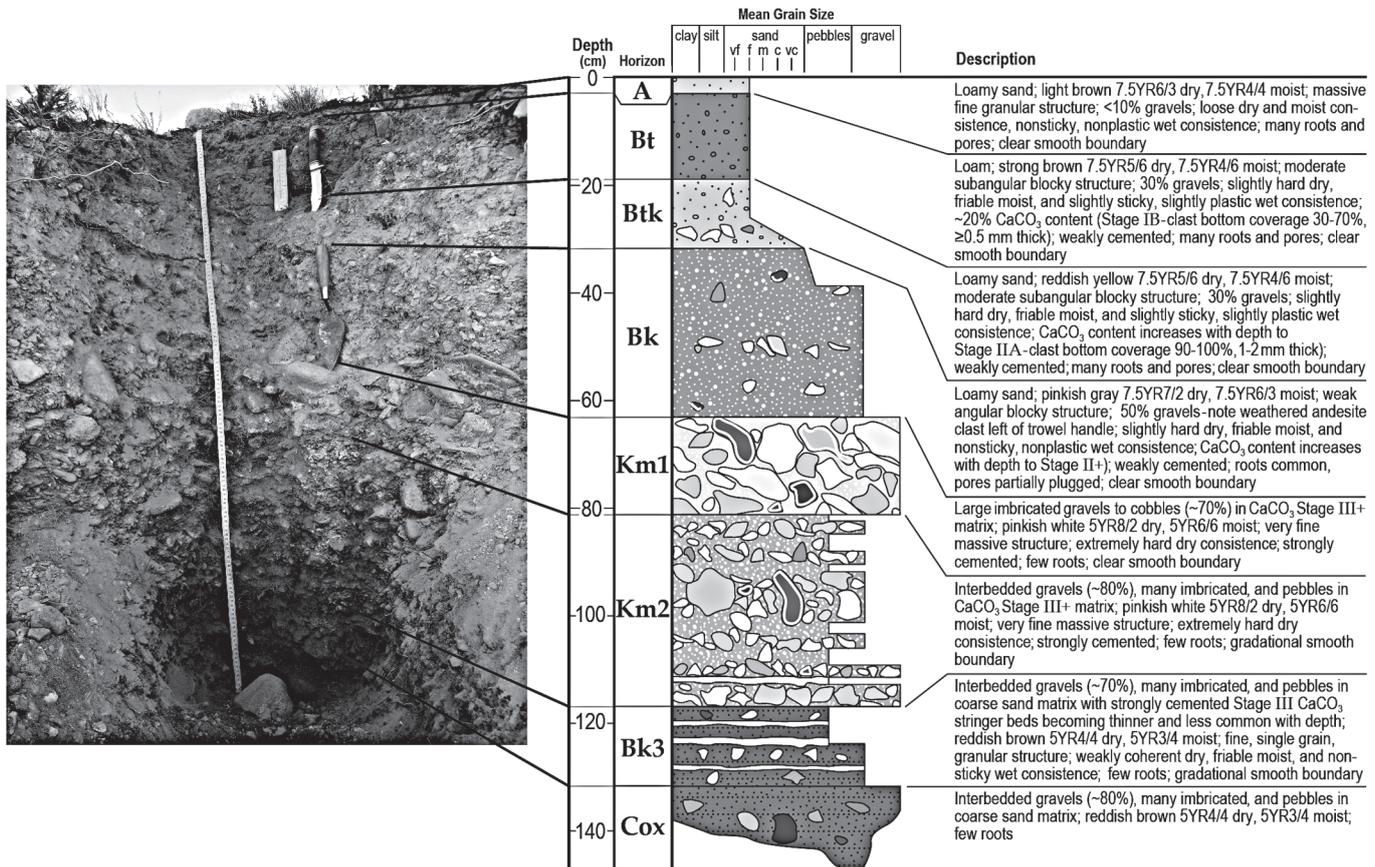


FIGURE 5. Soil profile developed on the Cuchillo surface adjacent to Aragon Wash on the North Alamosa remnant described for Stop 1 of the supplemental road log out the Red Rock Road (McCraw, 2012, this guidebook). For further location information and description, refer to this minipaper.

although the volcanic rocks have clearly been buried by Palomas Formation in places and have been used as a line of evidence for surface age. In addition to the Pliocene extrusive rocks, the distribution of upper Oligocene Mogollon Group volcanic rocks is complex along the Black Range margin south of Percha Creek, and Palomas Formation deposits appear to be very thin on aerial imagery and possibly discontinuous in a few places, resulting in a highly dissected Cuchillo surface here.

Seager and Mack (1991) informally suggested that Camp Rice Formation terminology would be more appropriately used to the south of Berrenda Creek and the southern boundary of the Cuchillo surface is defined accordingly, just north of this drainage. There is an extensive surface occurring at approximately the same elevation as the Berrenda Cuchillo remnant (seen at the bottom of Fig. 6) south of Berrenda Creek and stretching far to the south, southwest to the vicinity of Nutt. While this surface

may be stratigraphically equivalent to the Cuchillo, at least at its northern limit, it extends completely out of the Rio Grande basin into the Mimbres Creek drainage, and is easily excluded.

Some might question why the small, isolated paleofans on the northwest flank of the Apache Canyon (Apache graben) are included as Cuchillo eastern fan remnants (east of the Rio Grande), since they presently appear far removed from the Rio Grande, effectively cut off by the Red Hills, Nakaye Mountain, and the Derry Hills. This was not the case at the time of Cuchillo surface formation, however, as Seager and Mack (1991) explain, when the ancestral Green Canyon fan and river alluvium largely buried the divide between the Red Hills and Nakaye Mountain, as well as most of the Derry Hills. The Cuchillo surface was extensive here at this time. The ensuing degradation of the Rio Grande and the superposition of the modern Green Canyon drainage have led to the exhumation of these uplands, erosion of Apache Canyon, and the isolation of the eastern fan remnants.



The Cuchillo surface atop the paleofans debouching from the Caballo Mountains, collectively referred to here as the eastern fan remnants, have been adequately described (but not delineated) by Mack and Seager (1990), Mack and James (1992), Mack and Leeder (1999), Seager and Mack (2003), Seager and Mack (2005) and Mack et al. (2006). Where not eroded, these extend south along the base of the mountain front from Red Canyon to the Green Canyon drainage in the Apache Valley. Although Seager and Mack (1998) map Palomas Formation still further south in the Rincon Valley and up McLeod Draw, these areas lie southeast of the Palomas basin in the Hatch-Rincon basin of Mack et al. (2006), and have therefore been excluded. The “Palomas surface” in the Rincon Valley that Hawley (1965), and Hawley et al. (1969, p. 61) describe is  $\geq 122$  m above the modern floodplain and thus too high to be Cuchillo; they correlate this to the “older parts of La Mesa surface near Las Cruces.”

### SUMMARY

The Cuchillo geomorphic surface, although long recognized as the constructional top of the Palomas Formation in the Engle and Palomas basins, has never systematically and comprehensively been delineated. In this overview, the characteristics of the surface are described in terms of the defining criteria of a geomorphic surface (geometry, landscape position, finite age, uniformity in degree of soil development, and a clearly defined geography): a) its planar surface formed at the cessation of Palomas Formation aggradation at  $\sim 0.8$  Ma; b) modern surface remnants generally slope only  $1-2^\circ$  with few exceptions and have a grade of  $\sim 90$  m above the modern floodplain of the Rio Grande; c) it consistently exhibits mature soils with thick argillic Bt horizons overlying petrocalcic stage III-IV K horizons with depths often exceeding 1.5 m; and d) while it is contemporaneous with the termination of the Palomas Formation, its distribution is restricted to the defined physiographic extent of the Engle and Palomas basins, where it could likely have been contiguous at time of formation and where the ensuing downcutting of the Rio Grande occurred uniformly. The distribution mapped, extending from just south of the San Jose Canyon fan to just north of Berrenda Creek west of the Rio Grande, as well as along the footwall escarpment of the Caballo Mountains south of Truth or Consequences to the Apache Valley, is presented here as a proposal to spark further discussions, which could ultimately lead to further refinement.

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