

APPENDIX 1. DESCRIPTION OF THE NOGAL CANYON STRATIGRAPHIC SECTION, CENTRAL CHUPADERA MOUNTAINS, LUIS LOPEZ 7.5-MINUTE QUADRANGLE [SE1/4 SE1/4 SECTION 33, T4S, R1W].

Grain sizes follow the Udden-Wentworth scale for clastic sediments (Udden, 1914; Wentworth, 1922) and are based on field estimates. Sand textures are abbreviated as follows: very fine-lower, vFL; very fine-upper, vfU; fine-lower, fL; fine-upper, fU; medium-lower, mL; medium-upper, mU; coarse-lower, cL; coarse-upper, cU; very coarse-lower, vcL; very coarse-upper, vcU. Pebble sizes are abbreviated as: very fine, vf; fine, f; medium, m; coarse, c; and very coarse, vc. The term “clast(s)” refers to the grain size fraction greater than 2 mm in diameter. Descriptions of bedding thickness follow Ingram (1954). “Micro-laminations” are 0.1-1 mm in thickness. Sand composition is estimated using a hand lens.

Nogal Canyon stratigraphic section. This section consists of the Upper Popotosa Formation and basalt of Broken Tank. The Popotosa Formation here consists of two contrasting piedmont deposits separated by a middle interval comprised of basalt (basalt of Broken Tank) overlain by relatively fine-grained basin floor facies. Measured in the southwestern Luiz Lopez 7.5-minute quadrangle, Socorro County, New Mexico [SE1/4 SE1/4 Section 33, T4S, R1W]. Section measured on north side of Nogal Canyon on either side of where the basalt of Broken Tank crosses the canyon. Measured and described by Dan Koning on December 22, 2021, using an abney level, brunton compass, Jacob's staff, and hand-held GPS unit. Assisted by Claire Koning (note taker) and Adele Koning (clast sizes). Andy Jochems and Kevin Hobbs measured clast imbrication and did clast counts. Blue-shaded text = photos. Red-shaded text = samples.

Unit	Description	Thickness (m) (Unit) (Total)	
	Depositional environment: Southeastward-sloping piedmont heading in the southeastern Magdalena Mountains. Lower part interfingers with fine-grained, basin floor deposits – likely transitional zone between distal piedmont and playa margin.		
	Top of Segment 4 is at the following UTM coordinates: 320609m E, 3,754,366 m N (zone 13, NAD 83).		
Unit 15ext	Estimated continuation of East-extension conglomerate – Inaccessible cliff exposure. <i>@16-31 m: Photo NC_SS_EastExt_aboveCS_06iste_ph: Jake staff overlaps CPF-2b and CC-2b. Very thin to medium, tabular to lenticular beds; note tangential cross stratification about 2 ft above and left of the top of the Jake staff.</i>	15	31
Unit 15	Sandy conglomerate and pebbly sandstone – Very thin to medium, tabular to lenticular beds. Gravel consist of pebbles with 10-15% cobbles that are subrounded-subangular and poorly sorted. Upper part of exposure, above clast-size measurement site CS-06, contains 1% boulders. Cobbles are commonly in lenticular, medium-thick beds. Pebbly sand beds are mostly very thin to thin and tabular (locally low-angle cross-stratified). Gravel is coarser here than in Segments 1 and 2 and slightly more rounded. Minor La Jara basalt clasts seen, and deep-reddish brown, K-metasomatized clasts also present (especially for coarse ignimbrite clasts). Sand is mostly light reddish brown (5YR 6/3) and medium to very coarse grained (<10% very fine to fine sand), subrounded-subangular, and high-poorly sorted, and composed of volcanic grains with 20-25% estimated clear quartz-feldspar. Estimate 1-3% mud in the matrix. Strongly cemented but weak HCl effervescence, except in lower few meters where the HCl effervescence is relatively strong. <i>@15-16.5 m: Clast size site CS-06</i> <i>@10.5-11 m: Paleoflow site PF-3b and Clast composition site CC-3b</i> <i>@10.5-13 m: Photo NC_SS_EastExt_10to12meters_ph: Jake staff overlaps CPF-2b and CC-2b. Very thin to medium, tabular to lenticular beds; note tangential cross stratification about 2 ft above and left of the top of the Jake staff.</i>	16.5	16.5

Unit	Description	Thickness (m)	
		(Unit)	(Total)
	@9-11.5 m: Clast size site CS-07		
	Base of Segment 4 – because I could not correlate strata across fault, I reset stratigraphic height here at 0.0.	0	0
	<p>@104 m, translate down-dip to east by tracing beds. This correlation was done by standing in the stream bed and looking north. I estimate +/- 2 m in this correlation. I correlated eastward to a major fault. At the fault, this traced stratigraphic interval is about 4 m above the base of exposure. The fault is east-side down, and I cannot trace strata across it with confidence. I estimate at least several meters of east-down throw.</p> <p><i>Location of fault (320,596 m E; 3,754,349 m N, NAD83, zone 13).</i></p> <p>Top of Segment 3.</p>		
Unit 14ext	<p>Sandy conglomerate and pebbly sandstone – As in Unit 4, but in an inaccessible cliff exposure. Inspection of topple block suggests subrounded textures are more common.</p> <p><i>Along cliff to east, strata tilts decrease to ~5 degrees E, but near the east-down fault increase to 14 degrees east.</i></p>	~18	122
Unit 14	<p>Sandy conglomerate and pebbly sandstone – Sandy pebble conglomerate with 5% interbeds of clayey-silty sand (with minor pebbles). Sandy gravel is in very thin to thin (minor medium), tabular to broadly lenticular beds; 3-7% lenticular beds. Gravel is clast-to matrix-supported, subangular, poorly to moderately sorted, composed of felsic volcanic rocks, and comprised of pebbles with 3-8% cobbles. Gravel matrix consists of light reddish brown (5YR 6/4), fL-vcU sand that is subangular, poorly sorted, and a volcanic litharenite; estimate 1-3% mud in the matrix. Sand beds are thin to medium and tabular; these consist mainly of light reddish brown (5YR 6/4), silty-clayey very fine sand with minor scattered grains of medium to very coarse sand – probably are deposited by hyperconcentrated flow processes.</p> <p>@ 102.5-106 m: Photo NC_SS_Unit_14_ph_01: Jake staff overlaps area of first clast count site I did with Adele. Note rightward apparent paleoflow based on imbricated clasts near the middle of the Jacob staff.</p> <p>@ 102.5-104 m: Paleoflow site PF-3d</p> <p>@ 102.5-107 m: Photo NC_SS_Unit_14_ph_02: Jake staff overlaps area of first clast count site I did with Adele. Note tabular to broadly lenticular beds and 5-8% cobbles.</p> <p>@ 98-100.5 m: Photo NC_SS_Unit_14_ph_03: thin to medium, tabular to broadly lenticular beds of sandy gravel; minor clayey-silty very fine-fine sand. The latter have minor amounts of scattered, m-vc sand and pebbles and are inferred to represent distal hyperconcentrated flow deposits.</p> <p>@ 97.8-99.8: Clast size measurement site.</p>	6.2	104

Unit	Description	Thickness (m)	
		(Unit)	(Total)
	Unit 5 in original field notes.		
Unit 13	<p>Clay-silt (upper recessed marker bed) – Internally massive and light reddish brown (5YR 6/3). 1% calcium carbonate nodules (fine pebble size), trace to 0.5% scattered medium to very coarse sand, and very trace (one or two) pebbles. In one location, sandy pebbles of Unit 14 fills a vertical fissure (a few cm wide) that completely goes through this unit. Highly scoured upper contact, with 10-30 cm of relief.</p> <p>Unit 4 in original field notes</p> <p>@ 97-99 m: Photo NC_SS_Unit_13_ph_01 and _ph_02: Unit 13 has a sharp, planar lower contact and a highly scoured upper contact. Note internally massive texture in the silt-clay of Unit 13.</p> <p>@ 97.3-97.8 m: Photo NC_SS_Unit_13_ph_03: Close-up of Unit 13. Note internally massive texture of the silt and clay. Trace amounts of scattered, m-vc sand can be noted in upper right of photo.</p> <p>Interpreted paleoenvironment: distal piedmont – playa margin.</p>	0.5	97.8
Unit 12	<p>Sandy conglomerate – Sandy pebble-conglomerate in relatively vague, thin (minor medium), tabular to broadly lenticular beds. Gravel are mostly clast-supported (minor matrix-supported), mostly subangular, and moderately to poorly sorted. Gravel matrix consists of light reddish brown (2.5YR 6/4), very fine to very coarse sand with 5-7% mud. Sand is subangular, poorly sorted, and the medium to very coarse sand grains are volcanic. High mud content in some beds suggestive of debris flows in much of unit. Coarsens upwards. There are 1% clasts of reworked fine-white tuff.</p> <p>@ 95-99 m: Photo NC_SS_Unit_12_ph: Color book at yellow field book for scale. Note how unit 12 coarsens upwards. Unit 13 has a sharp, planar lower contact and a highly scoured upper contact.</p> <p>@ 95.5-97.3 m: Paleoflow site PF-3c.</p>	1.8	97.3
Unit 11	<p>Very fine-grained sandstone and silt-clay (lower recessed marker bed) – Light reddish brown (5YR 6/3), internally massive, silt-clay and very fine sand with 5% fL-mU sand. 0.5% scattered coarse to very coarse sand and trace pebbles. Well-consolidated, but fine-grained nature leads to this bed being recessed. 5-10% nodules of calcium carbonate that are up to 2 cm long; these get more abundant up-section. Lower 15 cm contains more medium to very coarse sand and contains minor very thin beds of coarse-very coarse sand + pebbles.</p> <p>@ 95-99 m: Photo NC_SS_Unit_10to13_ph: Jake staff for scale. Lower recessed bed is 0.5 m above the top of the Jake staff. The gravelly fissure fill of Unit 13 is seen about 1.5 m right (east) of the main nook recess.</p> <p>Interpreted paleoenvironment: distal piedmont (sourced from NW) – basin floor margin.</p>	0.5	95.5
Unit 10	<p>Pebbly sandstone – Pebbly sandstone containing 15-20% beds of sandy pebbles. Both sediment types are in thin (minor medium), tabular beds. Gravel is subangular, low-moderately sorted, and composed mainly of felsic clasts. Matrix is light reddish brown (5YR 6/4), very fine- to very coarse-grained sand; estimate 1-3% mud in matrix. Sand is subrounded to subangular, poorly sorted, and the medium to very coarse sand grains are composed of volcanic lithics.</p>	2	95

Unit	Description	Thickness (m)	
		(Unit)	(Total)
	Interpreted paleoenvironment: distal piedmont (sourced from NW)		
Unit 9	<p>Sandy Conglomerate – Tabular to broadly lenticular, thin to medium beds (mostly thin). Gravel is sand- to clast-supported, subangular, and mostly moderately sorted within a bed. Estimate 5-10% cobbles; definitely less cobbles than Units 1-3. Matrix sand is light reddish brown (5YR 6/4), very fine to very coarse, and subangular (minor subrounded and minor angular). Medium-very coarse sand is composed of volcanic lithic grains. Matrix contains 1-3% mud. Well consolidated and moderately-strongly cemented, but no to very weak effervescence in HCl.</p> <p>@ 89-93 m: Exposures to west exhibit minor very thin, tabular beds of clayey silt sand. Also features fracture zones up to 8 cm wide containing massive and crystalline quartz and calcite in-fillings.</p> <p>@-88-94 m: Photo NC_SS_Unit_09_ph: Jake staff for scale. The head of the Jake staff is where PF-2a and CC-2a sites are located.</p> <p>@ 91.2-93 m: Clast size measurement site CS-04.</p> <p>@ 89.5-90.3 m: Paleoflow site PF-3a and Clast count site CC-3a.</p> <p>Interpreted paleoenvironment: distal piedmont (sourced from NW)</p>	5	93
	<p>@ ~88 m, a decent bedding plane measurement of (strike\dip) 315°\14°. But I measured vertically along the cliff face and traced beds eastwards in measuring this part of the strat section.</p> <p><i>Base of Segment 3. Placed stake that is labeled (erroneously) as “base of Segment 2”. Base of Segment 3 is at base of lowest cliff exposure, just east of a large fall block of conglomerate, at the following UTM coordinate (NAD 83, zone 13): 320,445 m E, 3,754,381m N.</i></p> <p><i>Top of Segment 2: 3,20,398 m E, 3,754,364 m N. The 4 m below the top of segment 2 overlaps with the Unit 9 described in the lowest part of Segment 2.</i></p>		88
Unit 8b	<p>Sandy conglomerate interbedded with minor clayey silt and sand – As in Unit 8a, but outcrop face exhibits 2% boulders, 5% cobbles, 20% pebbles, and 10% very coarse sand. There are minor very thin, tabular beds of clayey silt sand. Also features fracture zones up to 8 cm wide containing massive and crystalline quartz and calcite in-fillings. Note that this unit correlates to Unit 9.</p> <p>Photo NC_SS_EastExtension_Unit8Fracture.</p>	4	93
No exp	No exposure – The relationship and contacts between units 8a and 8b is uncertain. There may also be an additional covered unit.	6	89
Unit 8a	<p>Sandy conglomerate – Very thin to medium, tabular to lenticular beds. Sand is pink to light brown (7.5YR 7/4 to 6/3), containing fL to vcL, subangular to subrounded, moderately sorted grains composed of 50% quartz, 30% lithic grains, and 20% feldspar. Outcrop face exhibits 15-30% pebble through boulders (maximum measured clast long-axis length of 30 cm). Conglomerate beds are mostly matrix-supported (30-60% pebbles or coarser), with minor clast-supported (50-70% pebbles or coarser). Granules, pebbles, cobbles, and boulders are predominately angular to subangular, with minor subrounded and trace rounded clasts. Reacts weakly to moderately with 10% HCl, and inferred to</p>	1.7	83

Unit	Description	Thickness (m)	
		(Unit)	(Total)
	be cemented by calcite and silica. Coarser beds are stronger and react less (or not at all) with HCl.		
Unit 7	<p>Sand – Single thin-medium bed with no observed internal structures (i.e., massive). Brown to light brown (7.5YR 5/2 to 6/3). Consists of fU to cL well-sorted subangular to subrounded sand composed of 60% quartz, 20% feldspar, and 20% lithic grains. No clay; trace silt. No pebbles. Sharp upper and lower contacts. Can be traced laterally for >4 m. Does not react with 10% HCl.</p> <p>Interpreted paleoenvironment: eolian deposition of locally derived sand during alluvial quiescence on distal piedmont.</p>	0.1	81.3
Unit 6	<p>Silty, pebbly sands – Faint thin (minor medium), tabular to lenticular beds. Granules, pebbles, and cobbles are angular to subangular, poorly sorted, sand-supported. Sand is brown (7.5YR 5/4), contains moderately sorted vfU-cU, subangular to subrounded grains. Estimated sand composition via hand lens: 40% quartz, 40% lithics, and 20% feldspar. Lithics include predominately local volcanics with minor mafics. Pebbles appear to be same composition as those in clast count of unit 9 (CC-3a). Pebble content increases upward through this unit, from 0% at 2.1 m height above basalt to 15% at 6.5 m height above basalt. No to very weak effervescence in 10% HCl.</p> <p>@79.3 m: Maximum pebble axis of 8 cm.</p> <p>@ 78.3 m: Maximum long gravel axis is 3 cm.</p> <p>Interpreted paleoenvironment: distal piedmont sourced from the northwest.</p>	5.9	81.2
Unit 5	<p>Silty very fine to fine sand – Massive; bedding not observed. Light brown (7.5YR 6/3-4), silty very fine sand with trace medium to coarse grains. Grains are vfL-fL, well-sorted, subangular to rounded. Trace coarse grains that are subangular. 96% of grains are clear or whitish; trace black lithics and oxides and trace orange chert. Very weak effervescence in 10% HCL. Poorly exposed. Upper contact is gradational.</p> <p>Interpreted paleoenvironment: eolian silt-fine sand on a basalt flow and/or basin floor deposits.</p>	2.3	75.3
	<p>Base of Section 2</p> <p><i>UTM coordinates of Unit 5/ Unit 4 contact in arroyo bottom: 320,411 m E, 3,754,348 m N (NAD83, zone 13).</i></p>		
Unit 4	<p>Basalt of Broken Tank – Not described in this work, but according to Chamberlin et al. (2002) the basalt here consists of stacked flows that are dark gray to grayish black and slightly porphyritic to fine-grained; vesicularity ranges from dense to microvesicular to amygdaloidal. Slightly porphyritic basal zones locally contain sparse, fine-grained (<1.5 mm) phenocrysts of plagioclase, clinopyroxene, and olivine (the latter commonly altered to reddish brown iddingsite). Calcite in amygdaloids and veins are fairly common. Thickness measured using trigonometry (true attitude of 319°\ 22° NE) and an along-dip distance of 108 m (latter from Google Earth).</p>	40	73
	<p>Top of Segment 1</p> <p><i>UTM coordinates of Unit 4/ Unit 3 contact in arroyo bottom: 3203045 m E, 3754300 m N (NAD83, zone 13).</i></p>		
Unit 3b	<p>Reddish sandy conglomerate and pebbly sandstone – Similar to unit 1. Features 10% fine to coarse cobbles (rest of gravel fraction are pebbles) and a light red color (2.5YR 7/6).</p>	2.6	35.6

Unit	Description	Thickness (m)	
		(Unit)	(Total)
	<p>@ 33.0-33.5 m: Paleoflow site PF-1d</p> <p>Bedding attitude: 301\26 NE, 333\23 NE, 323\16 NE. I think the 333\23NE attitude is most representative.</p>		
Unit 3a	<p>Sandy conglomerate and pebbly sandstone – Similar to unit 1; features 10-15% cobbles but exhibits a light red color (2.5YR 7/6). 10% cobbles in gravel fraction, rest are pebbles.</p> <p>@30-33 m: Paleoflow site PF-1c.</p> <p>@33.8-34.6 m: Clast-count site CC-1b</p> <p>@30-33 m: Clast-size measurement site CS-03.</p> <p>@27-35 m: Photo NC_SS_Units_02to03_ph_01: Andy is standing on the Unit 03a/02 contact. Base of unit 2 corresponds to the mouth of the side-gully at the extreme left of the photo. At right-center is the lower part of the basalt of Broken Tank. The reddish strata below the basalt corresponds to unit 3b.</p> <p>@27-35 m: Photo NC_SS_Units_02to03_ph_02: Andy is standing on the Unit 03a/02 contact. Base of unit 2 corresponds to the mouth of the side-gully at the extreme left of the photo. Oranger sediment near mesquite (top right) is lateral continuation of Unit 3b, but here cobbles are relatively sparse.</p>	3.4	33.0
Unit 2	<p>Pebbly sandstone sand sandy pebble-conglomerate – Similar to Unit 1, but lacking cobbles (1% cobbles).</p> <p>Bottom of unit corresponds to base of a prominent side gully.</p> <p>@27 m: Change to trend and dip of 095 \ 15 E based on apparent dip on outcrop face.</p>	2.6	29.6
Unit 1	<p>Sandy conglomerate and pebbly sandstone – About subequal sandy conglomerate vs. pebbly sandstone. Strata are in thin to medium, tabular-lenticular beds. Gravel consists of pebbles with 8-10% cobbles. Cobble-bearing beds tend to be lenticular. Gravel are subangular-angular, moderately to poorly sorted within a bed, and composed of felsic clasts with trace amounts of reworked Popotosa Formation (reddish and strongly cemented). Sand in the pebbly sand beds is pink (5YR 7/3), fU-vcU, subangular (minor angular), poorly sorted, and contains 1-3% silt-clay; volcanic grains > [quartz + feldspar]; quartz is about 10-15%. In sandy pebble-conglomerate, the matrix mostly consists of subangular, coarse to very coarse sand grains composed of volcanic lithic grains. Moderately cemented.</p> <p>@22.2-25.5 m: Photo NC_SS_Unit_01_ph_05: Thin to medium, tabular to lenticular beds of pebbly sand and sandy gravel. Gift box for scale. The side canyon noted in the descriptions is in the upper right of the photo.</p> <p>@20-21.5: Paleoflow site 1b.</p> <p>@19-22.5 m: Photo NC_SS_Unit_01_ph_04: Thin to medium, tabular to lenticular beds of pebbly sand and sandy gravel. Between the two back packs is the location of the PF-1b paleoflow site.</p>	27	27

Unit	Description	Thickness (m)	
		(Unit)	(Total)
	<p>@15-18 m: Clast size measurement site CS-02.</p> <p>@15 m: E-dipping normal fault with about 1 m of east-down throw.</p> <p>@10-12.5: Clast size measurement site CS-01.</p> <p>@9 m: Normal fault with 0.4 m of west-down throw.</p> <p>@7.5 m: Normal fault with 0.2 m of west-down throw.</p> <p>@7-10.5 m: Photo NC_SS_Unit_01_ph_03: Kevin standing between two west-down, minor normal faults. Note the tabular to lenticular beds and lack of distinct, U-shaped channel fills nor cross-stratification. Consistent with alluvial fan facies.</p> <p>@2-4 m: Clast count site CC-1a and Paleoflow site PF-1a.</p> <p>@ 0-4.5 m: Photo NC_SS_Unit_01_ph_01 through ph_02: Kevin for scale. The CC-01 and PF-01 sites are located in the coarser gravel bed to right of Kevin's head. .</p>		
	<p><i>Base of section at UTM coordinates: 320,186 m E, 3,754,301 N m (NAD 83, zone 13). From here used a trend and dip of 095° and 16° NE based on apparent attitude of (strike/dip) of 005°\22°NE . Strata are high-moderately to well cemented.</i></p>		

References

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