

NEW MEXICO BUREAU OF GEOLOGY AND MINERAL RESOURCES A RESEARCH DIVISION OF NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

New Mexico Bureau of Geology and Mineral Resources Open-File Geologic Map 287

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# Geologic Map of the San Marcial 7.5-Minute Quadrangle, Socorro County, New Mexico

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Digital layout and cartography by the NMBGMR Map Production Group: Phil L. Miller, Amy L. Dunn, Ann D. Knight, and Justine L. Nicolette

Quadrangle Location

New Mexico Bureau of Geology and Mineral Resources

New Mexico Tech

801 Leroy Place

Socorro, New Mexico

87801-4796

[575] 835-5490

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for free download in both PDF and ArcGIS formats at:

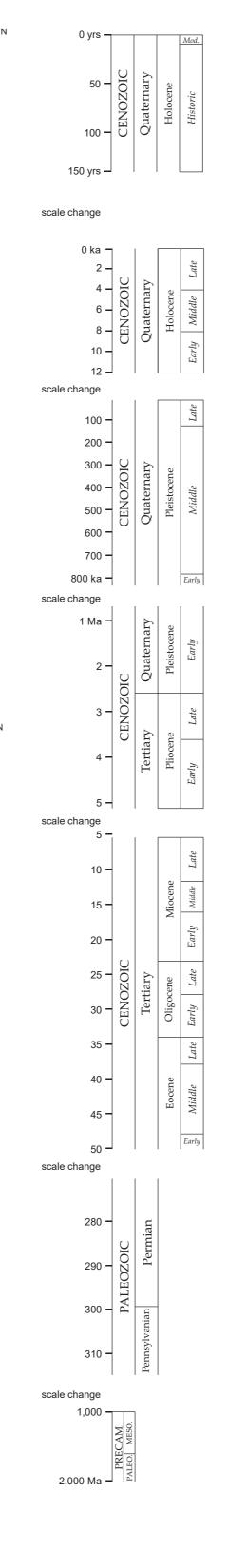
http://geoinfo.nmt.edu

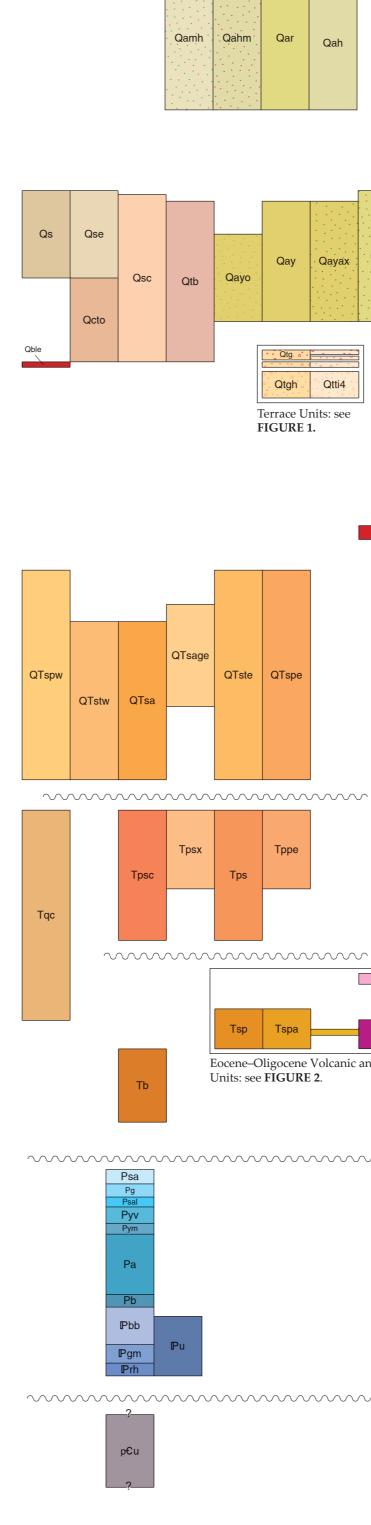
Magnetic Declination

At Map Center

June 2018 8º 29' East

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# colanation of Map Symbols

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	Gradational contact—Identity and existence are cer queried. Location is accurate where solid or approx			
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<u></u> ?	Fault in cross section showing local up/down off existence are certain or questionable where que where solid or approximate where dashed. A motion along the fault plane.			
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$\oplus$	Horizontal bedding			
× <sup>11</sup>	Inclined bedding—Showing strike and dip.			
$\times$	Vertical bedding—Showing strike.			
×, <sup>12</sup>	Approximate orientation of inclined bedding strike and dip.			
× <sup>10</sup>	Inclined flow banding, lamination, layering, rock—Showing strike and dip.			
83 <b>x</b>	Inclined aligned stretched-object lineation—Show			
K	Paleocurrent transport direction determined from			
₹ <sub>8</sub>	Paleocurrent transport direction determined from			
57	Paleocurrent transport direction determined from			
N-A	Bi-directional paleocurrent transport direction symetric ripplemarks.			
	Sediment transport direction determined from vertical or near-vertical section.			
R	Direction of paleo ground-waterflow-Location is			

Gradational contact—Identity and existence queried. Location is accurate where solid or	
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Fault in cross section showing local up/do existence are certain or questionable where where solid or approximate where das motion along the fault plane.	ere
Normal fault—Identity and existence are queried. Location is accurate where solid concealed where dotted. Ball and bar on o value and direction on inclined faults.	, a
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Key beds—Identity and existence are certa Guaje pumiceous sandstone	in.
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Monocline, anticlinal bend—Identity and accurate where solid or approximate where of dip; shorter arrow on steeper limb.	
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Unconformity in the Correlation of Map U	nit
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Small, minor syncline, vertical or near-verti	cal
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Inclined bedding—Showing strike and dip	
Vertical bedding—Showing strike.	
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### Comments to Map Users

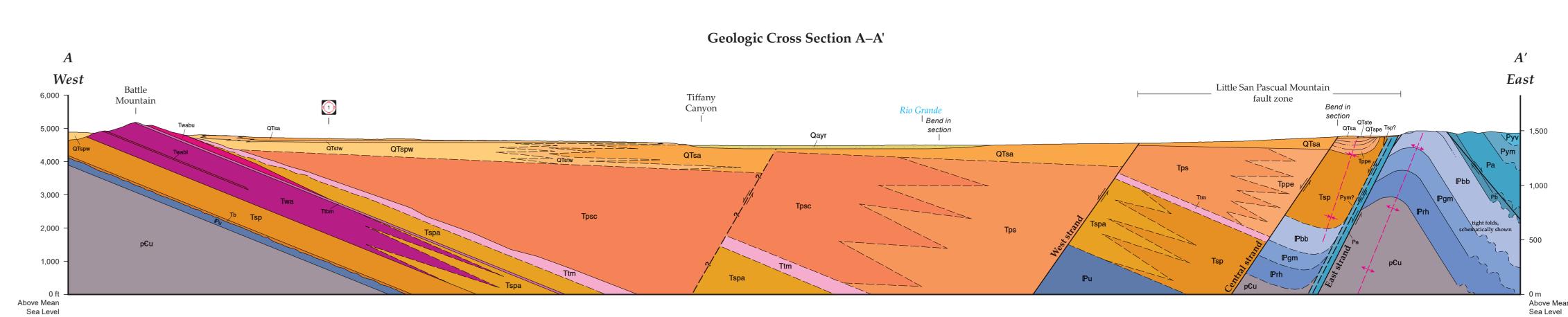
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map documents are those of the authors and should not be interpreted as necessarily representing the official policies,

either expressed or implied, of the State of New Mexico, or the U.S. Government.

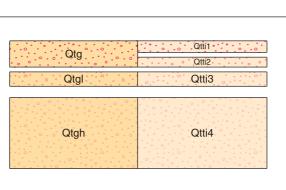
	Correlation of Map Ur	nits			
Qam Qamh Qahm Qah Qah Qah Qah Qah Qah Qah	hm. Qfmh Qfr Qfh entirely within the modern (<10 yrs) and historical (10–150 yrs)	afd yrs) timescale are shown above.	Rch Rcs Rsb Rau	Qtg Qtgl Qtgh	Qtti2 Qtti2 Qtti3 Qtti4
	on the Holocene timescale below may extend up to or overla	p with the recent timescale.		FIGURE 1—Close-up view of m	
Qse Qsc Qtb Qcto Qcto Qcto Qtb Qcto Qcto Qcto Qcto Qcto Qcto Qcto Qcto	Qfyo	Qe Qelo Qelo	ele Qeled Qerc	Terrace Units deposited along ca Grande, shown at 1:9,000.	nyons west of the Rio
Qtgh     Qtti4       Terrace Units: see       FIGURE 1.	Qfo			Description of I	Map Units
FIGURE I.	QUATERNARY Anthropogenic Units		<b>Rio Grande Floodplain Units</b> Mapped primarily using 2014 aerial imagery from the National Agriculture Imagery Program (NAIP). Almost all features likely postdate the flood of 1941.		unit <b>Qay</b> but forms an alluvial fan at s. See description of <b>Qay</b> . Weakly to m thick.
Qbu Qbucc Obubr	atd accumulations of sediment used a	<b>nic fill</b> —Altered ground and thick s artificial fill for levees, berms, or narily of sand with minor pebbles or od 1.6 m thick	Rw14 Water—Flowing or standing water apparent in 2014 digital aerial imagery.		ium, undivided—Younger ( <b>Qfy</b> ) and rium. See detailed descriptions of each lated and 1–4(?) m thick.
	Eolian Units		Rio       Grande bar deposits — Unvegetated, longitudinal bars of sand and perhaps minor gravel apparent in 2014 digital aerial imagery.         Rio       Grande channel deposits — Areas of the Rio Grande floodplain with	<b>Qfyr Younger and recent fan alluvium</b> , forms an alluvial fan at the mouths o	<b>undivided</b> —Similar to unit <b>Qary</b> but f tributary drainages. See descriptions of erately consolidated and 1–4(?) m thick.
QTsage QTspe	Qe light-brown to light-yellowish-browr to strong-brown (7.5YR 6/5–6), fine subrounded, well-sorted, and comp	-blown (eolian), massive sand. Sand is n (7.5–10YR 6/4), minor reddish-yellow - to medium-grained, subangular to posed of quartz, minor feldspar, and an 10% dunes except for local low II). Loose. 0.2–3 m thick.	<ul> <li>Banded surface textures (such as vegetation trends) apparent in 2014 digital aerial imagery. These textures mostly parallel the axis of the modern floodplain. The unit is laterally gradational with unit Rcs (modified from Cikoski [2018]).</li> <li>Rio Grande channel-splay deposits—Areas of the floodplain with</li> </ul>	Offyo Offyo Offyo Offyo Offyo Debbly beds. Sand is mostly in m light-brown to light-yellowish-brown 10% scattered pebbles and 1–3% ver to pebbly sand. Minor buried soils v	<b>inger fan alluvium</b> —Sand with minor edium to thick beds or else massive, n, and very fine- to coarse-grained; up to y thin, lenticular beds of sandy pebbles vith Stage I to II calcic horizons. Topsoil
DTstw QTsa	Qelo very fine-grained sand. Massive, b	eomorphic surfaces. May be buried by	<b>Rcs</b> fanning/distributary surface textures (such as vegetation trends) apparent in 2014 digital aerial imagery. Distributary textures commonly can be traced back to current or former locations of the Rio Grande channel. The unit is laterally gradational with unit <b>Rch</b> (modified from Cikoski [2018]).	<b>Debris flow-dominated fans</b> -Rela	. Tread height is 1–5 m. 5–7 m thick. tively massive sand and basaltic gravel Gravel is derived from the upper basalt
	Qes Eolian sand sheet—Sheet of eolian dune forms. Common paleosols cha (ped development, Stage I carbonal underlain by one or more weak calc weak ped development, no notable	sand draping the land surface. <10% racterized by cumulic calcic horizons te morphology) or a cambic horizon ic horizons (Stage I to II). Topsoil has clay illuviation, and a weak Stage I	<ul> <li>Rio Grande scroll-bar deposits—Areas of the floodplain with scrolled surface textures (such as vegetation trends) apparent in 2014 digital aerial imagery. These textures are comprised of tightly parallel, arcuate shapes formed by migration of the river channel.</li> <li>Rio Grande undifferentiated deposits, primarily floodplain alluvium—</li> </ul>	Qfo       Older fan deposits—Thick alluvia buttressed against paleoslopes east	<ul> <li>u). Sand is light-colored, fine- to very ibangular, and rich in quartz grains Weakly consolidated and 1–4 m thick.</li> <li>l fan deposits filling paleovalleys and t of Rio Grande. May have more than of: 1) massive sand with 1–15% pebbles</li> </ul>
Tpsx     Tppe       Tpsc     Tps	Qele sand on north side of ridges west o thin to medium (mostly thin to me contacts. Beds are internally ma	olidated. 0.2–3 m thick. of topographic slopes—Thick eolian f Little San Pascual Mountains. Very dium), tabular beds. Sharp deflation ssive or exhibit horizontal-planar- ngential, 3–10 cm tall foresets facing	Rau Areas of the floodplain with non-distinct surface textures. Includes areas of the floodplain that have been artificially disturbed by land management or former agricultural activities such that primary surface textures are unrecognizable (modified from Cikoski [2018]). Consists of sand (mostly very fine- to medium-grained) and lesser silt or clay. Merges downward into unit <b>Qay</b> .	(scattered or in lenses), common we horizons); and 2) pebbly sand chan axial sand with minor pebbles. 1–18	akly developed paleosols (Stage I calcic nel fills. Unit includes thick tongues of
	northeast). Paleosols with Stage I tongues of alluvium. 2–12 m thick. <i>Eolian Sand, Featuring Dunes</i> Unless otherwise noted, the sand in these depos	to II carbonate morphology. Minor its is similar to that in unit <b>Qe</b> above.	<b>Valley-floor Units</b> Many of the valley-floor map units reflect combinations of deposits, such as combined younger alluvium and modern alluvium ( <b>Qaym</b> ). In these combined units, the unit with the largest exposed area is shown first, followed by the unit with the lesser area of exposure. Where modern and historic deposits are subequal (±20%) the resulting map unit is called Recent and abbreviated as <b>Qar</b> .	clast-supported, lenticular beds; grade. Gravel comprised of pebbl composed of felsic to intermedia strong-brown to reddish-brown, n	yon, discontinuous—Sandy gravel in tread stands 2–3 m above modern es, 50% cobbles, and 1–15% boulders te volcanic rocks. Matrix consists of nedium- to very coarse-grained sand. weak to moderate desert pavement.
Tb Topic Twa Twa Twa Eocene–Oligocene Volcanic and Volcaniclastic Units: see FIGURE 2.	Qed along the western foot of the Little Sa parabolic, transverse, longitudinal, Dune sand is light-brown to light-ye	arious undivided dune forms found an Pascual Mountains. Dunes include and irregular forms 0.2–2.0 m tall. llowish-brown (7.5–10YR 6/4), fine- to bangular, well-sorted, and composed 6 mafic-lithics. 0.2–3 m thick.	Qam Modern alluvium—Loose sand and gravel forming bars and underlying channels in ephemeral drainages. Gravel includes pebbles, cobbles, and minor boulders. Sand is brown to grayish-brown to pinkish-gray to light-gray (7.5–10YR) and mostly medium- to very coarse-grained. Bar-and-swale topography (0.1–0.6 m relief), steep-walled channels, and lack of topsoil development characterize the surface. Thickness ≈0.5–2 m.	Second-from-lowest terrace alon Sandy gravel that is grayish and cla lenticular beds. Gravel consists of fine boulders. Moderately consoli	<b>g Tiffany Canyon, discontinuous</b> — ist-supported. Vague, medium to thick, pebbles with ≈35% cobbles and 5–7% dated. Sharp, scoured lower contact.
Psa Pg Psal Pyv	Qesc eolian sand, as in unit <b>Qes</b> but coppice to irregular dunes 0.05–0.7 dunes is bioturbated, eolian sand w massive, with local vague cross-lar	pice and irregular dunes—Sheet of with 10–100% surface coverage by m tall (locally up to 1 m). Between with minor pebbles. Sand is relatively minations up to 5 cm tall; up to 5% able topsoil. Local, weakly developed	Qah Historic alluvium—Sandy gravel, pebbly sand, and sand whose geomorphic surface exhibits bar-and-swale topography and lacks notable topsoil development. Sediment typically in very thin to medium, tabular to lenticular beds. Sand beds are internally massive or laminated. No visible calcium carbonate accumulation in topsoil. Tread height commonly	underlying the lower extensive ter unit <b>Qtgl</b> . Cobbly sediment is in pebbly sediment is in laminated t Gravel includes pebbles, 15–20% brown to reddish-brown and fine- t	<b>Canyon, continuous</b> —Sandy gravel race in Tiffany Canyon, correlative to medium to thick, lenticular beds and o medium, lenticular to tabular beds. cobbles and 1–3% boulders. Sand is o very coarse-grained. Tread lies 7–9 m
Pym Pa Pb	Qeled Thick eolian sand on the lee side of by dunes—Unit Qele superimposed irregular, coppice, parabolic, trans loose, 0.2–2 m tall, and lack soil dev vaguely cross-laminated and comp	<b>of topographic slopes, superimposed</b> I by various dune forms that include verse, and longitudinal. Dunes are elopment. Dune deposit is massive to posed of light-brown, fine-upper- to	<ul> <li>Qar</li> <li>Recent (historic + modern) alluvium—Historic alluvium and modern alluvium (Qam) in subequal (±20%) proportions. See descriptions of units Qam and Qah. Weakly consolidated and 0.5–3 m thick.</li> <li>Modern and historic alluvium, undivided—Modern alluvium (Qam) and</li> </ul>	A Citian higher extensive terrace along Tiff Gravel comprised of pebbles and cob of very fine to very coarse sand. To	<b>n, continuous</b> —Sandy gravel underlying any Canyon, correlative to unit <b>Qtgh</b> . bles with 1–3% boulders. Matrix consists psoil carbonate horizon exhibits a Stage . Moderately consolidated. Moderately
Pbb Pgm Prh	Qerc Eolian sand ramp with coppice an Sand ramp along foot of Little San I coppice and irregular dunes up t light-yellowish-brown, fine-upper- to	<b>Id irregular dunes on the surface</b> Pascual Mountains, superimposed by o 1 m tall. Sand is light-brown to medium-lower-grained, subrounded	Qamh       subordinate historic alluvium (Qah). See detailed descriptions of each respective unit. 0.5–2 m thick.         Qahm       Historic and modern alluvium, undivided—Historic alluvium (Qah) and subordinate modern alluvium (Qam). See detailed descriptions of each respective unit. 0.5–2 m thick.	developed desert pavement. Tread he Gravelly terrace deposit west of Sandy gravel comprised of peb clast-supported, subrounded, and dominated volcanic clasts (west	
p€u	10–15% mafic-lithic grains. Loose. Li up to several meters thick.	posed of quartz, minor feldspar, and kely intertongues with colluvium and	Qary Qary Recent (historic + modern) and younger alluvium, undivided—Recent alluvium ( <b>Qar</b> ) and subordinate younger alluvium ( <b>Qay</b> ). See detailed descriptions of <b>Qam</b> , <b>Qah</b> , and <b>Qay</b> . 0.5–4 m thick.	coarse-grained, and has 0.5–3% clay of Rio Grande) or 10–20 m (east of R	v in matrix. Tread height of 3–6 m (west
2	Qedl       longitudinal dunes; dunes are orier         low (<2 m height). Loose and 1–4 thic	as described in the unit <b>Qe</b> , forming ntated ≈60 degrees and are relatively k. Eolian sand, as described in the unit ngitudinal dunes. Barchan dunes are ree trend of the longitudinal dunes.	Qahy       Historic and younger alluvium, undivided—Historic alluvium (Qah) and subordinate younger alluvium (Qay). See detailed descriptions of each respective unit. 0.5–4 m thick.         Qay       Younger alluvium—Interbedded pebbly sand, sand, and sandy gravel. Sand outside of gravely beds is light-brown, mostly fine- to medium-	sandy gravel, locally coarsening up thin to medium, lenticular beds planar-laminated; 1–20% cross-stra with 1–20% cobbles. Sand is fine- matrix. Tread has a weak to moder	owards. Sandy gravel is mostly in very ; pebbly sand is mostly horizontal- atification. Gravel consists of pebbles to very coarse-grained; 0–1% clay in ate pavement and stands 7–10 m above
anation of Map Symbols Contact—Identity and existence are certain or questionable where queried.	Locally, the eastern end (tail) of a l with a longitudinal dune. Dunes vegetation. Loose and 1–4 m thick. <b>Barchan and longitudinal dunes</b> Eolian sand, as described in the ur	superimposed by coppice dunes— nit Qe, forming small coppice dunes	<ul> <li>grained, and has trace to 20% pebbles. Underlies geomorphic surface w/no bar-and-swale topography, standing 0.5–3 m above modern grade, whose topsoil has calcic horizons with visible Stage I to I(+) calcium carbonate morphology. May have &gt;1 allostratigraphic subunits. 1–4 m thick.</li> <li>Younger alluvium deposited by axial river—Poorly exposed and loose sand similar in composition and texture to sand in unit OTsa but underlying low</li> </ul>	OtghHigher gravelly terrace deposit w underlying an extensive geomo Consists of sandy gravel with less pebbles, 5–10% cobbles and trac typically are >2 m and 10–18 m	rest of the Rio Grande—Thick deposit rphic surface west of Rio Grande. ser pebbly sand. Gravel comprised of e to 3% boulders. Strath and tread above modern grade, respectively.
<ul> <li>Location is accurate where solid, approximate where long-dashed, inferred where short-dashed, or dotted where concealed.</li> <li>Gradational contact—Identity and existence are certain or questionable where</li> </ul>	dunes. Longitudinal and barchan du up to 3 m tall. Loose and 1–4 m thick		Similar in composition and texture to sand in unit <b>QTsa</b> , but underlying low (<3 m above modern grade) terraces that parallel the Rio Grande. Surface lacks bar-and-swale topography, and its topsoil has at least one calcic horizon exhibiting Stage I to I(+) calcium carbonate morphology. 1–4 m thick.	Thickness range of 1–12 m, but mos	l(+) petrocalcic horizon >0.5 m thick. stly 3–6 m.
<ul> <li>queried. Location is accurate where solid or approximate where dashed.</li> <li>Internal contact, shown in cross section—Identity and existence are certain.</li> <li>Location is accurate.</li> <li>Fault (generic; vertical, subvertical, or high- angle; or unknown or</li> </ul>	Qedtlc in unit <b>Qe</b> , forming both linear tran that are relatively low-lying (<2 m, commonly superimposed by small barchan dunes. Loose and 1–3 m thic	<ul> <li>ice dunes—Eolian sand, as described sverse dunes and longitudinal dunes commonly 0.5–1 m tall). These are coppice dunes. Includes 1–3% large k.</li> <li>se dunes—Fine- to medium-grained</li> </ul>	<ul> <li>Younger and modern alluvium, undivided—Younger alluvium (Qay) and subordinate modern alluvium (Qam). See detailed descriptions of each unit. 1–4 m thick.</li> <li>Younger and recent (historic + modern) alluvium, undivided— Younger alluvium (Qay) and subordinate recent alluvium (Qar). See detailed</li> </ul>	Qble Subordinate basalt outcrops within the subordinate basalt outcrops occur within the Eolian sand as in unit <b>Qe</b> . Basalt highly vesicular, and contains the Pleistocene age based on unpublic	eolian sand—Mapped where small, vithin thick eolian sand accumulations. is black to very dark-gray (N 2.5/–3/), race to 1% olivine phenocrysts. Late ished <sup>40</sup> Ar/ <sup>39</sup> Ar data (Matt Zimmerer,
unspecified orientation or sense of slip)—Identity and existence are certain or questionable where queried. Location is accurate where solid, approximate where dashed, or concealed where dotted. Fault in cross section showing local up/down offset (generic)—Identity and existence are certain or questionable where queried. Location is accurate where solid or approximate where dashed. Arrows show the relative	Gedpt sand that forms irregular, parabolic height. Sand is light-brown to light-y fine-upper- to medium-lower-gra well-sorted, and composed of q mafic-lithic grains (including chert).	c, and transverse dunes $\approx 0.5-2$ m in ellowish-brown (7.5–10YR 6/4), mostly ined, subrounded to subangular, uartz, 10–≈20% feldspar, and 15%	<ul> <li>Qayo</li> <li>Younger alluvium, oldest allostratigraphic unit—Highest allostratigraphic unit of younger alluvium (Qay). Interbedded pebbly sand, sand, and sandy gravel. Less cobbles than Pleistocene-age alluvium. Underlies a smooth, pebbly geomorphic surface (no bar-and-swale topography), standing 2–5 m above modern grade, with varnish on 0–10% of clasts. Topsoil has Stage I(+)</li> </ul>	Qbucc Cinder cone, source for upper by Black to red, basaltic cinder (prima up to 20 cm) and welded agglutir lobes. Basalt contains 7–8% pheno are in steeply dipping, tabular bed	asalt capping Mesa del Contadero— urily lapilli with minor ash and bombs nate interbedded with localized basalt crysts of olivine and pyroxene. Strata s that underlie a 25 m tall cinder cone,
motion along the fault plane. Normal fault—Identity and existence are certain or questionable where queried. Location is accurate where solid, approximate where dashed, or concealed where dotted. Ball and bar on downthrown block. Showing dip value and direction on inclined faults.	Qse reworking substantial eolian sand. C overprinted by weak paleosols. Sa yellow) and mostly fine- to medium-	<b>eolian sand</b> —Sheetflood deposits Composed of massive sand commonly and is light-brown (minor reddish- grained; 1–15% scattered coarser sand by Stage I calcic horizons and ped	calcic horizons locally overlain by a thick A horizon. 2–6 m thick. <b>Alluvial Fan Units</b> Many of the alluvial fan map units reflect combinations of deposits, such as combined younger alluvium and historic alluvium ( <b>Qfyh</b> ). In these combined units, the unit with the largest exposed area is shown first, followed by the unit with the	Qbu Upper basalt capping Mesa d vesicular basalt containing 8–12 phenocrysts of pyroxene; phenocry 1.5 mm long. 3–7 m thick.	e northeast side of Mesa del Contadero. el Contadero—Dark-gray to black, % phenocrysts of olivine and 1–2% sts are 0.2–1 mm long, with trace up to
Strike-slip fault, right-lateral offset—Identity and existence are certain. Location is accurate. Arrows show relative motion. Strike-slip fault, left-lateral offset—Identity or existence are questionable.	development that typically lacks cla consolidated. 1–10 m thick.	ay illuviation. Weakly to moderately	lesser area of exposure. Where modern and historic deposits are subequal (±20%), then the resulting map unit is called Recent and abbreviated as <b>Qfr</b> . Modern fan alluvium—Similar to unit <b>Qam</b> but forms an alluvial fan at	<b>Qbuhm</b> <b>del Contadero</b> —Horizontal-planar very coarse-grained sand and f laminations up to 10 cm tall. Stra	ving the upper basalt capping Mesa , well-defined laminations of fine- to ine pebbles. Contains 1–10% cross- ta are grayish-brown to olive-gray to
Location is approximate where dashed or concealed where dotted. Arrows show relative motion. Oblique-slip fault, right-lateral offset—Identity and existence are certain.	Qs pebbles. The unit includes minor, y pebbles. Sand is massive, brown to (7.5–10YR 5–6/4), very fine- to coar	very thin to thin, lenticular beds of light-brown to light-yellowish-brown rse-grained (1–10% silt to clay), and	Qfm       the mouths of tributary drainages. See description of unit Qam. Weakly consolidated and 0.5–2 m thick.         Historic fan alluvium—Similar to unit Qah but forms an alluvial fan at	pale-brown. Sand is well-sorted y subangular basalt and quartz-dom Pebbles primarily of basalt with tra	vithin a lamina and composed of of inated sand (similar to sand in <b>QTsa</b> ).
Location is accurate. Arrows show relative motion; ball and bar on downthrown block. Key beds—Identity and existence are certain. Location is accurate.	moderately to poorly sorted. Weak to carbonate morphology. 1–4 m thick. Hillslope Deposits	op soil development exhibiting Stage I	Qfh       the mouths of tributary drainages. See description of unit Qah. Weakly consolidated and 1–3 m thick.         Recent (historic + modern) fan alluvium—Similar to unit Qar but forms	QUATERNARY–TERTIARY Basin-fill Units These units collectively belong to the Santa Fe	
Guaje pumiceous sandstone Andesite lava flow Rio Grande gravel interval	to medium-grained, massive sand; co and pebbles. Unit is 5% tongues of gr subangular to angular, poorly sorted, & 1–3% boulders. Gravel proportion is	<b>ndivided</b> —Pink to pinkish-white, fine- ontains 5–10%, scattered, coarser sand avelly channel-fill deposits. Gravel are and comprised of pebbles, 5% cobbles, ikely increases towards bedrock highs,	Qfr       an alluvial fan at the mouths of tributary drainages. See description of units Qah and Qam. Weakly consolidated and 1–3 m thick.         Qfmh       Modern and historic alluvium, undivided—Modern fan alluvium (Qfm) and subordinate historic fan alluvium (Qfh). Similar to unit Qamh but forms an alluvial fan at the mouths of tributary drainages. See	the upper Santa Fe Gp. is called the Sierra quadrangle, STATEMAP work is using the a lower Santa Fe Gp is called the Popotosa F between these two formations. The contact ma	ge-equivalent term Palomas Fm. The Fm. An unconformable contact exists
Anticline—Identity and existenceare certain. Location is accurate where solid or approximate where dashed. Large arrowhead shows direction of plunge. Syncline—Identity and existenceare certain. Location is accurate where solid or approximate where dashed. Large arrowhead shows direction of plunge. Monocline, anticlinal bend—Identity and existence are certain. Location is	form a talus apron overlying sand underlying, relatively loose sand from	rith lesser cobbles and pebbles, that of unit <b>QTsa</b> . The talus protects the	<ul> <li>descriptions of Qam and Qah. Weakly consolidated and 1–3 m thick.</li> <li>Historic and modern alluvium, undivided—Historic fan alluvium (Qfh) and subordinate modern fan alluvium (Qfm). Similar to unit Qahm but forms an alluvial fan at the mouths of tributary drainages. See descriptions of units Qah and Qam. Weakly consolidated and 1–3 m thick.</li> </ul>	<b>QTspw</b> Western piedmont facies—Orangis and gravel prograding over unit <b>QT</b> and pebbly sand in medium to (subequal to subordinate) tongues of	sh to reddish, clayey, interbedded sand <b>Sa</b> . Consists of fine to very coarse sand thick, tabular beds; hosting variable of sandy gravel that exhibit very thin to ar) beds or is cross-stratified. Weak alcie horizons 2–150 m thick
Monocline, anticlinal bend—Identity and existence are certain. Location is accurate where solid or approximate where dashed. Arrows show direction of dip; shorter arrow on steeper limb. Cross section line and label. Unconformity in the Correlation of Map Units.		s) of unit <b>Ttbm</b> that drape unit <b>Tws</b>	<ul> <li>Younger alluvial fans and slope wash deposits, undivided—Historic fan alluvium (Qfh) and subordinate younger fan alluvium (Qfm). Similar to unit Qahy but forms an alluvial fan at the mouths of tributary drainages. See descriptions of units Qah and Qay. Weakly consolidated and 1–4 m thick.</li> <li>Recent (historical + modern) and younger fan alluvium, undivided—</li> </ul>	QTstw Western margin, piedmont-axi medium-grained, axial sand inter brown, thin to thick beds of silt, w with scattered coarser sand and tabular-bedded (internally massive	<b>ial transition zone</b> —Light-colored, bedded with 30–70% orange to light- rery fine- to fine-grained sand (locally pebbles), and clay. Fine sediment is or laminated to very thinly bedded).
Small, minor anticline, vertical or near-vertical axial surface—Showing strike. Inclined fold hinge of small, minor anticline—Showing bearing and plunge. Inclined fold hinge of small, minor syncline—Showing bearing and plunge. Small, minor syncline, vertical or near-vertical axial surface—Showing strike. Small, minor syncline, inclined axial surface—Showing strike and dip.			Qfry Recent fan alluvium (Qfr) and subordinate younger fan alluvium (Qfy). Similar to unit Qary but forms an alluvial fan at the mouths of tributary drainages. See descriptions of Qah, Qam, and Qay. Weakly consolidated and 1–4(?) m thick.	Includes 1–3 m-thick tongues of p (unit <b>QTspw</b> ). 5–20 m thick.	viedmont lithofacies with <30% gravel



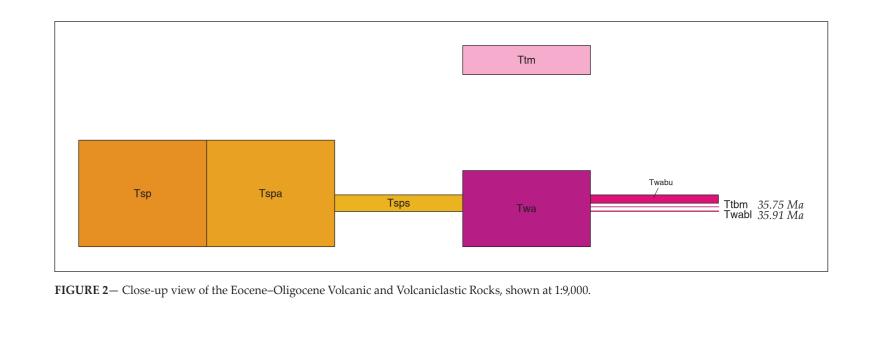
dding-Showing approximate

- ring, or foliation in igneous
- -Showing bearing and plunge. d from channel trend.
- d from gravel imbrication.
- from cross-beds—Showing dip. direction determined from
- from eolian cross-bedding in
- tion is accurate.

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**IGURE 1**—Close-up view of middle–late Quaternary age errace Units deposited along canyons west of the Rio Grande, shown at 1:9,000.



## **Description of Map Units**

s flow-dominated fans—Relatively massive sand and basaltic gravel rily cobbles and boulders). Gravel is derived from the upper basalt s Mesa del Contadero (Qbu). Sand is light-colored, fine- to very grained, subrounded to subangular, and rich in quartz grains reworked from unit **QTsa**). Weakly consolidated and 1–4 m thick. fan deposits-Thick alluvial fan deposits filling paleovalleys and essed against paleoslopes east of Rio Grande. May have more than ostratigraphic unit. Consists of: 1) massive sand with 1–15% pebbles red or in lenses), common weakly developed paleosols (Stage I calcic ons); and 2) pebbly sand channel fills. Unit includes thick tongues of Popotosa Formation and with minor pebbles. 1–18 m thick.

terrace along Tiffany Canyon, continuous—Sandy gravel underlying extensive terrace along Tiffany Canyon, correlative to unit Qtgh. comprised of pebbles and cobbles with 1–3% boulders. Matrix consists fine to very coarse sand. Topsoil carbonate horizon exhibits a Stage Precipitate Rocks III(+) carbonate morphology. Moderately consolidated. Moderately bed desert pavement. Tread height is 11–13 m. Deposit is ≈6 m thick.

y gravel, locally coarsening upwards. Sandy gravel is mostly in very o medium, lenticular beds; pebbly sand is mostly horizontallaminated; 1-20% cross-stratification. Gravel consists of pebbles 1–20% cobbles. Sand is fine- to very coarse-grained; 0–1% clay in Eocene–Oligocene Volcanic and Volcaniclastic Rocks x. Tread has a weak to moderate pavement and stands 7–10 m above Note that volcaniclastic strata are assigned to the Spears Group, and ignimbrites rn grade. 2–10 m thick.

r gravelly terrace deposit west of the Rio Grande–Thick deposit lying an extensive geomorphic surface west of Rio Grande. s of sandy gravel with lesser pebbly sand. Gravel comprised of y are >2 m and 10–18 m above modern grade, respectively. contains a Stage III to III(+) petrocalcic horizon >0.5 m thick. ness range of 1–12 m, but mostly 3–6 m. canic Units

Axial-fluvial facies—Light-colored (10YR–2.5Y), fine- to coarse-grained Eocene Sedimentary Rocks, Non-volcanic sand that is cross-laminated (common trough forms), horizontal-planarlaminated to very thinly bedded, or massive. Unit has 1–15% pebbly beds with exotic clasts (e.g., 1-15% quartzite and 10-25% chert, decreasing down-section). Deposited in paleochannels or lobes by the ancestral Rio Grande, <10% fine-grained, floodplain deposits. 20–250(?) m thick.

Axial-fluvial facies with gravel assemblage mainly sourced from the sage eastern piedmont–Poorly exposed sand, similar to that in unit QTsa, mixed with pebbles and cobbles (95% pebbles vs 5% cobbles) composed of Paleozoic carbonates, 1–5% chert, 1–20% Permian siltstones and sandstones, trace to 10% volcanic rocks, 1% granite, and trace quartzite. Gravel are Note subangular to subrounded (chert may be rounded to subrounded) and Laram poorly sorted. May form SSW-trending ridges. 2–10 m thick.

Eastern margin, piedmont-axial transition zone-Pink to pinkish- white, very fine- to fine-grained sand, silty sand and silt in medium to thick, tabular beds (internally massive & bioturbated). <25%, scattered, coarser sand grains and 1-5% pebbles. Minor tongues of sandy gravel (pebbles, 15–20% cobbles; composed of limestone and minor chert) that are medium to thick and lenticular. Paleosols with Stage I to II calcic horizons. 5–40 m thick.

Eastern piedmont facies-Interbedded sandy gravel and very fine- to medium-grained sand. Gravelly tongues exhibit thin to thick, tabular to enticular beds and 0–10% cross-stratification. Gravel comprised of angular to subangular pebbles, 1-20% cobbles, 1-5% boulders; composed of Paleozoic limestone, 0-20% Permian clastics, and 0.5-15% chert. Fine sediment has 1–20% scattered coarse sand, and 1–20% pebbles. 2–50 m thick.

Gravelly eastern piedmont facies-Conglomerate, composed mainly of limestone clasts; subrounded to rounded and comprised of pebbles, 10–25% fine to coarse cobbles, and trace to 5% boulders. Vague, thin to thick, lenticular to tabular beds. Local (up to 20%) sandstone interbeds. Upper strata possibly time-correlative to the lower Sierra Ladrones Fm. Wellcemented by calcium carbonate; local silica cementation. 10-1,600(?) m thick.

Sandstone-Well-sorted sandstone in thin to thick (mostly thick), tabular beds (internally massive, horizontal-planar-laminated, or locally low-angle cross-laminated). Sand is light-gray to pink to red, mostly fine-grained and subrounded, lacks fines, and composed of quartz, 20–45% feldspar, and 1–10% mafic-lithic grains. Commonly well-cemented by silica and outcrops are strongly varnished. 10–1,600(?) m thick.

Cross-stratified sandstone-Well-sorted, reddish-brown, fine-grained sandstone that is cross-stratified within very thick, tabular beds. Foresets dip steeply to NE and >0.5 m tall. Grains are mostly fine-lower- to fine-upper-grained, rounded-well rounded, and composed of quartz, minor feldspar, and 5–15% mafic-lithic grains. Well-cemented by hematite (locally nodular) and possibly silica. Eolian depositional environment. >30 m thick.

Sandstone and conglomerate—Cross section only. Sandstone inferred to p reddish-brown and fine- to very coarse-grained. Tread lies 7–9 m sandstone. Conglomerates may be tuff-dominated or andesitedominated. Correlates with Popotosa-age units in the Indian Well Wilderness quadrangle to the north (Chamberlin and Cikoski, 2010). Possibly 1,300 m thick.

> **Travertine**—Laminated to very thin, tabular beds of calcium carbonate. Rock is light-gray, variably vuggy, and has local root traces (up to 2 cm wide). Locally interbedded with minor (up to 30%) very thin to medium, tabular beds of sandy pebbles; pebbles are angular to subangular and Bar B Formation. Uncertain due to lack of subsurface data. 200–600 m thick. composed of Paleozoic carbonates and minor Permian siltstones to sandstones; westward paleoflow. Up to  $\approx 6$  m thick.

Quartz and chert bodies—White to grayish, crystalline to microcrystalline quartz (≤2 mm crystal size) and reddish-gray to dark-orange to reddish-brown chert. Occurs as stratiform bodies that replaced original limestone. Deposits are typically massive, but locally occur as 1-5 centimeter-scale, tabular bands of alternating chert and quartz. Local geodes. Mapped where unit occupies >50% of outcrop area. 1–15 m thick.

younger than 32-33 Ma is included in the Mogollon Group (per Cather et al., 1994). The andesite flows mapped on this quadrangle, in addition to the tuff of Battle Mountain, belong to the Datil Group (per Cather et al., 1994).

Undivided tuffs of the Mogollon Group-Cross section only. Various es, 5–10% cobbles and trace to 3% boulders. Strath and tread Ttm rhyolitic ignimbrites; partially to densely welded with 1–40% phenocrysts (mostly 0.5–3 mm) dominated by sanidine and quartz with variable (typically <1%) plagioclase and trace to 1% biotite. Most likely includes the phenocryst-poor (≤5%) and densely welded La Jencia and Vicks Peak tuffs; possibly the Lemitar and South Canyon tuffs. Thickness uncertain; 1–120(?) m.

> Upper biotite-bearing andesite flow-Medium-gray lava with 15-35% agioclase phenocrysts (subhedral and 0.5–5 mm, mostly 1–2 mm long) and 5% biotite phenocrysts (an- to subhedral, ≤1 mm long and bronze-colored). Forms a ledge that weathers into 5–10 cm-thick plates. 40–50 m thick. **Tuff of Battle Mountain**—Welded and foliated tuff; variably eutaxitic and

overlies a 0.5-2 m thick, black vitrophyre. Phenocrysts include 10-25% feldspar (0.5-4 mm, probably plagioclase and minor sanidine) and 1-7% to red, basaltic cinder (primarily lapilli with minor ash and bombs \_\_\_\_\_\_ biotite crystals (0.1–1 mm); very minor hornblende. ≈10% flattened and locally stretched pumice. May correlate to 33.7–33.9 Ma tuff of Chupadera Wilderness (see Chamberlin and Cikoski, 2010). 18 m thick. Spears Group, silt and fine sand-Tan (locally reddish) and massive, silt

and very fine to fine sand occurring as 1–15 m-thick tongues within unit Twa. Sand is subangular and apparently composed of feldspar with 20% dark grains (volcanic lithics and pyroxene). Locally, up to 15% scattered coarse to very coarse sand (including pyroxene crystals) and 1–10% andesite pebbles. Interpreted as eolian sand reworked by sheetflooding.

Andesite of Willow Springs—Gray, pyroxene- and plagioclase-phyric andesite, weathering to a light-brown to brown to reddish-brown. Variably vesicular. Phenocryst assemblage: 0.5-10% (mostly 5-10%) pyroxene (anhedral to subhedral, mostly 0.2-2 mm); 10-40% plagioclase (euhedral to subhedral, mostly 0.5-2 mm). Groundmass has abundant plagioclase crystals (≤0.5 mm). Includes 1–10% tongues of reddish breccia or sandstone. ≈300 m thick.

lava. Reddish-gray, varnishing to a dark-reddish-brown to light-maroon to ectively belong to the Santa Fe Gp. In the Socorro Basin to the north mostly 1–3 mm) and 30–7% biotite (sub- to euhedral, 0.1–2 mm). Both light-gray. Phenocrysts include 12–20% plagioclase (subhedral & 0.5–7 mm, pyroxene (5–7%) and biotite (5–7%) phenocrysts observed within 2 m above base. Top and base of flow is vesicular; flow breccia at top. 14 m thick. Spears Group volcaniclastic strata intertonguing with andesite of Willow

Springs-Cross section only. Tongues of volcaniclastic conglomerate, conglomeratic sandstone and sandstone that are inferred to intertongue with andesite flows correlative to the andesite of Willow Springs. See descriptions for units **Tsp** and **Twa**. Uncertain inferred thickness of 700–750 m. Spears Group volcaniclastic strata, undivided-Weak-red, thick-bedded conglomerate, conglomeratic sandstone and sandstone. Gravel is mainly

intermediate volcanic (with sedimentary clasts near base) and ranges from pebbles to boulders; associated beds are matrix-supported and massive, consistent with lahar or debris flow deposition. Sandstone beds are variably clayey and relatively tabular (internally massive to laminated). 190–250 m thick.

Tb	massive, very fine- to fine-grained sand and silty-clayey fine sand (0–10%, scattered, coarser sand grains and 1–3% pebbles); 2) gray, fine- to medium-grained sand with feldspar and lithic fragments; and 3) fining-upward conglomerates and conglomeratic sandstones; gravel composed mainly of subrounded Paleozoic carbonates. 20–40 m thick.
te that	ZOIC t Paleozoic strata thin westward in the subsurface due to erosion of a -age highland.
osa	<b>San Andres Formation, main body above Glorieta Sandstone tongue</b> — Thick, tabular beds of a packstone limestone. Limestone is light-gray (fresh) weathering to light-brownish-gray (10YR–2.5Y 6/2). Local bivalves. Top not exposed. >3 m thick.
Pg	<b>Glorieta Sandstone Tongue within the San Andres Formation</b> —Thick, tabular beds of white to yellowish-tan sandstone. Sand is very fine- to fine-grained, well-sorted, and quartzose. Beds are internally massive. Fresh colors are typically whitish to very pale-brown. Weathered colors of pale-brown to very pale-brown. Well-cemented by silica. 1–10% limestone interbeds commonly replaced by stratiform quartz or chert (unit <b>Tqc</b> ). 40 m thick.
Psal	Lower San Andres Formation below the Glorieta Sandstone tongue— Dark-gray to gray, micritic limestone in thick, tabular beds. Weathered faces are pale-brown to light-gray. At base is a thick, tabular bed of Glorieta Sandstone that is internally massive, white to very pale-brown (weathering to a grayish-brown), fine-grained, well-sorted, and quartzose. Upper part of unit has abundant stratiform chert beds that likely replaced limestone. 15–16 m thick.
⊃yv	Yeso Group, Los Vallos Formation—Intertonguing reddish-brown mudstone to siltstone to very fine-grained sandstone, white to yellowish siltstone to fine-grained sandstone, and light-gray to light-brownish-gray limestone-dolomite. Individual tongues are 1–10 m thick. Clastic sediment is well-sorted, quartzose, and internally horizontal-planar-laminated to massive. Carbonates are thin to thick, tabular-bedded. ≈200-230 m thick.
<sup>o</sup> ym	<b>Yeso Group, Meseta Blanca Formation</b> —Also called Arroyo de Alamillo Fm. Reddish-brown (minor white or yellow), well-bedded siltstone & very fine- to fine-grained sandstone. Beds are very thin to medium (minor thick), tabular, and internally massive to horizontal-planar-laminated. Local ripple marks on bed planes. Sand is well-sorted & quartzose. Minor poorly bedded, reddish, clayey siltstone to very fine sandstone. 110–130 m thick.
Pa	<b>Abo Formation</b> —Reddish-brown mudstones, siltstones and very fine-grained sandstones interbedded with minor very fine- to medium-grained sandstones. Mudstones are chunky and in tabular beds. Siltstones and very fine-grained sandstones are in medium to thick, well-laminated beds. Includes 5–10% channel fills with very fine- to medium-grained, arkosic sandstone and minor intra-formational conglomerate. 220 m thick.
Pb	<b>Bursum Formation</b> —Reddish to maroon siltstone, mudstone, and very fine sandstone interbedded with subordinate light-gray limestone (micrite to packstone in thin to thick, tabular beds). Very minor intra-formational conglomerates. Includes 1–5% thick, tabular beds of brownish horizontal-planar-laminated sandstone. Commonly capped by a thick bed of yellowish dolomite. Age from Lucas et al. (2017). 55–60 m thick.
Pu	<b>Pennsylvanian strata, undivided</b> —Cross section only. Consists of Red House Formation and probably Gray Mesa Formation; possibly includes the Bar B Formation. Uncertain due to lack of subsurface data. 200–600 m thick.

Baca Formation—Meter-scale, intercalated tongues of: 1) reddish-brown,

**Bar B Formation**—Interbedded limestone with 30–70% clastic sediment. Limestone is in 1-15 m thick intervals having medium to very thick, tabular beds. Limestone is grayish, has ≤5% chert, and composed of micrite, wackestone, and lesser packstone. Poorly exposed clastic sediment (probably shale and siltstone; possible sandstones) in 1–25 m thick intervals. 270(?) m thick (age & thicknesses from Lucas et al., 2017).

**Gray Mesa Formation**—Cross section only. Comprised of three members (ascending order): Elephant Butte (45 m of limestone with 40% [shale and overed intervals]); Whiskey Canyon (37 m of mostly ledge-forming, cherty limestone intervals up to 12 m thick); and Garcia (87 m of alternating limestone and covered intervals, with its lower 5 m being a cross-stratified sandstone). 170 m thick (from Lucas et al., 2017). Red House Formation-Cross section only. Yellowish to brownish,

intercalated limestone, shale, and sandstone. Lower interval (>42 m) consists of sandstone, pebbly sandstone, shale, and limestone. The middle interval (≈45 m) is dominated by shale with a few thin limestone beds. The upper interval (≈53 m) consists of interbedded limestone and thin shale intervals. >200 m thick (from Lucas et al., 2017).

**Precambrian rocks, undivided**—Cross section only. Schist, amphibolite, felsic porphyry, and granite. Highly variable thicknesses of lithologic types. Protoliths for schist and amphibolite were arkosic sandstones and muddy siltstones, with minor interbedded volcanic flows; these were later intruded by granite (synthesized by Richard Chamberlin [in Chamberlin and Cikoski, 2010] from Kent [1982] and Bowring et al. [1983]).

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Sea Level