Geologic Map of the Horcado Ranch Quadrangle, Santa Fe County, New Mexico.

By

Daniel J. Koning and Florian Maldonado

May, 2001
Rev. March, 2013

New Mexico Bureau of Geology and Mineral Resources
Open-file Digital Geologic Map OF-GM 44

Scale 1:24,000

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New Mexico Bureau of Geology and Mineral Resources
801 Leroy Place, Socorro, New Mexico, 87801-4796

GEOLOGIC MAP OF THE HORCADO RANCH 7.5-MINUTE QUADRANGLE, SANTA FE COUNTY, NEW MEXICO

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*1 (*danchikoning@yahoo.com)*;* described late Cenozoic sedimentary strata (including the Tesuque Formation plus Pliocene and Quaternary sediment deposits) and constructed the cross-section.

2 United States Geological Survey, Denver (fmaldona@usgs.gov); described the volcanic flows on the Caja del Rio Plateau.

DESCRIPTION OF MAP UNITS

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. Clast percentages are based on percent volume and were estimated in the field with the aid of percentage charts. Descriptions of bedding thickness follow Ingram (1954). Colors of unconsolidated sediment are based on visual comparison of dry samples to the Munsell Soil Color Charts (Munsell Color, 1994) and those of volcanic flows are compared to the rock chart of Goddard et al. (1948). Surficial units are only delineated on the map if estimated to be at least 1 m thick. Fractional map symbol **Qs/Tcb** denotes areas where slope wash mantles underlying basalt flows. Soil horizon designations and descriptive terms follow those of the Soil Survey Staff (1992) and Birkeland (1999). Stages of pedogenic calcium carbonate morphology follow those of Gile et al. (1966) and Birkeland (1999).

Use of the term "amphibolite" may also include minor mafic-rich rocks such as gabbro, diorite, and pyroxene- or hornblende-gneiss. However, most of the clasts referred to as "amphibolite" appear to be true amphibolite in hand sample. The term "granitic clasts" includes foliated granite as well as feldspar and quartz clasts that were probably derived from the weathering of coarse-grained granite rock.

Volcanic rock units cover a small area on this quadrangle and were generally classified according to work done on the adjacent White Rock quadrangle (Dethier, 1997). No chemical analyses of volcanic rocks were conducted on this quadrangle.

Mapping of the geology was accomplished using aerial photographs, field traverses, and close inspection of numerous outcrops across the quadrangle. Terrace correlations were generally made by field comparison of strath heights and construction of longitudinal profiles. The authors did not receive permission to enter San Ildefonso Pueblo lands so that area has not been field-checked, except for the extreme northwest corner of the quadrangle. Also, most faults drawn in the northwest quadrant of the map, where exposure is poor, are tentatively interpreted from aeromagnetic lineaments of Grauch et al. (2009) and lineaments on aerial photographs.

Note that in the following text we use the term Sangre de Cristo Mountains for the mountains east and northeast of Santa Fe and south of the Taos Mountains.

ANTHROPOGENIC DEPOSITS

af **Artificial fill (Recent) --** Sand, silt, clay, and gravel under highways or in landfills; loose or compacted.

QUATERNARY TALUS, COLLUVIUM, SLOPEWASH, AND EOLIAN DEPOSITS

Qtc **Talus and colluvium (late Pleistocene to Recent) --** Talus and colluvium west of Cañada Ancha derived from Cerros del Rio volcanic flows and phreatomagmatic deposits and arkosic sandstone and conglomerate of the Tesuque and Ancha formations. The talus is in poorly defined, medium to thick beds. These beds slope 20-25 degrees to the east away from the basalt flows. Beds are both matrix- and clast-supported. The talus includes pebbles, cobbles, and boulders. These clasts are poorly sorted and are generally angular to subangular. Boulders may be several meters in diameter. Clasts are mostly basalt, basaltic andesite(?), and andesite, but include minor pebbles and cobbles of quartzite (less than 2%) and granitic pebbles (generally less than 5%). The matrix is pale-brown to brown (10YR 5-6/3) silt-clay and very fine-grained sand with subordinate fine- to very coarse-grained sand. The talus unconformably overlies the Cuarteles Member of the Tesuque Formation (unit **Ttcu**). Soil possesses calcic horizon(s) with stage I or II or calcium carbonate morphology. Generally loose but soils may provide some cohesion. Thickness is 1-4 m.

Qs
Tcb **Slope wash that overlies basalt flows (Holocene) --** Pale-brown to light-yellowish-brown to yellowish-brown (10YR 5-6/3-4) clay-silt and very fine- to fine-grained sand with 5- 40% basalt pebbles. Pebbles are very fine to very coarse and angular to subangular. Sand is well sorted, angular to subrounded, and a lithic-rich arkose. Most of clay-silt and sand are probably eolian in origin. Sediment is loose and estimated to be 1-2 m thick.

Qesd **Eolian sand dunes (upper Holocene to Recent)** -- Linear and coppice sand dunes that have formed immediately east of, and parallel to, the Arroyo Ancho active stream channel. Dunes are 80 to 90 cm high. Laminae may be wavy or cross-laminated, with foresets ≤10 cm tall. The sediment is typically light-yellowish-brown to light-brown (7.5YR-10Y 6/4) silt and very fine- to medium-grained sand. The sand is well sorted, subangular to subrounded, and arkosic. The soil development on these dunes is very weak, thin (less than 80 cm thickness), and generally marked by A horizon(s) overlying C horizon(s). Dunes partially bury trees. The deposit is loose and 1 to 1.5 m thick.

QUATERNARY ALLUVIAL DEPOSITS

Qam **Modern stream alluvium (subject to annual deposition)** – Light-brown to pink (7.5YR 6-8/3-4) sand, gravelly sand, and sandy gravel that underlie modern ephemeral or active channels. Beds are typically very thin to thin, and horizontal-planar or cross-stratified. Gravel is generally poorly sorted and consists of subangular to subrounded pebbles with less than 50% rounded to subrounded cobbles. Gravel composition varies according to the location of the parent material but is generally granitic with 1-3% amphibolite, 1-5% calcium carbonate-cemented sandstone, and trace to 5% quartzite. Sand is generally coarse- to very coarse-grained, poorly to moderately sorted, subrounded to subangular, and arkosic. There is no soil development and the sediment is loose. This unit is equivalent to the Qc unit in the Tesuque 7.5 minute quadrangle to the east (Borchert et al., 1998) and to the Qa3 unit in the White Rock 7.5 minute quadrangle to the west (Dethier, 1997). Estimated to be 1-2 m thick.

Qay2 **Youngest alluvium (estimated to be 20 to 200 years old) –** Light-brown to pink (7.5YR 6-7/4) sand, gravelly sand, and sandy gravel with minor clay-silt and silt. Locally underlies valley floors and inset below the surface of unit **Qay1**. Sediment occurs in very thin to medium beds that may be internally horizontal-planar-laminated or cross-laminated. Gravel clasts are generally pebbles with less than 5% cobbles. Gravel composition varies according to the location of the parent material but is generally granitic with 1-3% amphibolite, 1-5% calcium carbonate-cemented sandstone, and trace to 5% quartzite. Cobbles and very coarse pebbles are rounded to subrounded whereas finer gravel are subrounded to angular. Within a bed, gravel is moderately to well sorted. Sand is very fine to very coarse, arkosic, subrounded to subangular, and moderately to well sorted (within a bed). Soil development is non-existent to very minimal; a calcic horizon is not evident and original sediment stratification is commonly present near the surface. The surface of this unit is approximately 0.5-1.5 m above the modern channel. Extreme flood events will rework this sediment. **Qay2** is included in the Qa3 unit in the White Rock 7.5 minute quadrangle to the west (Dethier, 1997) and the Qal unit in the Tesuque 7.5 minute quadrangle to the east (Borchert et al., 1998). Sediment is loose and generally 1-3 m thick.

Qay1 **Younger alluvium (upper Pleistocene to upper Holocene) --** Pink (7.5YR 6-7/4), light-yellowish-brown (10YR 6/4), light-brown (7.5YR 6/3), pale-brown (10YR 6/3), yellowish-brown (10YR 5/4), very-pale-brown (10YR 7/4), reddish-yellow (5YR 6/6), or light-grayish-brown to grayish-brown (10YR 5-6/2) sand, clayey-silty sand, clay-silt, and minor gravel. Locally underlies floors of valleys below Pleistocene gravelly terrace deposits, and its surface is above **Qay2**. Sediment occurs in very thin to medium, tabular or lenticular beds. Horizontal-planar- or cross-laminations are commonly observed within a bed. Gravel is clast- or matrix-supported and composed of pebbles with less than 10% cobbles. Pebbles occur in medium to very coarse sand and tend to be moderately sorted and subrounded to subangular. Clast composition is granitic with 1-3% amphibolite, trace to 5% calcium carbonate-sandstone, and trace to 5% quartzite. Sand is mostly very fine- to medium-grained and is commonly clayey or silty. Sand is generally arkosic, poorly to well sorted, and subangular to subrounded.

The sediment may be differentiated into 1 to 3 (possibly more) soil-bounded, stacked, alluvial allostratigraphic units. The top soil has a calcic horizon with stage I morphology (10-50 cm thick). Buried soils have calcic horizons with stage I to II pedogenic carbonate morphology (10-50 cm thick) and may have Bt soil horizons (5-15 cm thick) with very few to common, faint to distinct, clay films on soil ped faces. **Qay1** is speculated to be generally younger in the upper reaches of the Rio Tesuque and Pojoaque River tributary drainages compared to Cañada Ancha tributary drainages to the south. For instance, in the Rio Tesuque and Pojoaque River tributary drainages, **Qay1** is more likely to consist of just one soil-bounded, alluvial unit whose top soil possesses calcic horizon(s) with weak to moderate stage I pedogenic carbonate morphologies. Downstream in the main Rio Tesuque drainage and lower Arroyo Ancho, **Qay1** generally thickens and multiple soil-bounded, stacked, alluvial allostratigraphic units become more common. Charcoal collected from 4 m-depth in **Qay1** alluvium underlying the Rio Tesuque valley west of this quadrangle returned a C-14 date of 2,230 ±250 radiocarbon years (Miller and Wendorf, 1958); moreover, the **Qay1** surface in this valley was probably abandoned sometime after 1299-1250 A.D., based on archeological evidence (Miller and Wendorf, 1958).

Qay1 may be covered by up to 30 cm of very young alluvium (**Qay2)** or overlain by a thin cover of eolian silt. Unless overgrazed, the surface of this unit commonly has a moderate to dense grass cover. During intense rainstorms, the surface of this unit experiences sheetflooding but erosion is minimal due to the grass diminishing water velocity and their roots holding the sediment together. The surface of this unit is commonly 1-5 m above the floor of the active channel. During rare, extreme flood events, the surface of this unit may receive minor, fine-grained, overbank deposition from nearby channels. **Qay1** is generally equivalent to the Qa2 unit in the White Rock 7.5 minute quadrangle to the west (Dethier, 1997), and is included in the Qal unit in the Tesuque quadrangle to the east (Borchert and Read, 1998). The sediment is loose to hard (hard due to clay-silt or cohesive calcic soil horizons) and is generally 1-6(?) m thick.

Qaou **Older tributary alluvium, undivided (lower to upper Pleistocene) --** Very-pale-brown to light-yellowish-brown (10YR 6-7/4) sand, sandy gravel, and gravelly sand that occurs under terraces that parallel modern tributary drainages to the Rio Tesuque and Pojoaque River. The alluvium was deposited by these tributary drainages rather than by the Rio Tesuque or Pojoaque River. **Qaou** lies below unit **QTgp3** and is about the same height above adjacent drainages as **Qgt** terrace deposits. Beds are very thin to medium, and lenticular or channel-shaped. Gravel is mostly pebbles with minor cobbles and is clast-supported. Clast composition varies according to parent lithology but is mostly granite with 1-3% amphibolite, trace muscovite schist, 0.5% yellowish Paleozoic sandstone and siltstone, and trace to 5% quartzite. Quartzite clasts are rounded to subrounded; for other rock types, cobbles are subrounded, coarse to very coarse pebbles are subrounded to subangular, and very fine to medium pebbles are angular to subrounded. Sand is very fine- to very coarse-grained, moderately to poorly sorted, subrounded to subangular, and arkosic. Deposit is loose and 1 to 7 m thick.

Qgt **Gravelly terrace deposits associated with the Rio Tesuque (lower to upper Pleistocene) --** Loose gravel, sand, and silt that underlie terraces adjacent to the Rio Tesuque and interpreted to have been formed by the ancestral Rio Tesuque based on sediment composition, sediment texture, and location. Sand and silt exhibit colors of light-yellowish-brown (10YR 6/4), light-brown (7.5YR 6/4), pink (7.5YR 7/4), reddish-yellow (7.5YR 6-7/6), or pale-yellow (2.5Y 7/3). The lower contact between these deposits and the underlying Tesuque Formation is marked by an unconformity and scour. Beds are very thin to medium, and commonly lenticular or "U-shaped." Gravel is clast-supported, moderately to poorly sorted, and generally composed of cobbles and pebbles with <5% boulders. Quartzite clasts are subrounded to rounded. Very coarse granitic pebbles and granitic cobbles are subrounded, coarse and medium granitic pebbles are subrounded to subangular, and very fine to fine granitic pebbles are subangular to angular. Gravel is clast-supported and generally larger and more rounded than the underlying Tesuque Formation gravel. Clast composition is granitic with 3-10% amphibolite, trace to 10% quartzite, trace to 5% Paleozoic siltstone and sandstone, trace to 2% muscovite schist, and trace to 2% chert. Sand is very fine- to very coarse-grained, poorly to well sorted, subangular to subrounded, and arkosic. Sediment is loose. The stream gravel is associated with four generalized mapped terrace deposits (**Qgt4** through **Qgt1**) correlated on the basis of strath height above the present stream (Figure 1), and to a lesser extent, texture and thickness of sediment fill. Except for **Qgt1**, strath heights of these terraces are lower than those of unit **QTgp**. **Qgt4-Qgt1** are described below:

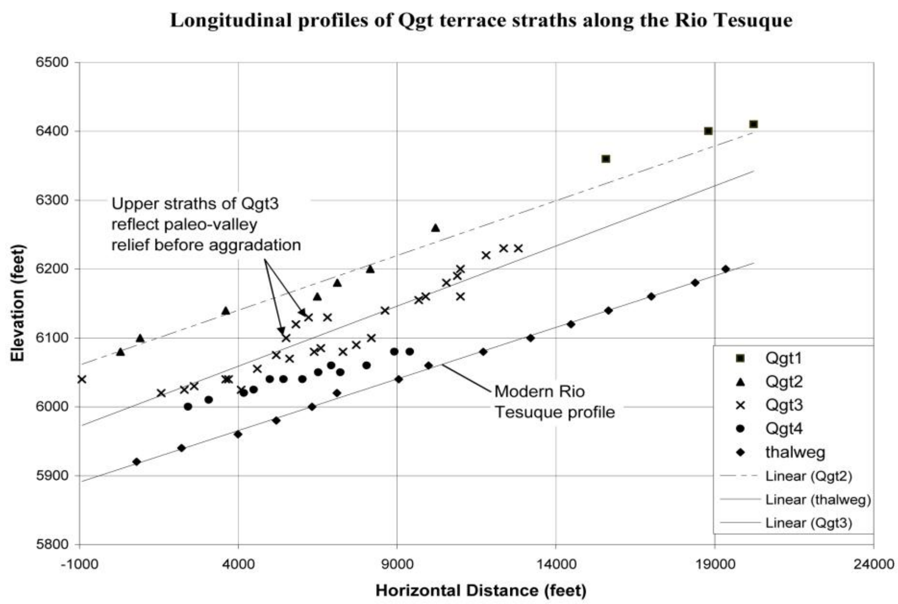

Figure1. Longitudinal profiles of straths developed under **Qgt** terrace deposits. The elevations of the straths were projected orthogonally onto a straight vertical plane that follows the trend of the Rio Tesuque (N25°W). The modern stream thalweg of the Rio Tesuque is also shown. Subunits **Qgt3a** and **Qgt3b** are grouped into unit **Qgt3**. Linear regression lines are given for the **Qgt2**, **Qgt3**, and thalweg data.

Qgt4 **Sandy gravel terrace deposit (upper Pleistocene) –** A strath terrace that may correlate to the Qgt5 unit in the Tesuque 7.5 minute quadrangle to the east (Borchert et al., 1998). Terrace likely correlates to Qtp2 in the Española quadrangle to the north (Koning, 2002). Strath is 10-17 m above modern channel. 1 to 5 m thick.

Qgt3 **Sand, silt, and gravel terrace deposit (upper Pleistocene) –** A fill terrace that is highly variable in thickness. North end of unit (west of town of Cuyamungue) is up to 18 m thick, mostly composed of silt and very-fine to medium-grained sand, and correlates to a terrace fill of similar thickness and texture south of the Pojoaque River and north of this quadrangle (unit Qtpt1 of Koning, 2002). There, the strath exhibits relief due to original valley wall and valley floor topography that was later covered by **Qgt3** aggradation. To the south, however, the thick fill diverges into two thinner (1-6 m) and more gravelly terrace deposits, labeled **Qgt3a** (upper) and **Qgt3b** (**lower**). Straths are 20-40 m above modern channel. **Qgt3a** and **Qgt3b** correlate to the Qgt3 and Qgt4 units, respectively, in the Tesuque 7.5 minute quadrangle to the east (Borchert et al., 1998). Up to 18 m thick.

One bed of white pumice lapilli is exposed in a gully about 0.6 km southwest of the town of Cuyamungue on the northeast corner of the quadrangle (Tables 1 and 2, sample HR-17ext-061201). This pumice is 30-50 cm thick and interbedded in massive silt. Pumice in this bed is mixed with silt and 1-2% biotite grains are observed in pumice clasts. Because the pumice bed roughly parallels the relatively steep slope of the present gully (gully slopes 4° compared to 0.5-1.0° slope of the Rio Tesuque and terrace straths; Figure 1), it probably reflects reworking of surface pumice into a deep post-**Qgt3** gully. Attempts at a radioisotopic age for sample HR-17ext-061201 were unsuccessful, but chemical analyses support correlation with the El Cajete tephra (Table 2 and Appendix 1). The El Cajete tephra consists of white, vesicular, pumice lapilli of rhyolitic composition erupted from the El Cajete crater within the southwestern Valles caldera. The age of the El Cajete tephra is likely 55-60 ka (Toyodo and Goff, 1996; Reneau et al., 1996). Therefore, the **Qgt3** terrace must pre-date 55-60 ka; it likely correlates to 70-90 ka terraces interpreted near Española (Dethier and McCoy, 1993; Dethier and Reneau, 1995; Koning, 2005).

Qgt2 **Sandy gravel terrace deposit (upper to middle Pleistocene) --** Paleocurrent from imbricated clasts is N75°W±15°; this strath terrace probably correlates to the Qgt2 or Qgt3 unit in the Tesuque quadrangle to the east (Borchert et al., 1998). Strath is 45-53 m above modern channel. 2 to 6 m thick.

Qgt1 **Gravelly sand and sand terrace deposit (lower Pleistocene) –** A very thick fill terrace that probably correlates to the Qgt2 unit in the Tesuque quadrangle to the east (Borchert et al., 1998). The height of the strath above Arroyo Ancho (60-65 m)

Table 1. Radioisotopic age control

Sample No.	Map unit	Location, UTM, NAD27, Zone 13S (m)	Description	NMGRL No.	WM K/Ca Ratio	Number of sanidine crystals (MSWD)	WM ±2σ age (Ma)
HR-17ext	Post-Qgt3 fill(?)	N: 3,968,930 E: 408,730	30-50 cm thick, white pumice lapilli interbedded in massive, loose silt; probably fills a gully eroded into the Qgt3 deposit.	pending	pending	pending	pending
H-62	Qgp3	N: 3,968,350 E: 406,400	50-70 cm thick, white pumice lapilli interbedded within top 1 m of Qgp3 sand and gravel. Gives age of upper Qgp3.	51927	58.1 ± 3.2	14	1.21 ± 0.02
H-294	Qgp2	N: 3,967,530 E: 406,470	Discontinuous, 55-90 cm thick, white pumice lapilli that probably fills former channel developed on top of terrace deposit.	51930	25.0 ± 9.5	14	1.53 ± 0.04
75-5-19-3*	Tca(?)	N: 3,958,935 E: 398,910	Collected from a lava flow described as a latite with $K_2 0$ = 3.2% (Manley, 1976a).	n.a.	n.a.	n.a.	1.96 ± 0.06
73A2**	Ta	N: 3,956,890 E: 399,807	2 m thick, white pumice in arkosic sand and granitic gravel; near or at base of Ta (Manley and Naeser, 1977; Kim Manley, pers. commun., 2002). Collected by Kim Manley.	n.a.	n.a.	n.a.	2.7 ± 0.4
DL-HR***	Ttpe	N: 3,956,680 E: 399,870	White lapilli bed ~20 m below basalt flow and 9 m below Ta at Cañada Ancha . Collected by Dave Love of the NMBMMR. Gives age of upper subunit of Pojoaque Member.	6049	0.06 $^{\psi}$	n.a.	8.48 ± 0.14
H-132	Ttpe	N: 3,961,480 E: 399,250	140 cm thick, white pumice lapilli interbedded in granitic gravel and arkosic sand.	51928	See Table 3	19	See Table 3 $^{\Upsilon}$
H-235	Ttpe	N: 3,970,200 E: 407,430	90 cm thick, tabular bed of bluish gray to white ash that lacks mafic minerals.	51929	17.8 ± 11.8	5	15.70 ± 1.10

Notes:

Tephras analyzed by the New Mexico Geochronological Research Laboratory (NMGRL; Peters, 2001) by the single-crystal laser fusion method, except for samples 75-5-19-3*, 73A2**, and DL-HR*** (see below). Geographic coordinates (Universal Transverse Mercator, 1927 North American Datum) are rounded to the nearest 5 meters.

Abbreviations include: not applicable (n.a.) and weighted mean (WM). Single asterisk (*) indicates sample underwent whole rock K-Ar dating (Manley, 1976a) and its exact location is uncertain. Double asterisk (**) means sample analyzed by zircon fission-track dating method (Manley and Naeser, 1977). Triple asterisk (***) indicates sample analyzed by incremental-heating-age-spectrum method on hornblende grains using $^{40}Ar/^{39}Ar$. (ψ) indicates K/Ca ratio measured from graphs because tabulated data was not available. (ϒ) weighted mean age not assigned because of the wide spread of $^{40}Ar/^{39}Ar$ age values.

Table 2. Chemical analyses of ashes collected in Pojoaque Pueblo lands

sample	P2O5	SiO2	SO2	TiO2	Al2O3	MgO	CaO	MnO	FeO	Na2O	K2O	F	Cl	Total
H235-1	0.00	76.59	0.01	0.15	10.95	0.00	0.18	0.12	2.79	2.65	6.03	0.35	0.18	100
H235-2	0.02	77.85	0.00	0.15	11.19	0.00	0.18	0.06	2.92	1.88	5.55	0.00	0.20	100
H235-3	0.00	76.07	0.02	0.16	10.86	0.00	0.13	0.08	2.84	3.16	6.35	0.17	0.16	100
H235-4	0.03	77.49	0.00	0.17	11.51	0.00	0.20	0.11	2.50	2.05	5.81	0.04	0.09	100
H235-5	0.00	76.02	0.00	0.12	11.18	0.01	0.20	0.07	2.88	2.87	6.18	0.18	0.29	100
H235-6	0.04	75.73	0.02	0.19	11.25	0.00		0.07	2.74	2.78	6.57	0.00	0.13	100
H235-7	0.07	76.21	0.01	0.14	11.11	0.00	0.25	0.07	2.72	2.84	6.36	0.10	0.13	100
H235-8	0.00	76.79	0.00	0.17	11.03	0.00	0.19	0.05	2.79	2.52	6.14	0.20	0.13	100
H235-9	0.00	76.44	0.00	0.13	10.85	0.00	0.19	0.11	2.61	2.84	6.48	0.19	0.16	100
H235-10	0.03	76.23	0.04	0.16	11.66	0.06		0.10	2.72	2.20	5.51	0.14	0.38	100
H235-11	0.02	76.27	0.02	0.17	11.47	0.00	0.22	0.05	2.46	2.89	6.32	0.00	0.11	100
H235-13	0.00	77.97	0.00	0.08	11.17	0.00	0.26	0.09	2.75	1.98	5.46	0.09	0.15	100
H235-14	0.02	76.29	0.00	0.15	11.11	0.00	0.14	0.09	2.75	2.78	6.27	0.24	0.15	100
H235-15	0.00	75.56	0.00	0.16	11.63	0.00	0.27	0.11	2.44	3.06	6.55	0.14	0.08	100
H235-mean	**0.02**	**76.54**	**0.01**	**0.15**	**11.21**	**0.01**	**0.20**	**0.08**	**2.71**	**2.61**	**6.11**	**0.13**	**0.17**	
stdev	0.02	0.74	0.01	0.03	0.26	0.02	0.04	0.02	0.15	0.42	0.39	0.10	0.08	
hr-17ext-061201-djk-1	0.05	75.50	0.00	0.34	13.60	0.24	1.35	0.02	1.42	2.82	4.58	0.02	0.05	100
hr-17ext-061201-djk-2	0.06	74.34	0.03	0.36	13.43	0.30	1.23	0.08	1.32	3.60	4.71	0.47	0.07	100
hr-17ext-061201-djk-3	0.07	75.26	0.00	0.27	13.49	0.27	1.19	0.05	1.34	3.66	4.31	0.04	0.04	100
hr-17ext-061201-djk-4	0.01	74.46	0.00	0.25	13.77	0.27	1.19	0.09	1.44	3.62	4.62	0.13	0.14	100
hr-17ext-061201-djk-5	0.09	75.18	0.01	0.23	13.42	0.23	1.31	0.03	1.47	3.33	4.48	0.11	0.10	100
hr-17ext-061201-djk-6	0.02	73.29	0.03	0.22	15.22	0.24	2.12	0.02	1.22	3.83	3.70	0.00	0.08	100
hr-17ext-061201-djk-7	0.00	74.80	0.01	0.27	13.41	0.30	1.21	0.00	1.39	3.60	4.39	0.16	0.45	100
hr-17ext-061201-djk-8	0.04	75.30	0.02	0.29	13.37	0.25	1.11	0.04	1.24	3.41	4.59	0.06	0.27	100
hr-17ext-061201-djk-9	0.04	75.14	0.03	0.24	13.58	0.28	1.13	0.01	1.28	3.65	4.46	0.00	0.16	100
hr-17ext-061201-djk-10	0.00	75.66	0.02	0.26	13.40	0.23	1.11	0.03	1.17	3.55	4.32	0.15	0.10	100
hr-17ext-061201-djk-11	0.01	74.70	0.05	0.25	13.31	0.27	1.86	0.03	1.36	3.46	4.43	0.16	0.12	100
hr-17ext-061201-djk-12	0.00	76.07	0.01	0.22	13.13	0.17	0.86	0.08	0.92	3.59	4.80	0.08	0.08	100
hr-17ext-061201-djk-13	0.03	76.36	0.02	0.16	13.01	0.17	0.82	0.06	1.00	3.38	4.74	0.04	0.21	100
hr-17ext-061201-djk-14	0.02	76.29	0.03	0.14	13.21	0.16	0.95	0.05	1.00	3.32	4.66	0.10	0.09	100
hr-17ext-061201-djk-15	0.04	74.56	0.02	0.29	13.93	0.29	1.26	0.05	1.41	3.60	4.42	0.04	0.09	100
hr-17ext-061201-djk-16	0.02	74.48	0.06	0.29	13.76	0.30	1.37	0.09	1.37	3.69	4.27	0.11	0.20	100
hr-17ext-061201-djk-m	**0.03**	**75.09**	**0.02**	**0.26**	**13.57**	**0.25**	**1.26**	**0.05**	**1.27**	**3.51**	**4.47**	**0.10**	**0.14**	
stdev	0.03	0.80	0.02	0.06	0.50	0.05	0.33	0.03	0.17	0.23	0.26	0.11	0.10	

Notes:

Analyses conducted by N.W. Dunbar of New Mexico Tech for Dan Koning, June of 2002.

Data normalized to 100%.

is comparable to the height of the strath of **QTgp3** above Arroyo Jacona in the northwest part of the quadrangle. Thus, **Qgt1** probably correlates with **QTgp3,** which has a ~1.2 Ma pumice bed. However, **Qgt1** is interpreted to have been constructed by the Rio Tesuque upstream from an ancestral confluence with the Pojoaque River and thus it is differentiated from **QTgp3**. Up to 18 m thick.

PLIOCENE TO QUATERNARY ALLUVIAL DEPOSITS

QTgp **Stream gravel deposits associated with the ancestral Pojoaque River drainage (lower Pleistocene) --** Sandy gravel terrace deposits inset into the Tesuque Formation south of the Pojoaque River (which flows westward ~1.5-2 km north of the quadrangle). Terraces differentiated on the basis of relative heights and $^{40}Ar/^{39}Ar$ dating (Table 1). Gravel is poorly to moderately sorted, clast-supported, and composed of 1-3% amphibolite, 1-5% quartzite, and 92-98% granitic clasts. Boulders, cobbles, and very coarse pebbles are rounded to subrounded, medium and coarse pebbles are subrounded to subangular, and very fine to fine pebbles are subrounded to angular. The lower contact between these deposits and the underlying Tesuque Formation is marked by an angular unconformity and scour. On a given terrace, the lower contact (strath) as well as the tread slopes to the north in an irregular manner. Based on limited exposures, it is interpreted that on a given terrace unit the sediment is progressively inset downwards to the north in small increments and thus becomes slightly younger to the north (similar to the QTg deposits on the Tesuque Quadrangle to the east; Borchert et al., 1998). Paleocurrent measurements from cross-stratification and clast imbrication range from west to northeast. Straths of these terraces are higher above present drainages than straths of **Qgt2-4**. The straths of **QTgp3** and **Qgt1** are both approximately 60 m above modern drainages and may be correlative. This unit is interpreted to have been deposited by a west to northwestward-flowing, ancestral Pojoaque River below its confluence with the Rio Tesuque or associated with deposition by tributaries draining into the Pojoaque River from the south (as in the case of **QTgpu**). It is possible that some of the eastern terraces were deposited above this confluence. This unit was generally correlated to the Santa Cruz pediment by Kelley (1979). However, we do not call these pediment gravels because at least three individual terrace deposits can be differentiated based on relative strath heights, these deposits are restricted to major drainages (i.e. the Pojoaque River), and there is no evidence of a regional pediment surface. This unit correlates to the QTg unit in the Tesuque 7.5 minute quadrangle to the east (Borchert et al., 1998).

QTgp3 **Sandy gravel terrace deposit (lower Pleistocene) --** Both sand and gravel beds are very thin to thin and lenticular. Paleocurrent from imbricated clasts is N60 °W ± 20°. Gravel consists of subequal, or slightly more, pebbles to cobbles and 1-2% boulders. The amount of quartzite clasts decreases to the south because of more input from the quartzite-poor Cuarteles Member of the Tesuque Formation (**Ttacu**) in the north-central part of the quadrangle. Sand is light yellowish brown (10YR 6/4), fine- to very coarse-grained, subangular, poorly sorted, and arkosic. Locally, pieces of indurated calcium carbonate suggest that a stage IV calcic soil horizon was present near the surface. Much of this horizon and associated soil has since been stripped away due to erosion. The deposit may be wedge-shaped, with thickening to the north. A thin veneer of locally derived, granite-rich gravel and arkosic sand from the Tesuque Formation may cover these terrace deposits along the south margin of the unit. Sediment is loose and 5-15 m thick.

Between Arroyo de Jaconito and Arroyo Jacona in the northwest part of the map, the top of this deposit locally contains a 50-70 cm-thick pumice lapilli bed that has been $^{40}Ar/^{39}Ar$ dated at 1.21 ± 0.02 Ma (Table 1, sample H-62), which is temporally correlative to the Tsankawi Pumice Bed (Peters, 2001). This pumice appears to be conformably underlain by **QTgp3** gravel (no soil is preserved in the gravel immediately beneath the pumice) and is overlain by 10-40 cm of loose, poorly exposed, gravelly sand. The overlying sand is light-brownish-gray to pale-brown (10YR 6/2-3), medium- to coarse-grained, plagioclase-rich (and slightly ashy) arkosic arenite that is angular to subangular and moderately sorted. The overlying gravel contains abundant quartzite and granitic cobbles. This overlying deposit is interpreted to be a thin cover of **QTgp3** fluvial gravel that was later bioturbated and eroded. Thus, the Tsankawi Pumice Bed appears to have been emplaced near the end of **QTgp3**-related deposition, which means this terrace deposit is about 1.2 Ma or slightly older. The straths of **QTgp3** and unit **Qgt1**, the latter interpreted to have been formed by the ancestral Rio Tesuque drainage, both are approximately 60 m above adjacent drainages and probably correlative.

QTgp2 **Sandy gravel terrace deposit (lower Pleistocene) --** Strath is 10-25 m above strath of **QTgp3** terrace. Sediment is in "U_shaped" channel-fills or in poorly defined, very thin to medium, lenticular beds. Gravel has slightly more pebbles than cobbles and 2-5% boulders (estimated by volume). Unit locally has up to 8% quartzite clasts but the amount of quartzite generally decreases to the south because of more input from the quartzite-poor Cuarteles Member of the Tesuque Formation (**Ttacu**) in the north-central part of the quadrangle. Sand is light yellowish brown to pale-brown to very-pale-brown (10YR 6-7/3-4), fine- to very coarse-grained but generally coarse- to very coarse-grained, poorly to moderately sorted, subangular to subrounded, and arkosic. The soil developed on top of this deposit has calcic horizons with stage III to IV calcium pedogenic carbonate morphology and Bt soil horizons. A thin veneer or fan-shaped lobes of locally derived, granitic sediment from the Tesuque Formation may cover this deposit along the south margin of the unit. This veneer is composed of granitic, angular to subrounded pebbles and sand. Sediment is loose and 5-14 m thick.

Sandy pebbles and cobbles of **QTgp2** are locally overlain by a lenticular and discontinuous, 20 to 90 cm thick bed(s) of pumice lapilli that has been dated at 1.53 ± 0.04 Ma using $^{40}Ar/^{39}Ar$ (Table 1, sample H-294), a date which is temporally correlative to the Cerro Toledo Rhyolite eruptions (Peters, 2001). No evidence of soil development is observed immediately beneath the pumice. The pumice locally consists of two 20-35 cm thick beds separated by 15 cm of coarse, arkosic sand and pebbles (see tephra descriptions below). The lower bed may represent the primary fallout deposit, and the overlying pumice and arkosic sediment may reflect later reworking of the valley floor surface. The pumice is locally overlain by 70 cm of deposits consisting of matrix-supported, massive silt and very fine-grained sand with 10% pebbles and cobbles; soil development is marked by calcic horizons with stage II morphology. This overlying sediment is interpreted to be sheetwash or reworked eolian deposits that probably were bioturbated and later eroded. Thus, the pumice is interpreted to have been emplaced near the end of **QTgp2** deposition and reworked into channels that existed on the ancestral valley floor of the Pojoaque River before subsequent incision created the **QTgp2** terrace. This interpretation would indicate that **QTgp2** deposition ended near or shortly prior to 1.5 Ma.

QTgp1 **Sandy gravel terrace deposit (upper Pliocene(?) to lower Pleistocene) --** Gravel generally has more pebbles than cobbles. Correlates to the QTg unit in the Tesuque 7.5 minute quadrangle to the east (Borchert, et al., 1998). Deposit is poorly exposed, loose, and 4-8 m thick.

QTgpu **Undivided, older alluvium from small tributaries to the ancestral Pojoaque River (upper Pliocene(?) to lower Pleistocene) –** Light-yellowish-brown (10YR 6/4), very-pale-brown (10YR 7/3-4), or pink (7.5YR 7/4) sandy gravel and gravelly sand that occur as remnant channel fills that now occupy ridges (because of topographic inversion) in the southern part of the Jacona land grant, or occur as fan-shaped lobes overlapping **QTgp2**. These well-packed, relatively coarse gravels are slightly more resistant to erosion than the underlying Tesuque Formation. Where this unit terminates in an up-slope (southwards) direction, the corresponding ridge generally becomes lower and steps abruptly to the right or left. The gravel has less than 1% boulders, less than 1/3 cobbles, and more than 2/3 pebbles. The gravel only has trace to 1% quartzite. Sand is very fine to very coarse, poorly sorted, subangular to subrounded, and arkosic. There are no natural exposures of this sediment. Deposit is loose and less than 4 m thick.

QTga **Stream gravel deposits associated with the Cañada Ancha drainage system (upper Pliocene(?) to upper Pleistocene)** -- Poorly exposed and loose sandy gravel that underlie four strath terraces in Calabasa Arroyo and Cañada Ancha in the southern part of the map. These terraces are inset into the Tesuque Formation and mapped on the basis of longitudinal profiles (using straths) and clast lithology. Sand is light-yellowish-brown (10YR 6/4). Gravel consists of granite and quartzite clasts that are moderately to poorly sorted. Quartzite pebbles and cobbles are subrounded to rounded. Granitic very coarse pebbles and cobbles are subrounded, medium pebbles are subrounded to subangular, and very fine to medium pebbles are subangular to angular. Except where noted, there are generally more cobbles than pebbles (by a 2/3 to 1/3 ratio, estimated by volume) and there are 2-10% boulders (estimated by volume). **Qtga1-4** are inset into the Tesuque Formation at least 12 m beneath **Tga** terrace deposits so they post-date **Tga**. **QTga1** may possibly project to the Ancha Formation (unit **Ta**) west of Cañada Ancha. Aside from these observations, age control is very poor for these units and consequently ages are not assigned to individual terrace deposits. The clast compositional range and thickness of these terrace deposits are given below:

QTga4 Subequal cobbles and pebbles; no boulders observed. <5% amphibolite, 1% muscovite schist, 3-5% chert, 1-3% limestone, 30-50% quartzite, and 45-60% granitic clasts. This unit is tentatively correlated to terraces west of Cañada Ancha, where it is mixed with basaltic cobbles and boulders and subordinate pebbles. 1-2 m thick.

QTga3 1-20% boulders. Gravel contains 1-3% amphibolite, 0.5-5% muscovite-schist, trace to 3% chert, 40-55% quartzite, and 35-50% granitic clasts. 1-3 m thick.

QTga2 Gravel contains 1-2% amphibolite, 1% muscovite schist, 40-50% quartzite, 45-60% granitic clasts. 1-3 m thick.

QTga1 Gravel contains 1-2% amphibolite, 1% muscovite schist, 0.5-1% limestone, 50-60% quartzite, and 35-45% granitic clasts. 1-2 m thick.

PLIOCENE ALLUVIAL DEPOSITS

Ta **Ancha Formation (upper Pliocene) –** Brownish-yellow (10YR 6/6), light-yellowish-brown (10YR 6/4), pink or light-brown (7.5 YR 6-7/4) sand and gravel under the Cerros del Rio volcanic flows and locally interbedded with Cerros del Rio volcanic lapilli and phreatomagmatic deposits (unit **Tlp**). Beds are generally thin and planar to lenticular. Gravel is generally poorly sorted pebbles with 5-20% cobbles. Clast composition is: 1-5% quartzite, 1-3% amphibolite, and 92-98% granite; locally trace andesite or basalt clasts. Sand is generally coarse, subangular to subrounded, moderately sorted, and arkosic. A 2 m thick, white pumice lapilli bed underlies arkosic sand and granitic gravel of the Ancha Formation and overlies a calcium carbonate-cemented ledge that may possibly be the Tesuque Formation (Manley, 1976b; Kim Manley, personal communication, 2002). The pumice returned a zircon apatite-fission track date of 2.7 ± 0.4 Ma (Table 1, sample 73A2). Unit **Ta** on this quadrangle is correlated with both the Ancha Formation in the Santa Fe embayment to the south and to unit Ta of Dethier (1997) to the northwest because these units are also interbedded with lapilli and phreatomagmatic deposits of the Cerros del Rio volcanic field, and thus occupy the same stratigraphic position. Terrace deposits to the east (units **Tga1-3**) project above the base of the Ancha Formation (Figure 2); these deposits also appear to be coarser and richer in quartzite clasts. Thus, we do not correlate the Ancha Formation with units **Tga1-3**. Projections or correlations to other terrace deposits to the east are ambiguous. Approximately 1-12 m thick.

Tga **Stream gravel deposits near Cañada Ancha drainage (lower(?) to upper Pliocene)** – Stream gravel terrace deposits that are typically poorly exposed and occupy the tops of ridges. Most of these deposits have been assigned to one of three mapped strath terrace deposits, **Tga3-Tga1** (youngest to oldest), which are described below. A few isolated terrace deposits could not be satisfactorily correlated with a particular unit of **Tga3-Tga1** because of long distances and are designated **Tgau**. An inset relationship with the Tesuque Formation is observed for unit **Tga2** near the south boundary of the quadrangle (NE1/4 of Section 35, T. 18 N., R. 8 E.). Beds are very thin to thin and dip less than 2° to the west. Gravel are poorly to moderately sorted and consist of 30-50% pebbles, 50-70% cobbles, and less than 20% boulders; the gravel forms a protective armor on exposed surfaces. Very fine to medium pebbles are angular to subrounded; coarse to very coarse pebbles, cobbles, and boulders are subrounded to rounded. Clast composition is generally about 25-50% quartzite and 50-75% granite with 1-5% amphibolite, trace to 3% mica-schist, and trace to 5% chert. Sand is mostly light yellowish brown (10YR 6/4) with minor pink (7.5YR 7/4) and yellowish brown (10YR 5/4). Sand is very fine- to very coarse-grained, moderately to well sorted, subangular to subrounded, and arkosic. The surfaces of these deposits were generally correlated to the Ortiz pediment by Kelley (1979). The straths of the terrace deposits are generally separated by a vertical distance of approximately 6 m; an inflection of the terrace strath profiles is present in the western quadrangle, where the slopes increase eastward by a factor of 2 over a distance of only 1 km (3,000-3,500 ft; Figure 2). West of this inflection, the **Tga1-2** terrace straths project at least 30 m above the scoured base of the Ancha Formation (unit **Ta**) west of Cañada Ancha (Figure 2); the strath of **Tga3** projects above the base of the Ancha Formation but below the Cerros del Rio basalt flows. Thus, the higher strath terraces are interpreted to have formed before erosion that produced the scoured lower contact of the Ancha Formation, approximately dated by zircon fission-track methods at 2.7 Ma (Table 1, sample 73A2). Because the textures and composition of **Tga** is notably different than the Ancha Formation (**Tga** being much coarser and significantly richer in quartzite clasts), the age difference between the Ancha Formation and unit **Tga** is interpreted to be significant, with the **Tga** deposits perhaps extending into the lower Pliocene.

Tga3 1-5% boulders. 1-4 m thick.

Tga2 5-20% boulders; generally subequal quartzite and granite clasts. 1-5 m thick.

Tga1 Approximately 5-20 % boulders; 40-50% quartzite and 50-60% granitic clasts. 1-6 m thick.

Tgau Undivided Pliocene sand and gravel in the southern portion of the quadrangle. <2% boulders. Gravel has 30-60% quartzite, 1-5% chert, 35-70% granitic clasts, 1-2% amphibolite, and trace mucscovite- schist. 1-12 m thick.

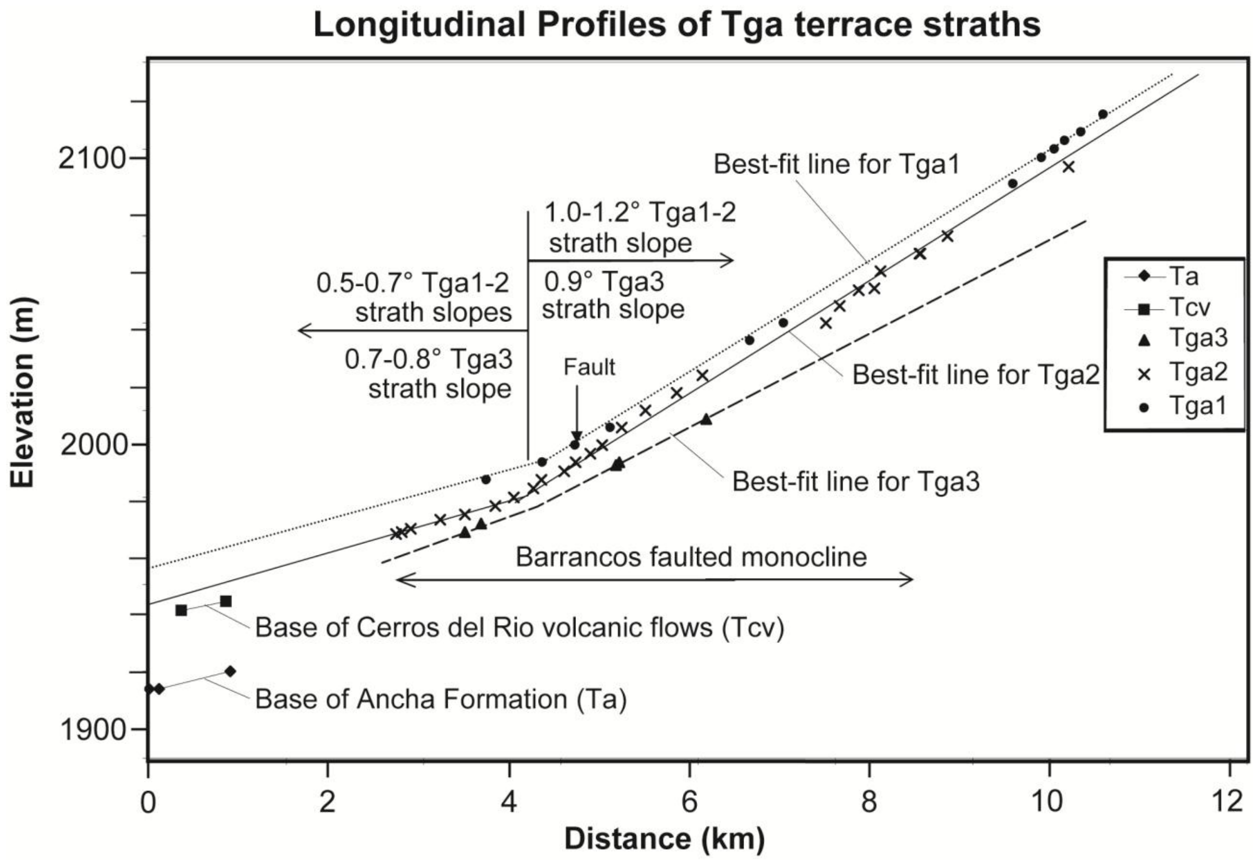

Figure 2. Longitudinal profiles of straths developed under **Tga** terrace deposits. Also shown for reference is the base of the Cerros del Rio basalt flows and the base of the Ancha Formation. The elevations of the straths were projected orthogonally onto a straight vertical plane that trends N84°W and is located 0.8 km north of the south margin of the quadrangle at Cañada Ancha.

LAVA FLOWS AND ASSOCIATED VOLCANICLASTICS OF THE CERROS DEL RIO VOLCANIC FIELD

Tca **Andesitic flows of the Cerros del Rio volcanic field (upper Pliocene) –** Brownish-gray (5YR 4/1) andesitic lava flows, occasionally flow banded. Contains about 5 percent olivine and pyroxene(?) phenocrysts in a fine- to medium-grained groundmass. Not well exposed and overlies unit **Tcb** and **Tcba** west of Cañada Ancha. Equivalent to unit Tca in the adjacent White Rock quadrangle (Dethier, 1997). A possible sample of **Tca** on this quadrangle was dated by K-Ar techniques and returned an age of 1.96 ± 0.06 Ma (Table 1, sample 75-5-19-3). Thickness is about 55 m.

Tcba **Basaltic andesite(?) (upper Pliocene) –** Medium-dark-gray (5YR N4) with olivine phenocrysts in a fine- to medium-grained groundmass. Looks similar to the **Tcb** unit but thicker and the lower part of the flows is platy (indicative of relatively more silica?).

Tcb **Basalt flows of the Cerros del Rio volcanic field (upper Pliocene) --** Medium-dark-gray (5YRN4), olivine-bearing basalt lava flows. Contains about 5 percent olivine phenocrysts. Lower part is brecciated and overlies fallout lapilli, phreatomagmatic beds, and other volcaniclastic deposits of unit **Tlp**. Underlies mesas along the east edge of the Caja del Rio Plateau, west of Cañada Ancha. Equivalent to unit Tcb2 in the adjacent White Rock quadrangle (Dethier, 1997). A Tcb2 flow exposed on the south rim of the Caja del Rio Canyon, approximately 1 km to the west in the adjacent White Rock 7.5-minute quadrangle, returned an $^{40}Ar/^{39}Ar$ age of 2.49 ± 0.03 Ma (WoldeGabriel et al., 1996). A K-Ar date of 2.6 ± 0.4 Ma was obtained by Bachman and Mehnert (1978) from a Tcb2 flow in Ancho Canyon, west of the Rio Grande in the White Rock quadrangle. Thickness is about 30 m.

Tlp **Basaltic lapilli and phreatomagmatic deposits (upper Pliocene) --** Interbedded basaltic lapilli (probably representing both primary and reworked magmatic ejecta) and phreatomagmatic sediments that underlie Cerros del Rio volcanic flows and overlie both the Ancha and Tesuque formations. This unit locally includes subordinate beds of the Ancha Formation (e.g., NE1/4, SW1/4 of Section 20, T. 18 N, R. 8 E.; UTM coord: 3,959,520N, 398,755E, zone 13). Unit **Tlp** correlates to unit Tcm of Dethier (1997). The primary ejecta lapilli is in very thin, planar to wavy, even, distinct, well to moderately sorted, and clast-supported beds or laminations. This lapilli is black (5Y 2.5/1) and generally has less than 1% granitic grains. Welding of adjacent lapilli is observed in some of these beds. Bombs, up to 25 cm long, have formed impact-related depressions on the underlying sediment. Reworked ejecta lapilli differs from primary ejecta by having significantly more granitic pebbles and sand grains (up to 25% of gravel volume), being poorly to well sorted, being very thinly to thickly bedded, being matrix-supported, and having a lighter color (grayish-brown (2.5Y 5/2) to light-brownish-gray or brownish-gray (10YR 6-7/2)).

The phreatomagmatic deposits are composed of pale brown to very pale brown (10YR 6-7/3) clayey-silty or silty sand with 3-20% pebbles. The sediment is in medium to very thick beds and is internally massive, matrix-supported, poorly sorted, and lacks sedimentary structures. Basaltic grains are subrounded and the granitic grains are subangular. The proportions of basalt to granite clasts vary greatly; basaltic clasts may be missing in some beds or compose all of the clasts in other beds. Quartzite comprises less than 2% of the clasts. Minor, 5-10 cm thick, clast-supported lapilli lenses of very coarse-grained sand are locally found within this sediment. Sand grains are very fine to very coarse, angular to subrounded, and composed of feldspar, quartz, and volcanic grains in widely varying proportions. Soils are commonly found on these phreatomagmatic deposits and possess 30-100 cm-thick calcic horizons with stage I+ to III pedogenic carbonate morphology. These soils also commonly have a 5-35 cm-thick Bt horizon(s) with common to many, faint to prominent, clay films on soil ped faces. Up to five of these well-developed soils have been observed on separate phreatomagmatic deposits in this map unit and indicate that the unit was deposited over a significant amount of time. These beds are hard and are more common near the lower part of the map unit.

The basaltic lapilli and phreatomagmatic deposits may locally be overlain by 1.5-6 m of light yellowish brown to very pale brown (10YR 6-7/4 and 10YR 8/2) silt and very fine- to fine-grained sand with 2-5% basaltic and granitic pebbles and coarse sand. This sediment is interpreted to be mostly eolian with minor, local, stream-flow deposits. A soil has developed in this unit that has a calcic horizon with stage II carbonate morphology. The top surface of this fine sediment is somewhat irregular because of post-depositional erosion. Tephra and basalt flows of **Tcb** and **Tcba** unconformably overlie this fine sediment and locally fill channels 10-15 m deep. 10 to 30(?) m thick.

MIOCENE BASIN FILL

Tesuque Formation (Oligocene to upper Miocene) -- Generally pinkish, brownish, or reddish sandstone, siltstone, claystone, and conglomerate. Sandstone is the most prevalent sediment. Bedding is generally very thin to medium and lenticular to tabular. The conglomerate is generally granitic and has 1-5% amphibolite and trace to 5% muscovite schist (other clasts may also be present, as described for Lithosome S below). The sand is poorly to well sorted and subangular to subrounded. Within the central Española Basin, the Tesuque Formation is subdivided into the Bishop's Lodge, Nambé, Skull Ridge, Pojoaque, Chama-El Rito, and Ojo Caliente members (Galusha and Blick, 1971). Of these, the Skull Ridge and Pojoaque members project into this quadrangle from the north. However, the contact between these two members cannot be confidently mapped more than 2.5 km south of the northern quadrangle boundary. We follow Cavazza (1986) in dividing the Tesuque Formation according to provenance. Lithosome A (which includes units **Ttacu**, **Tta2**, and **Tta1**) composes most of the exposed Tesuque Formation on this quadrangle. Lithosome A is derived from the Sangre de Cristo Mountains to the east and is characterized by a granite-dominated gravel assemblage, arkosic sand, and westerly paleocurrent directions. Near the northern quadrangle boundary are three units that are a mix of Lithosome B and Lithosome A sediment (but mostly Lithosome B): one near the northwest corner (**Ttm3**), one in Arroyo Jacona (**Ttm2**), and one in Arroyo Ancho and the Rio Tesuque (**Ttm1**). Sediment of Lithosome B was derived from a large south- to southwest-trending drainage system that had two sources: 1) the mountains east of the Pecos-Picuris fault at the head of the Peñasco embayment (south of the Picuris Mountains), and 2) the San Luis Basin (Cavazza, 1986). Sediment of units **Ttm1** and **Ttm2** is fine-grained with a high proportion of lithics in the sand. In the southern portion of the quadrangle, a new lithosome was designated (Lithosome S) that is characterized by common laterally extensive channels (compared with those in Lithosome A) and hetereolithic gravel (mostly granite but with 0-30% yellowish Paleozoic siltstone and sandstone, 0-20% yellowish to grayish Paleozoic limestone, 0-5% brownish chert, and trace to 40% quartzite). Lithosome S reflects deposition from an interpreted westward-flowing ancestral Santa Fe River.

Ttcu **Cuarteles Member of the Tesuque Formation (middle to upper Miocene) –** Sandstone, clayey sandstone, gravelly sandstone, sandy conglomerate, and minor (<10%) mudstone beds. The overall color of the sediment is reddish-yellow (7.5YR-5YR 6/6) to pink (7.5YR 7/3-4), particularly for the clayey sandstone and sandy conglomerate, respectively, with subordinate light-yellowish-brown (10YR 6/4), pale-brown (10YR 6/3), and very-pale-brown (10YR 7/4). Beds are very thin to medium, with broadly lenticular beds and "U-shaped channels;" subordinate tabular beds; locally, beds are cross-stratified. Conglomerate beds are generally clast-supported and moderately sorted. Some beds are internally massive and matrix-supported and may represent hyperconcentrated flows. Gravel clasts are mostly pebbles with less than 25% cobbles; angular to subangular (for very fine to medium pebbles) or subangular to subrounded (for coarse to very coarse pebbles and cobbles). Composition of the gravel clasts is: 0-1% quartzite, 1-3% amphibolite, and 95-99% granitic clasts. Sand is very fine- to very coarse-grained but mostly medium-to very coarse-grained, moderately to poorly sorted, mostly subangular with minor subrounded grains, and arkosic. At a site in the Calabasa Arroyo (NW1/4 SW1/4 NW1/4 of Section 23, T. 18 N., R. 8 E.; UTM coordinates: 3,959,790N 403,140E, zone 13 and NAD27) buried soils define stacked alluvial allostratigraphic units that are up to 2 m thick. These buried soils have 10-50 cm-thick calcic horizons with stage I to II+ morphology; also, some soils possess 5-15 cm-thick, clayey Bt horizons. The sediment of this unit is generally loose to weakly consolidated (except for strongly cemented sandy gravel beds, which comprise less than 5% of the exposure). The lower contact is gradational over 6-12 m stratigraphic thickness, in the south half of the quadrangle but is much more gradational and diffuse within 3 km south of the northern quadrangle border.

Near the mapped pumice-lapilli beds in this unit at Cañada Ancha (unit **pl**, described below), there are several beds of pale brown to yellowish brown to light brownish gray (10YR 6/2-4), massive, hard (due to calcium carbonate cementation), muddy to slightly muddy sandstone along with very fine- to medium-pebbly sandstone (15-100 cm thick). Volcanic lithic grains and clasts are much more common in these beds (5-40% with up to 3% olivine) than in the adjoining sediment; the beds also contain trace to 25 % pumice. This sand is poorly sorted, very fine- to very coarse-grained, subangular to subrounded, and a lithic-rich arkose. These beds may represent phreatomagmatic deposits.

To the south of this quadrangle, Spiegel and Baldwin (1963) correlated this unit to the Ancha Formation. However, Galusha and Blick (1971) include this unit in the Pojoaque Member of the Tesuque Formation and comment on the causes of its relative coarseness (p. 116-117). Work by the senior author in the Tesuque Formation to the north indicates that this unit should be separated from the Pojoaque Member (Koning et al., 2005).

An age of 13.2-8 Ma is interpreted based on a synthesis of radiometric ages, biostratigraphy, and geomagnetic polarity studies (further discussed in Koning et al., 2005; Koning and Aby, 2005; Koning et al., 2007). A sample from a pumice lapilli bed (unit **pl**) was dated by the 40Ar/39Ar method and returned an age of 8.48 ± 0.14 Ma (Table 1, sample DL-HR).

This unit was probably deposited on an alluvial slope (Smith, 2000a) because of the paucity of tabular, laterally extensive, planar-bedded couplets of relatively coarse- and fine-grained sediment that commonly represent sheetflood deposits, which are generally diagnostic of waterlaid alluvial fans (e.g., facies A of Blair, 1999). Instead, channel deposits are present in broadly lenticular to tabular beds of clayey to gravelly sandstone. Local cross-stratification in the channel deposits also supports relatively deep confined flow, such as would be expected on an alluvial slope. Up to 350 m thick.

Ttcuf **Cuarteles Member of the Tesuque Formation, fine-grained, distal sediment (upper middle to upper Miocene) –** Extra-channel and overbank deposits of silty very fine- to fine-grained sandstone with subordinate siltstone and mudstone exposed in the northwest part of the quadrangle in the Buckman well field. Channels of pebbly sandstone and sandy-pebble-conglomerate comprise about 3-30% of the unit. Fine, non-channelized beds are laminated or very thin to thick, and tabular-bedded. Non-channelized sand is generally very fine- to medium-grained, arkosic, well sorted, and subangular to subrounded. Channel deposits are generally present as scattered, lenticular to tabular complexes up to 100 cm-thick. The pebbles are moderately to poorly sorted, subangular to subrounded, and granitic (with trace to 1% yellowish Paleozoic siltstone and limestone, quartzite, and gneiss; up to 3% volcanic clasts near basin floor facies). Channel sand is fine- to very coarse-grained, arkosic, subangular to subrounded, and poorly to well sorted. Individual channels are up to 35 cm-deep and have westward-orientated paleoflow indicators. The finer, non-channelized sediment of the unit is moderately to well consolidated and weakly cemented by calcium carbonate. Coarse white ash and basaltic ash beds are locally present. Unit grades laterally into basin floor facies and very likely grades laterally into the coarse upper unit of the Tesuque Formation.

Ttce **Cejita Member, Tesuque Formation (middle to upper Miocene) –** Channel-fill complexes of pebbly very fine- to very coarse-grained sand and sandy pebble-cobble conglomerate; channel-fills are 1-2 m-thick. Channel-fills are extensively very thinly to thinly cross-stratified (up to ~ 1 m-thick foresets). Gravel are dominated by Paleozoic sandstone, limestone, and siltstone, with an estimated 10-50% granite and 5-8% quartzite. Locally, granites are the dominant lithologic type, probably due to input from alluvial-slope tributaries to the east. Also, there may be 10-90% pink-gray dacites and rhyolites together with light gray dacites-andesites(?). Clast imbrication data indicate a southward paleoflow direction. Well data in the Buckman well field indicates a thickness of 130 m.

Ttcc **Lateral gradation between the Cuarteles and Cejita Members of the Tesuque Formation (middle to upper Miocene) –** Unit is generally fine-grained and shares characteristics of units **Ttcu** and **Ttce**. Please see the descriptions for those individual units. About 130 m-thick.

Tta2 **Lithosome A of the Tesuque Formation, upper unit (middle Miocene) –** Very fine- to medium-grained sandstone with subordinate siltstone, subordinate coarse to very coarse sandstone, very minor mudstone, and 1-5% pebbly conglomerate. Colors of the sandy sediment range from very-pale-brown (10YR 7-8/3-4), light-yellowish-brown (10YR 6/4), pink to light-brown (7.5YR 6-7/3-4), light-brown (7.5YR 6/3-4), and pale-brown (10YR 6/3) (most common to least common). Pebbly sandstone and sandy pebble-conglomerate beds are commonly indurated by calcium carbonate, may form resistant ledges up to 2 m thick, and are commonly very thin to thin and lenticular to "U"-channel-shaped. The gravel is poorly to moderately sorted and subrounded to angular (quartzite clasts are generally rounded to subrounded). Conglomerate beds are most common near the contact with the underlying **Tta1** unit. Clast composition is generally granitic with 1-3% amphibolite. Sand is subangular to subrounded, moderately to well sorted, and arkosic. This unit grades laterally southward into unit **Tts2**.

Thin to thick beds of white ash are common in the northeast part of the quadrangle; a 30-40 cm thick bed of basaltic lapilli is also present at one outcrop (see description of tephras below). Tedford and Barghoorn (1993) interpret stratigraphically similar ashes in the Pojoaque type section to the north as ranging in age from 13 to 15 Ma. One correlative ash in the Pojoaque type section returned a $^{40}Ar/^{39}Ar$ age of 13.7 ± 0.18 Ma (Izett and Obradovich, 2001).

Except for its lower 55-75 m of strata, this unit correlates to the Pojoaque Member of Galusha and Blick (1971) to the north. Tedford and Barghoorn (1993) have identified fauna associated with the late Barstovian North American Land Mammal age (11.8-14.5 Ma) throughout the Pojoaque Member except for possibly the tops of the conglomerate-rich bluffs near and north of Los Barrancos (Richard Tedford, personal communication, 2002). The lower part of this unit includes a tephra correlated with the Road Ash of Izett and Obradovich (2001) (compare sample H-235, listed in Table 2 and Appendix 1, with ashes discussed in Koning, 2002). The Road Ash returned a $^{40}Ar/^{39}Ar$ age of 15.1 ± 0.06 Ma (Izett and Obradovich, 2001). These data and the age of the overlying Cuarteles Member indicate an approximate age of 13-15.3 Ma.

The lower contact of this unit appears conformable because no soils or significant, extensive scour surfaces are observed. The contact is also laterally variable, with the general trend of becoming more gradational to the south. North of about 35° 50' N latitude, the contact is relatively sharp and occurs at the base of a greenish-gray to light-greenish-gray (5GY 6-7/1) or light-gray (5Y 7/2) claystone, mudstone, or sandstone bed. Here it corresponds to the Pojoaque – Skull Ridge Member contact as interpreted by Galusha and Blick (figure 25, 1971); however, recent mapping by Koning (2002) indicates that the Pojoaque – Skull Ridge Member contact lies 55-75 m higher and corresponds to the base of unit **Ttm2**. In sections 18 and 19 of T. 19 N., R. 9 E., where the previously mentioned greenish to grayish bed is largely missing, the contact occurs at the base of a reddish-brown to light-brown (7.5YR 6/3-4) mudstone bed that overlies unit **Ttm1**. Between approximately 35° 50' N latitude and 35° 49' N latitude, the contact occurs in a 1-9 m-thick, muddy, gradational zone that includes a bentonitic, 25-35 cm-thick, whitish to purplish ash bed. Here, the contact separates reddish-yellow, pink, and very-pale-brown sandstone, siltstone, mudstone, and minor conglomerate beds of unit **Tta2** from the more multicolored (particularly light-brown, reddish-brown, pink, very pale brown, and pale-brown) upper **Tta1, Ttas1** and **Ttsa1**.

The sediment in this unit is either well-bedded and moderately to well-consolidated, or loose to weakly consolidated and more vaguely bedded. The presence of distinct, lenticular, and coarse-grained channel-fill deposits with clast imbrication, the presence of finer-grained overbank deposits, and the lack of distinct sheetflood deposits probably indicate an alluvial slope environment, as characterized by Smith (2000a). Compared to unit **Ttcu**, the gravelly channel deposits are thinner and the overbank deposits are finer. Approximately 180-240 m thick.

Tts2 **Lithosome S of the Tesuque Formation, upper unit (middle Miocene) –** Very fine- to medium-grained sandstone with subordinate siltstone, subordinate coarse to very coarse sandstone, 1-5% pebbly conglomerate, and 5-10% mudstone or claystone beds. Colors of the sandy sediment range from very-pale-brown (10YR 7-8/3-4), light-yellowish-brown (10YR 6/4), pink to light-brown (7.5YR 6-7/3-4), light-brown (7.5YR 6/3-4), and pale-brown (10YR 6/3) (most common to least common). The mudstone and claystone are commonly reddish-brown (5YR 4-5/3-4), light-reddish-brown (5YR 6/4), light-brown (7.5YR 6/3-4), brown (7.5YR 5/4), or yellowish-red (5YR 5/6). Sandstone and mudstone generally occurs in very thin to thick, tabular beds. Clast composition is 2-30% yellowish Paleozoic sandstone and siltstone, 1-20% Paleozoic limestone, 1% muscovite schist, 1-5% chert, 3-5% amphibolite, 10-35% quartzite, and 25-85% granitic clasts. In the southernmost 3 km of the quadrangle, the lower contact is difficult to locate, gradational over 10-20 m stratigraphic thickness, and separates reddish-yellow sandstone of the upper **Tts1** from pink, very pale brown, and light-brown silty sandstone of the lower **Tts2**. This unit grades laterally with unit **Tta2** to the north, and so has a similar age estimate of 13-15.3 Ma. Approximately 180-240 m thick.

Ttas2 **Gradational zone between the upper units of lithosomes A and S (middle Miocene) –** Unit shares characteristics of **Tta2** and **Tts2**. See the descriptions for those individual units.

Ttm2 **Middle mixed Lithosome A-B, fine-grained sediment (middle Miocene) –** Pale-brown to light-brownish-gray (10YR 6/2-3), brown (10YR 5/3), or light-brown (7.5YR 6/4) claystone, siltstone, and very fine- to fine-grained sandstone. Sediment is massive, laminated, or in horizontal planar, very thin to medium beds. Sand is well sorted, subrounded to subangular, and lithic-rich. Sand composition differs from unit **Tta2** in that it contains more dark lithics and greenish quartz grains; generally, there is an approximate 1:1 ratio of these dark lithics and greenish quartz grains compared to potassium feldspar. This unit is correlated along strike to outcrops several km to the north of this quadrangle (unit Ttbp1 of Koning, 2002), where sand of similar composition and color is associated with a mixed assemblage of gravel that includes greenish Paleozoic sandstone and siltstone, rhyolitic tuffs, limestone, quartzite, and granite. Locally, siltstone and claystone contain 20-40% calcium carbonate nodules 1 to 5 cm in length. Unit contains about 5 percent (estimated by volume) very thin to medium, planar to lenticular interbeds of strongly cemented (by calcium carbonate), arkosic, very fine- to very coarse-grained sandstone with very sparse pebbly sandstone whose clasts consist of calcium carbonate-indurated sandstone nodules with minor clasts of subangular granite derived from the Sangre de Cristo Mountains. Unit grades southwards along strike into unit the middle-upper parts of **Tta2**. Unit **Ttm2**'s correlative to the north, unit Ttbp1 of Koning (2002), belongs to the lowermost Pojoaque Member of Galusha and Blick (1971) and lies between two ashes dated at approximately 15.1 and 13.7 Ma by Izett and Obradovich (2001). Therefore, the age of unit **Ttm2** on this quadrangle lies between 15.1 and 13.7 Ma. Upper and lower contacts are relatively sharp and planar. Sediment is weakly consolidated and erodes to form strike valleys. This unit is interpreted to mostly represent basin floor floodplain or floodplain-related paludal facies along the eastern margin of a river that drained uplifts located to the northeast, consistent with the interpreted provenance of province B by Cavazza (1986). Minor arkosic sand and granitic gravel interbeds were deposited as a result of brief periods of westward progradation of the piedmont flanking the Sangre de Cristo Mountains. 50-60 m thick.

Tta1 **Lithosome A of the Tesuque Formation, lower unit (middle Miocene) --** Sandstone, siltstone, and claystone with 1-15% conglomerate beds. Conglomerate is commonly pinkish-gray (7.5YR 7/2), clast-supported, and consists of pebbles with subordinate cobbles. Conglomerate beds are very thin to medium and lenticular. Within a bed there may be cross-laminations or horizontal-planar laminations. Conglomerate clasts are granitic with 1-5% amphibolite, 1-5% reworked, calcium carbonate-cemented sandstone clasts, and 0.5-5% quartzite. Coarse to very coarse pebbles and cobbles are rounded to subrounded; very fine to medium pebbles are subangular to subrounded. Conglomerate clasts are moderately to poorly sorted within a bed. Siltstone and claystone beds are very thin to thick, tabular, and range in color from brown (7.5YR 5/4), reddish-brown (2.5YR-5YR 4-6/3-4), light-reddish-brown (5YR 6/4), light-yellowish-brown (10YR 6/4), light-brown (7.5YR 6/3-4) to pink (7.5YR 7/3-4). Sandstone and silty sandstone are very pale brown (10YR 7/3 to 8/2), light-yellowish-brown (10YR 6/4), pink (7.5YR 7/4), or light-brown (7.5YR 6/4). Sandstone is commonly in very thin to thick, tabular or lenticular beds. Sandstone is very fine- to very coarse-grained, subrounded to subangular, mostly well sorted with some moderate sorting, and arkosic. Several medium to thick ash beds are present in the northern part of the quadrangle. The non-gravelly sediment is weakly to moderately consolidated.

Unit approximately correlates to the Skull Ridge Member of Galusha and Blick (1971). Smith (2000a) and Kuhle and Smith (2001) have interpreted the Skull Ridge Member to represent an alluvial slope environment fed by drainages in the Sangre de Cristo Mountains, and we concur. The age of the Skull Ridge Member on this quadrangle is interpreted to be 15.1 to 16 Ma based on its Barstovian fossil assemblage and paleomagnetic correlations (Galusha and Blick, 1971; Barghoorn, 1981; Tedford and Barghoorn, 1993), our geochemical correlations (sample H-235 of Table 2 and Appendix 1), in addition to $^{40}Ar/^{39}Ar$ dates of ash beds to the north (Izett and Obradovich, 2001). Total thickness is approximately 250-430 m.

Tts1 **Lithosome S of the Tesuque Formation, lower unit (middle Miocene) –** Sandstone, siltstone, and claystone with 1-15% conglomerate beds. Conglomerate is commonly pinkish-gray (7.5YR 7/2), clast-supported, and consists of pebbles with subordinate cobbles. Conglomerate beds are very thin to medium, lenticular, and commonly indurated by calcium carbonate to form resistant ledges up to about 2 m thick. Within a bed there may be cross-laminations or horizontal-planar laminations. Conglomerate clasts are granitic with 1-5% amphibolite, 3-15% yellowish Paleozoic siltstone and sandstone, trace-10% grayish to yellowish Paleozoic limestone, trace-5% muscovite- schist, 1-5% brownish chert, and up to 40% quartzite. Coarse to very coarse pebbles and cobbles are rounded to subrounded; very fine to medium pebbles are subangular to subrounded. Conglomerate clasts are moderately to poorly sorted within a bed. Siltstone and claystone beds are very thin to thick, tabular, and range in color from brown (7.5YR 5/4), reddish-brown (2.5YR-5YR 4-6/3-4), light-reddish-brown (5YR 6/4), light-yellowish-brown (10YR 6/4), light-brown (7.5YR 6/3-4) to pink (7.5YR 7/3-4). Sandstone and silty sandstone are light-brown (7.5YR 6/3-4), pink (7.5YR 7/4), or reddish-yellow (10YR 6/6). Sandstone is commonly in very thin to thick, tabular or lenticular beds. Sandstone is very fine- to very coarse-grained, subrounded to subangular, mostly well sorted with some moderate sorting, and arkosic. Within 3 km of the south border of the quadrangle, the sediment is more reddish, sandy, and the clasts more granitic (with 5-10% quartzite) than to the north. The non-gravelly sediment is weakly to moderately consolidated.

Unit approximately correlates to the Skull Ridge Member of Galusha and Blick (1971). Smith (2000a) and Kuhle and Smith (2001) have interpreted the Skull Ridge Member to represent an alluvial slope environment fed by drainages in the Sangre de Cristo Mountains, and we concur. The age of the Skull Ridge Member on this quadrangle is interpreted to be 15.1 to 16 Ma based on its Barstovian fossil assemblage and paleomagnetic correlations (Galusha and Blick, 1971; Barghoorn, 1981; Tedford and Barghoorn, 1993), our geochemical correlations (sample H-235 of Table 2 and Appendix 1), in addition to $^{40}Ar/^{39}Ar$ dates of ash beds to the north (Izett and Obradovich, 2001). In the subsurface, this unit is as old as late Oligocene. Total thickness is approximately 250-430 m.

Ttas1 **Gradational zone between the lower units of lithosomes A and S, mostly like lithosome A (middle Miocene) –** Unit shares characteristics of **Tta1** and **Tts1** but is mostly like Ttal. See the descriptions for those individual units.

Ttsa1 **Gradational zone between the lower units of lithosomes S and A, mostly like lithosome S (middle Miocene) –** Unit shares characteristics of **Tts1** and **Tta1** but is mostly like Tts1. See the descriptions for those individual units.

Ttm1 **Lower mixed Lithosome A-B, fine-grained (middle Miocene) –** Pale-brown to light-gray to light-brownish-gray (10YR 6-7/2-3 and 2.5Y 7/2) or pinkish-gray (7.5YR 7/2) siltstone, mudstone, and very fine- to medium-grained sandstone. Sediment is horizontal-planar-laminated or in very thin to thin, generally planar beds. Sand is well sorted and subangular to subrounded. Sand composition differs from unit **Tta1** in that it contains more dark lithics and greenish quartz grains; generally, there is an approximate 1:1 ratio of these dark lithics and greenish quartz grains compared to potassium feldspar. This unit is correlated along strike to outcrops several km to the north of this quadrangle, where sand of similar composition and color is associated with a mixed assemblage of gravel that includes greenish Paleozoic sandstone and siltstone, rhyolitic tuffs, limestone, quartzite, and granite (province B of Cavazza, 1986). The lower contact of the unit is very gradational (over hundreds of meters stratigraphic height) and the upper contact is somewhat gradational (over tens of meters stratigraphic height). This unit grades southward along strike into unit **Tta1** (across the gradational units of **Ttas1** and **Ttsa1**). Unit correlates to the Skull Ridge Member of Galusha and Blick (1971) and to unit Ttms1 of Koning (2002). Unit Ttms1 of Koning (2002) is above White Ash #4 of the Skull Ridge Member but below the Road Ash of Izett and Obradovich (2001); this indicates that this unit was deposited sometime between 15.4 and 15.1 Ma, based on ^{40}Ar-^{39}Ar data of tephras listed in Izett and Obradovich (2001) and McIntosh and Quade (1995). Sediment is weakly consolidated and erodes to form strike valleys. Unit is interpreted to represent a basin floor floodplain immediately adjacent to a piedmont flanking the Sangre de Cristo Mountains. We infer that a river was associated with this floodplain, and that this river delivered sediment to this unit from uplifts to the northeast (Cavazza, 1986), although some mixing occurred with arkosic sand from the Sangre de Cristo Mountains south of the Peñasco embayment. Most of unit is covered by Quaternary alluvium. Approximate thickness is 140-150 m.

Silica cementation of quartz-rich sandstone

Within 0.5 km of the south boundary of the quadrangle, local silica-cementation of gravel and sand of unit **Tts1** has been observed at three locations. These locations are noted on the map (see "explanation of map symbols" below). The cementation has resulted in a very well-indurated, pebble- and cobble-conglomerate and sandstone that looks like the sediment of unit **Tts1** except that these rocks lack granitic clasts; instead, quartz grains and quartzite clasts dominate. These well-indurated and erosionally resistant rocks generally form angular blocks up to 3 m in diameter, some of which are still in place (based on their geometry and consistent attitudes between the beds within these blocks and the surrounding strata of the Tesuque Formation). Calcium carbonate nodules (1-7 cm in diameter) may coat the outside of the in-situ blocks. The clast lithology is: 85-90% quartzite and quartz, 10% yellow, green, and black chert, and trace to 5% schist and amphibolite. Sand grains are estimated (using a hand lens) to have 75% quartz and 25% feldspar and are generally medium to very coarse. Granitic clasts are generally not observed except near the margins of the in-situ blocks, where they comprise approximately 1% of the clasts. These silica-indurated rocks commonly occur along a north-south or northwest-southeast trend. In an exposure located in the extreme southeast corner of the quadrangle (NW1/4, NE1/4 of Section 32, T. 18 N., R 9 E.; UTM coordinates: 3,956, 810N 408, 975 E, zone 13 and NAD27), silica cementation occurs adjacent to a fault that strikes N10° W and similar faults may be located adjacent to the other outcrops as well. The authors agree with the interpretations by Borton (1979) that these outcrops are not from an upthrown fault block. We speculate that quartz-rich, mud-free sand beds of relatively high permeability were preferentially cemented by silica-rich fluids that flowed up from relatively deep depths adjacent to faults. A somewhat similar, silica-indurated, sandstone dike occurs on the northeast corner of Pueblo Road and U.S. 84/285 (3-5 mi south of Española and 8 mi north of Pojoaque).

TEPHRA BEDS

(refer to Explanation of Map Symbols for identifying respective tephra locations on the map)

Tsankawi Pumice Bed (lower Pleistocene) -- Clast-supported pumice interbedded within 1 m of the top of **QTgp3**. Typical pumice size is 6-20 mm : 5-10 mm (a:b axes). The pumice is massive, laminated, or very thinly to thinly bedded. The pumice clasts fine upward and are loose to moderately consolidated; the top may be indurated by calcium carbonate. No cross-stratification or significant scour surfaces have been observed in the pumice; no buried soils were observed underneath. 50-90 cm thick.

Cerro Toledo Rhyolite pumice bed (lower Pleistocene) -- Clast-supported pumice found in lenticular, discontinuous channel fills on or near top of **QTgp2** deposits. Pumice locally occurs in two beds. The lower bed is 20 cm thick, with a typical pumice size of 15-20 : 7-10 cm (a:b axes). This bed is overlain by 15 cm of moderately to poorly sorted, medium- to very coarse-grained, arkosic sand with minor pebbles. The upper bed is 35 cm thick, with a typical pumice diameter of 2-8 mm. 20-90 cm thick.

Pumice lapilli in coarse upper unit of the Tesuque Formation (upper Miocene) – Deposited near Cañada Ancha, this unit consists of two or more beds of pumice lapilli. The pumice is stratigraphically associated with beds of brownish to grayish, massive, poorly sorted, pumice- and volcaniclastic-bearing, muddy sandstone beds.

pl: White (5Y 8/1) pumice lapilli bed that lacks sedimentary fabric. Lapilli clast size is 3-20:1-11 mm (a:b axes) and the pumice is mixed with 1-10%, 0.5-6 mm-diameter clasts of granite and volcanic rocks (latter includes black volcanic lithics). Pumice has trace amounts of fine-grained pyroxene(?) or amphibole(?). Weakly to moderately consolidated and interpreted to be slightly fluvially reworked. One sample dated using the $^{40}Ar/^{39}Ar$ method returned an 8.48±0.14 Ma age (Table 1, sample DL-HR). Another sample was submitted for $^{40}Ar/^{39}Ar$ analyses but did not return a precise age, although the age range is generally 7-11 Ma (Table 3, sample H-132). Locally, two pumice beds are present and separated by about 2.2 m of brownish to grayish, massive, poorly sorted, hard, pumiceous and volcaniclastic-bearing, sandstone beds. 20-150 cm thick.

Basaltic lapilli in unit Tta2 of the Tesuque Formation (middle Miocene) -- A 30-40 cm thick bed of basaltic lapilli found interbedded in siltstone and very fine- to medium-grained sandstone; the latter contain subordinate thin to medium, lenticular channels of

Table 3. Argon isotopic results for single-crystal plagioclase of sample H-132

ID	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$ ($x10^{-3}$)	$^{39}Ar_k$ ($x10^{-15}$ mol)	K/Ca	$\%^{40}Ar$*	Age (Ma)	±1σ (Ma)
13	8.549	6.656	22.59	0.022	0.077	28.3	3.1	2.3
14	8.136	9.175	18.34	0.032	0.056	42.6	4.5	1.9
18	8.149	8.848	15.26	0.034	0.058	53.6	5.6	1.7
15	8.385	7.583	12.58	0.038	0.067	63.1	6.8	1.5
19	7.766	7.517	8.963	0.041	0.068	73.8	7.4	1.2
12	8.200	7.749	10.09	0.057	0.066	71.4	7.50	0.80
01	7.919	7.685	7.345	0.062	0.066	80.6	8.18	0.84
10	9.029	7.661	9.611	0.044	0.067	75.5	8.7	1.2
11	9.019	7.243	9.208	0.064	0.070	76.4	8.83	0.75
17	8.556	6.931	7.345	0.067	0.074	81.3	8.90	0.91
02	7.902	9.227	5.420	0.034	0.055	89.3	9.1	1.6
05	7.680	8.762	4.375	0.121	0.058	92.5	9.11	0.44
08	8.076	10.40	5.523	0.041	0.049	90.4	9.4	1.5
16	9.449	8.502	9.101	0.094	0.060	78.9	9.56	0.67
07	8.705	5.821	5.508	0.179	0.088	86.8	9.66	0.30
03	8.671	7.898	5.891	0.085	0.065	87.4	9.71	0.63
09	8.268	8.593	3.489	0.054	0.059	96.1	10.18	0.89
06	7.567	8.177	0.7109	0.113	0.062	106.1	10.29	0.53
04	9.360	6.732	6.270	0.091	0.076	86.1	10.31	0.61

Notes:

Tephras analyzed by the New Mexico Geochronological Research Laboratory (NMGRL; Peters, 2001) by the single-crystal laser fusion method. NMGRL # = 51928. Isotopic ratios corrected for blank, radioactive decay, and mass discrimination, not corrected for interfering reactions. Individual analyses show analytical error only. See Table 1 for location of sample.

* 2σ error

coarse-grained, arkosic sandstone and granitic, pebbly sandstone channels. These strata lie 8-14 m above unit **Ttm2**. Lapilli consists of very fine to medium pebbles, subrounded, and moderately sorted.

Non-correlated ashes in the Tesuque Formation (Miocene) -- These ash deposits are generally whitish (N 8/ to 5Y 8/1) to bluish gray with 0-2% mafic minerals (commonly biotite). The ashes may be altered to bentonite or other clays. The presence of cross-strata and detrital sand in many of the beds indicate that the ashes have been fluvially reworked. 10-120 cm thick

Correlated ashes in the Tesuque Formation (Miocene) -- 6 ash deposits (a-1 through a-6 on the map, oldest to youngest) were correlated in the Tesuque Formation based on lithologic similarities and stratigraphic position. The presence of detrital sand and cross-stratification in many of these beds indicate fluvial reworking.

a-6: White to very-pale-brown (N8 to 10YR-2.5Y 8/1-2) and clayey to silty in texture. Ash generally lacks mafics but south of 35° 50' N latitude it has trace mafic minerals or manganese(?) dendrites (about 1 mm in diameter). Locally, it may have 10-25% detrital sand. This ash is generally not noticeably altered. South of 35° 50' latitude and 1.5-3 m under this ash, there is a light greenish gray to light gray (10Y 7/1 to 5Y 7/1-2), non-mafic bearing, silty-textured ash (25 cm thick and 1.5-3 m below this described white ash). Ash thickness varies laterally from 25 cm to 200 cm thick.

a-5: White (N8/ to 10YR 8/1) and silty in texture. Trace to 0.5-1% dendritic manganese (?) or other mafic minerals (0.5 to 1 mm in diameter). Immediately south of the southern Pojoaque Pueblo boundary, this ash is light gray (N7) in color. 60-120 cm thick.

a-4: White or bluish to yellowish white (N8/ to Y8/1) and silty in texture. Trace to 1% dendritic MnO(?) minerals (0.5 to 1 mm in diameter). Sharp base and gradational upper contact. 45-100 cm thick.

a-3: White (10YR 8/1) and silty in texture. Ash has none to trace mafic minerals and is mixed with 1-50% very fine- to fine-grained sand detritus. Massive to laminated. Generally 25-90 cm thick.

a-2: White (N8/) and silty in texture. Ash has trace to 1% biotite grains (fine-grained sand in size) and may contain up to 5% very fine-grained sand detritus. Altered to clay in varying degrees. Ash grades upwards into ashy silt. Ash is generally 25-40 cm thick, overlying ashy silt is 0-30 cm thick.

a-1: White (N8-9/ to 5Y 8/1) with 0.5-3% biotite grains that are very fine-grained sand in size. The top 30 cm has calcium carbonate nodules (nodules are 1-5 cm in diameter) and is indurated. The lower 60 cm is altered to bentonite(?). 90 cm thick.

UNITS DEPICTED IN CROSS-SECTIONS BUT NOT SHOWN ON MAP

Descriptions are based on cuttings of the Yates Petroleum Corporation's La Mesa Unit No. 2 well that was drilled 10 km south of cross-section F-F' (SW1/4 NE1/4 of Section 24, T. 17 N., R. 8 E.; UTM coordinates: 3,949,872N, 405, 611E ± 15 m; cuttings on file at New Mexico Library of Subsurface Data, NMBMMR; summary well report by Black Oil, Inc.), in addition to descriptions given in Borchert et al. (1998) and inspection of cuttings from four recent deep supply wells drilled along Cañada Ancha in or near the western part of the quadrangle (cuttings stored by Shomaker and Associates).

Tta **Lithosome A of the Tesuque Formation, undifferentiated (middle Miocene) –** For **Tta** depicted in the western cross-sections, see descriptions for the upper and lower map units of lithosome A (**Tta1** and **Tta2**). **Tta** in the eastern cross-sections is probably an arkosic sandstone to silty-clayey sandstone, with minor tongues of conglomerate composed of granitic gravel.

Tts **Lithosome S of the Tesuque Formation, undivided (middle Miocene) –** See descriptions for units **Tts1** and **Tts2**.

Ttb **Lithosome B of the Tesuque Formation (upper Oligocene to middle Miocene) –** Generally mudstone, siltstone, and very fine to medium sandstone deposits; sand has greenish quartz grains and trace volcanics. Deposited on a basin floor by a river sourced in the San Luis Basin and Penasco embayment to the northeast (province B of Cavazza, 1986).

Ttalc **Lithosome A of the Tesuque Formation, lower coarse unit (upper Oligocene to lowest Miocene) –** Sandy pebbles, pebbly sandstone, and sandstone. Pebbles are dominated by granite and sand is arkosic.

Ttbab **Interbedded and mixed Abiquiu Formation and lithosome B of the Tesuque Formation (upper Oligocene to lower Miocene) –** Strata inferred to reflect mixing and interfingering of lithosome B (Tesuque Formation) and the Abiquiu Formation. Lithosome B sediment probably consists of mudstone, siltstone, and very fine to medium sandstone deposits; the sand fraction has greenish quartz grains and trace volcanics. It was deposited on a basin floor by a river sourced in the San Luis Basin and Penasco embayment to the northeast (province B of Cavazza, 1986). The Abiquiu Formation is probably composed of light gray, ash-rich, silty sandstone and siltstone. This subsurface unit is inferred to be similar to Abiquiu Formation strata exposed in prominent cliffs (85 m in height) immediately north of the Santa Fe River, near the town of La Bajada. There, reworked ash, mixed with detrital silt-clay and arkosic sand, is common in the section and there are a few primary ash-fall beds 20-50 cm-thick. Sand is mostly very fine- to medium-grained. However, the sand in this subsurface unit is likely not arkosic, as observed at the Santa Fe River, but rather a lithic arenite or lithic wacke (with the lithics being felsic volcanic grains) – similar to what is noted in the Abiquiu Formation near Abiquiu (Smith, 1995, and Smith et al., 2002).

Tcb+Tte **Interbedded Cieneguilla basanite flows and lithosome E of the Tesuque Formation (Oligocene) –** Gray, red, green, purple or black, sandy and gravelly volcaniclastic deposits, tuffs, and lava flows. In the southern part of this quadrangle, prominent seismic reflector(s) are located in the lower part of this unit (seismic data in Biehler et al., 1991). Upon following these reflectors southwards in an unpublished north-south seismic line through the Yates La Mesa Unit No. 2 well, and comparing the depths of these reflectors with the Cieneguilla basanite picks of Myer and Smith (2006) in that well, we interpret that these reflectors correlate to the Cieneguilla basanite. The volcaniclastic sediment in the upper part of this unit may be detritus eroded from paleo-uplands composed of the Espinaso Formation and Cieneguilla basanite, and thus is consistent with lithosome E of the Tesuque Formation (Koning and Johnson, 2006). The unit is interpreted to interfinger with the Nambé Member of the Tesuque Formation to the east. The lower part of this unit (less than 100 m?) may be composed of intermediate volcanic detritus that correlate with the Espinaso Formation. Unit probably underlies most of the quadrangle; moderately to well consolidated; 640-910 m thick.

Te **Espinaso Formation (Oligocene) –** White to light gray, tuffaceous, silty-clayey sandstone and sandstone, with subordinate gray, pebbly volcaniclastic sandstone and pebble to boulder conglomerate. Unit correlates with the Bishop's Lodge Member of the Tesuque Formation, but work by Smith (2000b) demonstrates correlation of the Bishop's Lodge Member with the Espinaso Formation. In outcrops of the Bishops Lodge Member to the east, clasts are composed of light to dark gray pyroxene (+ biotite) latite. Unit is interpreted to have been deposited on the distal portions of an alluvial fan.

Mz-Pzu **Mesozoic and Paleozoic strata, undifferentiated (Pennsylvanian through Cretaceous) –** Lower and middle part of unit probably consists of reddish, reddish brown, and reddish orange sediment of the Yeso, Abo, and Moenkopi Formations, with possible Chinle Group strata as well. In the upper part of unit may be Jurassic and Cretaceous strata of the Entrada Sandstone, Todilto, Summerville, and Morrison Formations (Jurassic) in addition to the Dakota Sandstone and Mancos Shale (Cretaceous).

Penn Lm **Pennsylvanian limestone (Pennsylvanian) –** Interbedded limestone with subordinate shale and sandstone beds. Limestone is gray to tan to white. Shale is gray to orange. Sandstone is white to gray and more common down-section. Unit probably correlates with the Pennsylvanian La Pasada Formation (P.K. Sutherland in Miller et al., 1963) and the Madera Group (Myer and Smith, 2006), with possible Mississippian strata as well (Myer and Smith, 2006; Read et al., 2000). There may be a sandstone at the base of the unit that correlates with the Sandia Formation (Read et al., 2000).

XYu **Proterozoic crystalline rocks --** Pinkish granite, granitic gneiss, and possible minor amphibolite, schist, and quartzite.

STRUCTURE

Bedding attitudes. Beds dip to the west at magnitudes ranging from 0-17° but mostly at 3-10°. Strata of the Cuarteles Member (**Ttcu**) commonly dip at angles of <5° while older strata of the Tesuque Formation (**Tta2, Tta1, Tts2, Tts1, Ttm2, Ttm1**) commonly dip 5-10°. Attitudes in the southeast quadrant may strike slightly more to the northeast than in other parts of the quadrangle. Seismic refraction and reflection data (Aldern, 1989, and Biehler et al., 1991) indicate a pronounced steepening of subsurface strata and the basin sediment-crystalline rock contact in the south-central portion of the quadrangle (see cross-section B-B'). Mapping indicates a continuation of this flexure, called the Barrancos monocline, to the northern part of the quadrangle. To the east of the Barrancos monocline lies the Cañada Ancha graben.

Fault zones. There are four important fault zones in the quad:

1. The Calabasa Arroyo fault is an east-down structure that extends 12.5 km in the west-central part of the quadrangle. Near the middle of its length, it changes from a north-south strike (to the south) to a northwest strike (to the north). There is no exposure of this fault, but its presence is strongly suggested by seismic reflection and aeromagnetic data (Grauch et al., 2009). Its throw is inferred to be 70 -140 m ft

2. The Jacona fault is found in the north-central and southeastern portions of the quadrangle and is named after the Jacona land grant (through which it runs). Striking north to northwest, the fault dips 60-80° to the east and exhibits down-to-the-east throw. This fault converges with the Pojoaque fault in the southeastern portion of the quadrangle. The maximum throw is probably 60-100 m.

3. The Pojoaque fault is found in the northeast and east-central part of the quadrangle, southwest of the Pojoaque Pueblo (after which it is named). It generally strikes north, dips 70-90° to the west, and exhibits down-to-the-west motion with a possible component of left strike-slip motion. North of 50° N latitude, it is marked by having one dominant strand. South of 35° 50' N latitude, the fault has many strands. The fault bends leftward near 35° 49'34" N latitude. About 1.8 km south of the southernmost exposure of ash **a-4**, displacement sense reverses polarity (down-to-the-east), possibly because of interaction with the down-to-the-east Jacona fault. The amount of throw is probably 50-150 m.

4. The Las Dos fault is a north-south fault zone that appears to display down-to-the-west throw in the subsurface, based on seismic refraction data (Aldern,1989, and Biehler et al., 1991), but down-to-the-east throw near the surface, based on interpreted drag folding in poor exposures of Tesuque Formation. Biehler et al. (1991) indicate a throw of about 200 m for this fault and we use that amount in the cross-section. In the seismic data, there are weak indications based on second-arrival information that this fault may break the top of the >3 km/s layer (Biehler et al., 1991); the >3km/s layer is interpreted by us to be unit **Tcb+Tte**. This fault aligns with the Pojoaque fault to the north. Both this fault and the Pojoaque fault probably formed over a north-south, structural discontinuity or weakness in the upper crust that itself may have existed throughout the Phanerozoic.

INTERPRETATIONS OF GEOLOGIC HISTORY AND PALEOENVIRONMENTS

Because subsurface Mesozoic and Paleozoic strata are either very thin or absent under this quadrangle and its surroundings, it has been interpreted that the area experienced uplift during the Laramide orogeny (see Cather, 1992). During the late Oligocene to early Miocene, the map area was a relative topographic low and this allowed significant accumulation of the volcaniclastic detritus, tuffs, and volcanic flows associated with unit **Tcb+Tte**. By the end of the Oligocene, the cessation of mafic volcanism together with possible tectonic uplift of the Sangre de Cristo Mountains allowed the westward progradation of the granitic-rich lithosome A of the Tesuque Formation.

There is evidence of tectonic deformation occurring on this quadrangle after the deposition of unit **Tcb+Tte** and before deposition of unit **Ttcu**. This is suggested by steep dips (as much as 16°) of unit **Tcb+Tte** in the subsurface of the south-central quadrangle (cross-section B-B'). There is no evidence of an angular unconformity at the top of this unit based on seismic reflection data presented in Biehler et al. (1991). However, younger strata of the Tesuque Formation (i.e., **Ttcu**, **Tta2,** and **Tts2)** have lesser dips (generally 4-7°) based on surface outcrops. This implies significant tectonic tilting in the time between the deposition of these younger units and **Tcb+Tte**. This tilting would have occurred sometime in the early Miocene to early middle Miocene. Also, the down-to-the-west subsurface strand of the Las Dos fault appears to break only the Precambrian basement and unit **Tov** in seismic data (Biehler et al., 1991; cross-section A-A').

Units **Tta1** and **Tts1** of the Tesuque Formation were deposited between 15.1 and 16 Ma on an alluvial slope environment (Smith, 2000a; Izett and Obradovich, 2001). This was followed by deposition of units **Tta2, Tts2,** and **Ttcu** of the Tesuque Formation during 15 to about 8.5 Ma in a probable alluvial slope environment. Units **Ttm1** and **Ttm2** were deposited 15.4-13.7 Ma on a broad basin floor and represent a mixture of sediment by (1) a fluvial system draining uplifts located to the northeast and (2) westward-flowing drainages from the Sangre de Cristo Mountains to the east. A pronounced change in gravel composition between units **Tts2** and **Ttcu** indicates a change in stream systems in the southern part of the quadrangle. Also, for units **Tts1** and **Tts2** there is significantly more clast diversity and a higher proportion of quartzite clasts than compared to laterally equivalent units **Tta1** and **Tta2** to the north. This data is compatible with a hypothesis, first implied by Smith (2000b) and elaborated in Koning et al. (2004), that the ancestral Santa Fe river (which deposited Lithosome S) extended eastward over the present-day drainage divide of the Sangre de Cristo Mountains and into the present-day Pecos drainage. This drainage is inferred to have brought most of the quartzite and Paleozoic clasts in Lithosome S from east of the Pecos-Picuris fault. The significant change in clast lithology between units **Tts2** and **Ttcu** is interpreted to reflect either: 1) a southward shift in the flow direction of the Santa Fe River (so that it ceased to flow on this quadrangle) or 2) piracy of the Pecos River into the former headwaters of the ancestral Santa Fe River, resulting in a cessation of Paleozoic-rich gravel transport onto the quadrangle.

There is no record of deposition from shortly after 8.5 Ma until the late Pliocene. Rather, most of the area experienced net erosion. Fluvial deposition was limited to thin stream gravel deposits (e.g. **Tga**) over strath surfaces.

The Cerros del Rio volcanic field was active starting after about 3 Ma and extending into the early Pleistocene (Bachman and Mehnert, 1978; WoldeGabriel et al., 1996). During the early stages of this volcanism on this quadrangle, basaltic lapilli and phreatomagmatic deposits of unit **Tlp**, along with thin deposits of the Ancha Formation (**Ta**), were deposited onto a low-relief erosional surface. Basalt, basaltic andesite(?), and andesite lava (units **Tcb**, **Tcba**, **Tca**) flowed over these deposits. The Cerros del Rio volcanic flows impeded westward-flowing drainages and created the ancestral Cañada Ancha. The ancestral Cañada Ancha flowed north because platy andesite gravel lag (from the **Tca** flow) is seen northeast of this flow unit at elevations of 6200 to 6300 ft in sections 8 and 16, T. 18 N., R. 8 E. No aggradation from westward-flowing streams likely occurred on top of the south **Tcb** flow unit and the **Tca** flow units because there are no granitic sediment or quartzite clasts on top of these flows. Minor, scattered clasts of rounded quartzite have been observed on top of **Tcb** north of 35° 47' N latitude so some minor fluvial deposition, presumably from the ancestral Cañada Ancha, occurred after the basalt flowed there.

Except where affected by the resistant Cerros del Rio volcanic flows, the general net incision that occurred in the Pliocene continued into the Quaternary and resulted in the suite of terraces present south of the Pojoaque River, near the Rio Tesuque, and south of Calabasa Arroyo. Minor aggradation associated with unit **QTgp2** occurred just prior to the deposition of pumice dated at 1.5 Ma. This aggradation was followed by 6-12 m of incision and then another aggradation event that formed unit **QTgp3**. Near the latter part of **QTgp3** aggradation, the Tsankawi Pumice Bed (1.2 Ma; Peters, 2001) was deposited from eruptions in the Jemez volcanic field. The incision that occurred between 1.5 and 1.2 Ma also is interpreted for the Santa Fe embayment south of Santa Fe, during which Ancha Formation deposition generally ceased (Koning et al., 2002).

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Appendix 1. Tephra correlations on the Horcado Ranch and Española 7.5-minute quadrangles, New Mexico

Tephra Correlation for Dan Koning
Analyses and interpretations made by N.W. Dunbar
June 19, 2002

Methods:
Samples were mounted in epoxy and polished with pure diamond powder suspended in distilled water. Analyses were made with a Cameca SX-100 electron microprobe, and, where possible, 15 shards were analyzed per sample. Accelerating voltage was 15 kV, beam current 10 nA, and as large a beam size as possible, up to 25 microns, was used. Major elements, plus Cl, F, and S were measured. ZAF recalculation procedures were used. Correlations were made using the statistical difference methods, and then compositions were double-checked by me. For discussion of statistical different method, see Perkins et al., 1995

The data from Claudia Borchert for sample LB1 and WA1 are indistinguishable from the data that we collected for samples with the same name. However, we use Cl as a reasonably heavily weighted element for statistical difference calculations, and Cl was not analyzed as part of Claudia's data set. So, the correlations for those samples are not made statistically, but just by looking at the data.

EC-711-041001-DJK

This ash correlates with Lava Creek B. The statistical difference values are between 4 and 10 for the 6 other samples that we have that are either known LCB or correlate to LCB. A diagnostic feature shown by LCB ash is the variable FeO content, which your ash shows.

HR-17ext-061201

Chemically consistent with El Cajete I (NMASH- 100, statistical difference 4.11)

EC-838-161001-djk

This ash falls within the range of chemical compositions observed within the El Cajete eruption, but doesn't correlation with a specific phase of the eruption as well as HR-17ext-061201. The best, although not perfect, statistical match is with sample "El Cajete mean", with a SD of 6.92.

EC-752-071001-djk

First, our analyses**:** This ash correlates with EC-775-091001-djk (SD 0.92), E706-041001-djk (SD 1.06), LB-1 (SD 2.97). It does not correlate with WA-1 (SD 11.46). This ash and its correlaries match a set of ashes found by Dave Love around the Isleta area, and some found by Sean Connell in the San Felipe area. We think, based on age and chemistry, that these are probably some part of the eruption of the Lower Bandelier Tuff or possible early-erupted Cerro Toledo rhyolite.

Comparison w/ Borchert data: Correlates with LB samples, not with WA samples.

EC-775-091001-djk

First, our analyses: This ash correlates with EC-752-071001-djk (SD 0.92), EC-706-041001-djk (SD 0.74) and LB-1 (3.42). It does not correlation with WA-1 (11.72).

Comparisons with Borchert data: Correlates with LB samples, not with WA samples.

EC-774-091001-djk

Correlates to EC-753-071001-djk (SD 3.27). No other correlaries either among your samples or in my database. The ash has chemical similarities to EC-706-041001-djk and its correlaries, visual comparison of the datasets suggests that they do not correlate. Maybe from the same volcano, though.

EC-706-041001-djk

First, our analyses: This ash correlates with EC-752-071001-djk (SD 1.06), EC-775-091001-djk (SD 0.74) and LB1 (SD 3.83). The ash has chemical similarities to EC-753-091001-djk and its correlary, visual comparison of the datasets suggests that they do not correlate. Maybe from the same volcano, though.

Comparisons with Borchert data: Correlates with LB samples, not with WA samples.

EC-753-071001

Correlates to EC-774-071001-djk (SD 3.27). No other correlaries either among your samples or in my database. The ash has chemical similarities to EC-706-041001-djk and its correlaries, visual comparison of the datasets suggests that they do not correlate. Maybe from the same volcano, though.

WA1a

I reanalyzed this so that I could do the SD calculations. The analyses match Claudia's very well, which is good. This ash correlates with EC-438-040701-djk (SD 1.84). It does not correlate with any of the ashes listed. These include EC-752-071001-djk (11.46), EC-706-041001 (SD 12.12), EC-775-091001 (SD 11.72), EC-774-091001-djk (SD 18.94) or EC-753-07001-djk (19.45).

LB1

I reanalyzed this so that I could do the SD calculations. The analyses match Claudia's very well, which is good. This ash correlates to EC-706-041001 (SD 3.83), EC-752-09001 (SD 2.97) and EC-775-091001 (SD 3.42). It does not correlate to EC-774-091001-djk (SD 11.55) or EC-753-07001-djk (11.72).

EC-87-150501-djk

This ash correlates with EC-73A-140501-djk (SD 1.37), EC-120-220501-djk (SD 1.22) and H-235 (SD 0.85). It is chemically similar to EC-92-150501-djk (5.14).

EC-50b-130501-djk

Does not correlate with H-235 (SD 17.73), EC-73A-140501-djk (SD 21.69) or EC-92-150501-djk (19.30).

I also don’t find any good correlary in my database.

EC-50a-130501-djk

This ash is compositionally heterogeneous, and doesn’t correlate with H-235 (SD 32.7), EC-73A-140501-djk (38.58), EC-87-150501-djk (37.43), EC-719-051001-djk (28.05) or EC-92-150501-djk (39.04).
Also no good correlary in database.

EC-120-220501-djk

This ash correlates to to EC-73A-140501-djk (SD 1.13) and EC-87-150501-djk (SD 1.22), H-235 (SD 1.85). It is also chemically similar to EC-92-150501-djk (SD 5.25). It does not match EC-719-051001-djk (SD 16.23).

EC-73A-140501-djk

This ash correlates to EC-120-220501-djk (SD 1.13) and EC-87-150501-djk (SD 1.37) and to H-235 (SD 1.82) It is chemically similar to EC-92-150501-djk (SD 5.07). It does not match EC-719-051001-djk (SD 15.96), or EC-50b-130501-djk (SD 21.69).

H-235

This ash correlates to EC-73A-140401-djk (SD 1.82), EC-120-220501-djk (SD 1.85), and EC-87-150501-djk (0.85). It is chemically similar to EC-92-150501-djk (SD 5.25). It does not match EC-50b-130501-djk (SD 20.32).

EC-92-150501-djk

This ash is chemically similar to EC-73A-140401-djk (SD 5.07), EC-120-220501-djk (SD 5.25), and EC-87-150501-djk (5.14), and H-235 (5.25). It does not correlate with EC-50b-130501 (19.26)

EC-719-051001-djk

This ash doesn't correlate with EC-50a-130301-djk (35.2), EC-73a-150501-djk (9.96), or EC-120-220501-djk (10.61). It shows some chemical similarities to the latter two.

MCE-1A-300601, MCE-1B-300601, EC-438-040701-djk

None of these ashes correlate with each other. MCE-1A-300601 and MCE-1B-300601B are chemically similar, and probably come from the same volcano. EC-438-040701 is also similar, but not indistinguishable. Note that EC-438-040701-djk correlates with WA1a (SD 1.84).