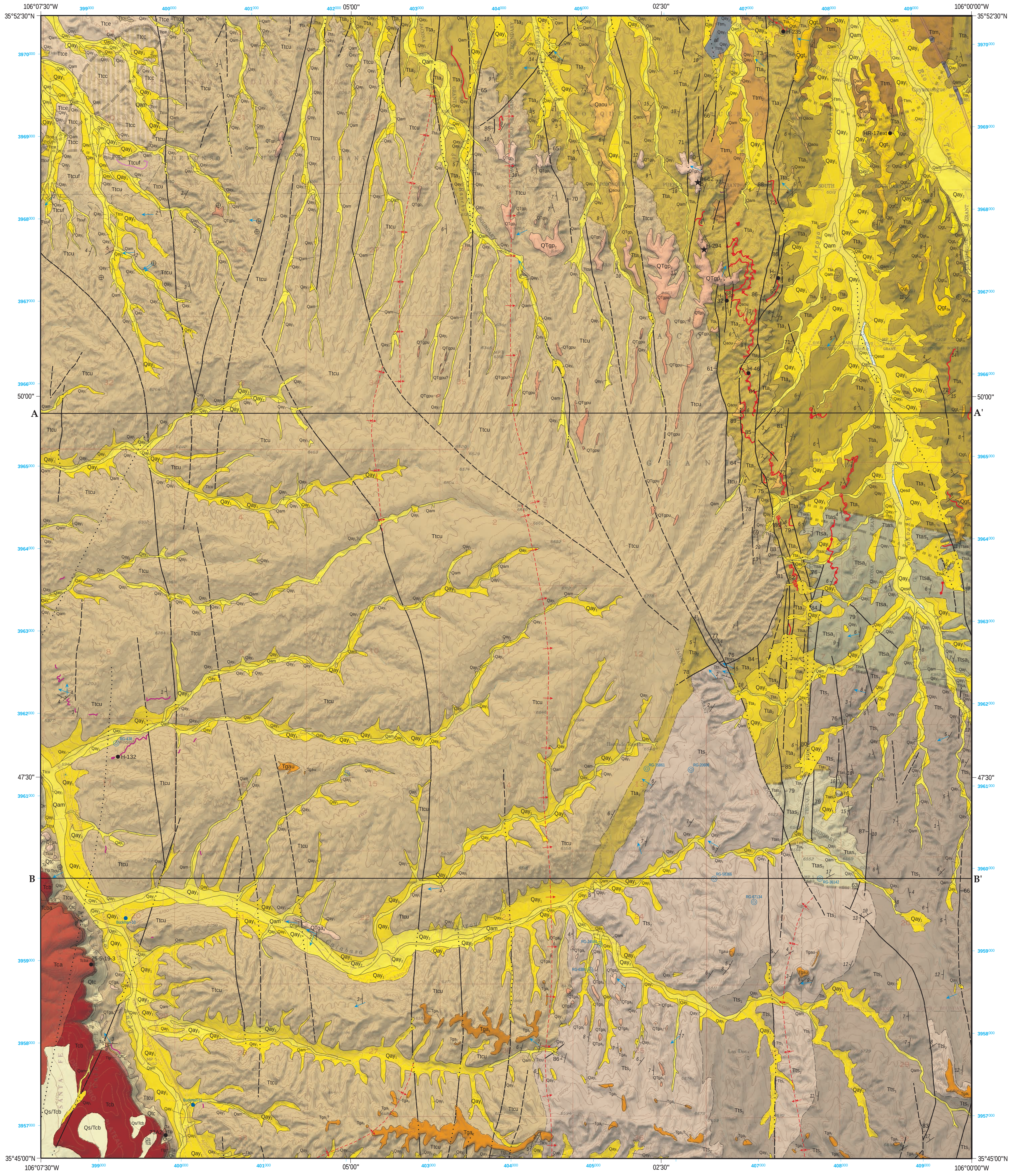
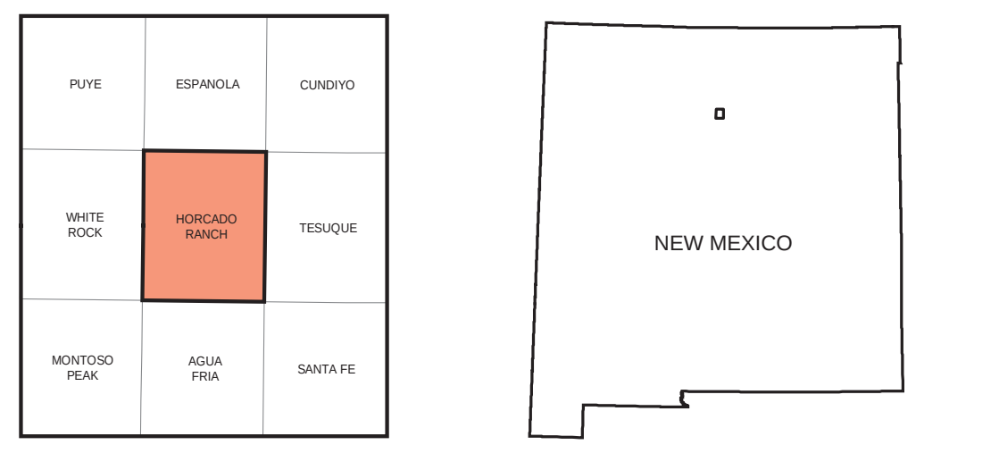


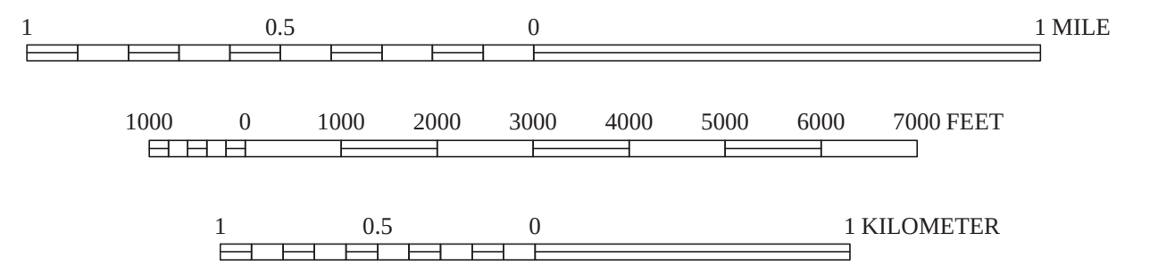
Base map from U.S. Geological Survey 1951, photorevised 1990, edited in 1993.
1927 North American datum, Universal Transverse Mercator projectionn.
1000-meter grid, UTM zone 13, shown in blue.



QUADRANGLE LOCATION

Magnetic Declination
May, 2002
10º 05' East
At Map Center

1:24,000



CONTOUR INTERVAL 20 FEET

NATIONAL GEODETIC VERTICAL DATUM OF 1929

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

[575] 835-5490

This and other STATEMAP quadrangles are available
for free download in both PDF and ArcGIS formats at:

http://geoinfo.nmt.edu

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

Mapping of this quadrangle was funded by a matching-funds grant from the STATEMAP program of the National Cooperative Geologic Mapping Act, administered by the U. S. Geological Survey, and by the New Mexico Bureau of Geology and Mineral Resources, (Dr. Peter A. Scholle, *Director and State Geologist*, Dr. J. Michael Timmons, *Geologic Mapping Program Manager*).

Geologic map of the Horcado Ranch quadrangle, Santa Fe County, New Mexico

June 2002

by
Daniel J. Koning [1], and Florian Madonado [2]

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MAP SYMBOLS

A ├──┤ A' Location of geologic cross section.
Geologic contact. Solid where exposed or known, dashed where approximately known, dotted where concealed.
Gradational contacts:
  location approximately known;
  location inferred and/or concealed.
Normal fault. Solid where exposed, dashed where exposed. Bar-ball on downthrown side.
Trace of concealed monocline showing direction of plunge.
Trace of concealed anticlinal bend of monocline showing direction of plunge.
Tephra Beds:
  Pumice beds, pumice lapilli
  Coarse black ash, lapilli layer
  Coarse white ash
  Fine Road Ash (see Izett and Obradovich, 2001)
  Non-correlated ashes in the Tesuque Formation
  Correlated Tesuque Formation ashes:
    a-1
    a-2
    a-3
    a-4
    a-5
    a-6
2 Strike and dip of inclined bedding.
Paleocurrent vector, tail of arrow is located at measurement.
● H-46 Sample location and number, including ash samples collected for geochemical correlation.
★ H-294 Tephra sample location for radiometric dating.
◎ RG-35861 Water well and NM Office of State Engineer permit number.
● Buckman-10 Domestic-water supply well.
△ Observation well for domestic-water supply.

COMMENTS TO MAP USERS

A geologic map displays information on the distribution, nature, orientation, and age relationships of rock and deposits and the occurrence of structural features. Geologic and fault contacts are irregular surfaces that form boundaries between different types or ages of units. Data depicted on this geologic quadrangle map are based on reconnaissance field geologic mapping, compilation of published and unpublished work, and photogeologic interpretation. Locations of contacts are not surveyed, but are plotted by interpretation of the position of a given contact onto a topographic base map; therefore, the accuracy of contact locations depends on the scale of mapping and the interpretation of the geologist(s). Any enlargement of this map could cause misunderstanding in the detail of mapping and may result in erroneous interpretations. Site-specific conditions should be verified by detailed surface mapping or subsurface exploration. Topographic and cultural changes associated with recent development may not be shown.

The map has not been reviewed according to New Mexico Bureau of Geology and Mineral Resources standards. Revision of the map is likely because of the on-going nature of work in the region. The contents of the report and map should not be considered final and complete until reviewed and published by the New Mexico Bureau of Mines and Mineral Resources. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the State of New Mexico, or the U.S. Government. Cross-sections are constructed based upon the interpretations of the authors made from geologic mapping, and available geophysical (regional gravity and aeromagnetic surveys), and subsurface (drillhole) data.

Cross-sections should be used as an aid to understanding the general geologic framework of the map area, and not be the sole source of information for use in locating or designing wells, buildings, roads, or other man-made structures.

MAP UNITS

(Partial description of units; complete descriptions found in the accompanying report.)

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, phreatomagmatic deposits and arkosic sandstone and conglomerate of the Tesuque and Ancha formations. The talus slope 20-25 degrees to the east away from the basalt flows in poorly defined, medium to thick, matrix- and clast-supported beds comprised of pebbles, cobbles, and boulders. 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*). Soils possess calcic horizon(s) with stage I - II calcium carbonate morphology. Thickness is 1-4 m.

Qs/Qcb **Slopewash 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. 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. 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. Gravel is generally poorly sorted, consists of subangular to subrounded pebbles with less than 50% rounded to subrounded cobbles, and its composition varies according to the location of the parent material. 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. Estimated to be 1-2 m thick.

Qay_2 **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 Qay_1. Gravel clasts are generally pebbles with less than 5% cobbles and composition varies according to the location of the parent material. Generally moderately to well sorted, 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. 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. The surface of this unit is approximately 0.5-1.5 m above the modern channel. Extreme flood events will rework this sediment. Generally 1-3 m thick.

Qay_1 **Younger alluvium (upper Pleistocene to upper Holocene) —** Sand, clayey-silty sand, and clay-silt with highly variable color from reddish-yellow (5YR 6/6) to yellowish-brown (10YR 6/4), and minor gravel. Locally underlies floors of valleys below Pleistocene gravelly terrace deposits; its surface is above Qay_2. Gravel is clast- or matrix-supported and composed of pebbles with less than 10% cobbles. Clast composition is granitic with 1-3% amphibolite, trace to 5% calcium carbonate-sandstone, and trace to 5% quartzite. Sand is generally arkosic, poorly to well sorted, subangular to subrounded, and mostly very fine- to medium-grained and is commonly clayey or silty. Surface soils have 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. Charcoal collected from 4 m-depth in Qay_1 alluvium underlying the Rio Tesuque valley west of this quadrangle returned a ^{14}C date of 2,230 ± 250 radiocarbon years (Miller and Wendorf, 1958); moreover, the Qay_1 surface in this valley was probably abandoned sometime after 1299-1250 A.D., based on archeological evidence (Miller and Wendorf, 1958). 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 $QTgp_3$ and is about the same height above adjacent drainages as *Qgt* terrace deposits. 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. 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 deposits that underlie terraces adjacent to the Rio Tesuque. 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. Gravel consists of clast-supported, moderately to poorly sorted, cobbles and pebbles with <5% boulders, 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. Quartzite clasts are subrounded to rounded. 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 (Qgt_4 through Qgt_1) 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 Qgt_1, strath heights of these terraces are lower than those of unit *QTgp*. Qgt_4-Qgt_1 are described below:

Qgt_4 **Sandy gravel terrace deposit (upper Pleistocene)** — A strath terrace that may correlate to the Qgt_5 unit in the Tesuque 7.5-minute quadrangle to the east (Borchert et al., 1998). Terrace likely correlates to Qtp_2 in the Española quadrangle to the north (Koning, 2002). Strath is 10-17 m above modern channel. 1 to 5 m thick.

Qgt_3 Qgt_{3a} Qgt_{3b} **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 $Qtpt_1$ of Koning, 2002). There, the strath exhibits relief due to original valley wall and valley floor topography that was later covered by Qgt_3 aggradation. To the south, however, the thick fill diverges into two thinner (1-6 m) and more gravelly terrace deposits, labeled Qgt_{3a} (upper) and Qgt_{3b} (lower). Straths are 20-40 m above modern channel. Qgt_{3a} and Qgt_{3b} correlate to the Qgt_3 and Qgt_4 units, respectively, in the Tesuque 7.5-minute quadrangle to the east (Borchert *et al*., 1998). Up to 18 m thick.

Qgt_2 **Sandy gravel terrace deposit (upper to middle Pleistocene)** — Paleocurrent from imbricated clasts is N75°W±15°; this strath terrace probably correlates to the Qgt_2 or Qgt_3 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.

Qgt_1 **Gravelly sand and sand terrace deposit (lower Pleistocene)** — A very thick fill terrace that probably correlates to the Qgt_2 unit in the Tesuque quadrangle to the east (Borchert *et al*., 1998). The height of the strath above Arroyo Ancho (60-65 m) is comparable to the height of the strath of $QTgp_3$ above Arroyo Jacona in the northwest part of the quadrangle. Thus, Qgt_1 probably correlates with $QTgp_3$, which has a ~1.2 Ma pumice bed. However, Qgt_1 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 $QTgp_3$. Up to 18 m thick.

Pliocene To Quaternary Alluvial Deposits

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. Straths of these terraces are higher above present drainages than straths of Qgt_{2-4}. The straths of $QTgp_3$ and Qgt_1 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*). 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).

$QTgp_3$ **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.

$QTgp_2$ **Sandy gravel terrace deposit (lower Pleistocene)** — Strath is 10-25 m above strath of $QTgp_3$ 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. 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.

$QTgp_1$ **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 $QTga_2$. 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) and there are 2-10% boulders (estimated by volume). $QTga_{1-4}$ are inset into the Tesuque Formation at least 12 m beneath *Tga* terrace deposits so they post-date *Tga*. $QTga_1$ may possibly project to the Ancha Formation (unit *Ta*) west of Cañada Ancha. Age control is very poor for these units and consequently ages are not assigned to individual terrace deposits.

$QTga_4$ ***$QTga_4$*** — 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.

$QTga_3$ ***$QTga_3$*** — 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.

$QTga_2$ ***$QTga_2$*** — Gravel contains 1-2% amphibolite, 1% muscovite schist, 40-50% quartzite, 45-60% granitic clasts. 1-3 m thick.

$QTga_1$ ***$QTga_1$*** — 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*). 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 2m thick, white pumice lapilli bed underlying *Ta* and overlying a calcium carbonate-cemented ledge that may possibly be the Tesuque Formation (Manley, 1976b; Kim Manley, personal communication, 2002) returned a zircon apatite-fission track date of 2.7 ± 0.4 Ma (Table 1, sample 73A2). Terrace deposits to the east (units Tga_{1-3}) project above the base of the Ancha Formation (Figure 2); these deposits also appear to be coarser and richer in quartzite clasts and are not correlated with the Ancha Formation. Approximately 1-12 m thick.

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, Tga_3-Tga_1 (youngest to oldest), which are described below. A few isolated terrace deposits could not be satisfactorily correlated with a particular unit of Tga_3-Tga_1 because of long distances and are designated *Tgau*. 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. 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), very fine- to very coarse-grained, moderately to well sorted, subangular to subrounded, and arkosic. 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 part of the 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 Tga_{1-2} terrace straths project at least 30 m above the scoured base of the Ancha Formation (unit *Ta*) west of Cañada Ancha (Figure 2); (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.

$QTga_3$ ***Tga_3*** — 1-5% boulders. The strath of Tga_3 projects above the base of the Ancha Formation but below the Cerros del Rio basalt flows. 1-4 m thick.

$QTga_2$ ***Tga_2*** — 5-20% boulders; generally subequal quartzite and granite clasts. An inset relationship with the Tesuque Formation is observed for unit Tga_2 near the south boundary of the quadrangle (NE1/4 of Section 35, T. 18 N., R. 8 E.). 1-5 m thick.

$QTga_1$ ***Tga_1*** — Approximately 5-20 % boulders; 40-50% quartzite and 50-60% granitic clasts. These 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. 1-6 m thick.

QTgau ***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.

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 40Ar/39Ar 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. The primary ejecta lapilli is black (5Y 2.5/1) with less than 1% granitic grains and occurs in very thin, planar to wavy, even, distinct, well to moderately sorted, and clast-supported beds or laminations. 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. 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. Unit *Tlp* correlates to unit Tcm of Dethier (1997). 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. 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*, Tta_2, and Tta_1) 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 (Ttm_3), one in Arroyo Jacona (Ttm_2), and one in Arroyo Ancho and the Rio Tesuque (Ttm_1). 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 Ttm_1 and Ttm_2 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 predominant 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. Gravel clasts are mostly pebbles with less than 25% cobbles; angular to to subrounded, and comprised of 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. 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. An age of 13.2-13.8 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 bedwithin *Ttcu* was dated by the ^{40}Ar/^{39}Ar 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. 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 in scattered, lenticular to tabular complexes up to 100 cm-thick. 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, while non-channelized sand is generally very fine- to medium-grained. Both are arkosic, subangular to subrounded, and poorly to well sorted. 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. See descriptions for those individual units above. About 130 m-thick.

Tta_2 **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) to pale-brown (10YR 6/3). Clast composition is generally granitic with 1-3% amphibolite. Sand is subangular to subrounded, moderately to well sorted, and arkosic. 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. They are most common near the contact with the underlying Tta_1 unit. ^{40}Ar/^{39}Ar-dated ashes in the unit and fauna associated with the late Barstovian North American Land Mammal age found throughout the correlative Pojoaque Member (Tedford and Barghoorn, 1993), indicate an approximate age of 13-15.3 Ma. This unit grades laterally southward into unit Tts_2. Approximately 180-240 m thick.

Tts_2 **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) to pink to light-brown (7.5YR 6-7/3-4). 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). 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 gradational over 10-20 m stratigraphic thickness, separating reddish-yellow sandstone of the upper Tts_1 from pink, very pale brown, and light-brown silty sandstone of the lower Tts_2. This unit grades laterally with unit Tta_2 to the north, and so has a similar age estimate of 13-15.3 Ma. Approximately 180-240 m thick.

$Ttas_2$ **Gradational zone between the upper units of lithosomes A and S (middle Miocene)** — Unit shares characteristics of Tta_2 and Tts_2. See the descriptions for those individual units.

Ttm_2 **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 Tta_2 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. *Ttbp1* lies between two ashes dated at approximately 15.1 and 13.7 Ma by Izett and Obradovich (2001), thus implying a similar age for Ttm_2. 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.

Tta_1 **Lithosome A of the Tesuque Formation, lower unit (middle Miocene)** — Sandstone, siltstone, and claystone with 1-15% conglomerate beds. Sandstone and silty sandstone are very pale brown (10YR 7/3 to 8/2), light-yellowish-brown to light-brown (7.5YR 6/4), very fine- to very coarse-grained, subrounded to subangular, mostly well sorted with some moderate sorting, and arkosic. Siltstone and claystone range in color from light-yellowish-brown (10YR 6/4) to reddish-brown (2.5YR-5YR 4-6/3-4). Conglomerate is commonly pinkish-gray (7.5YR 7/2), clast-supported, and consists of pebbles with subordinate cobbles composed of granitic clasts with 1-5% amphibolite, 1-5% reworked, calcium carbonate-cemented sandstone clasts, and 0.5-5% quartzite. 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.

Tts_1 **Lithosome S of the Tesuque Formation, lower unit (middle Miocene)** — Sandstone, siltstone, and claystone with 1-15% conglomerate beds. Sandstone and silty sandstone are light-brown (7.5YR 6/3-4), pink (7.5YR 7/4), or reddish-yellow (10YR 6/6), very fine- to very coarse-grained, subrounded to subangular, mostly well sorted with some moderate sorting, and arkosic. Siltstone and claystone range in color from brown (7.5YR 5/4) to pink (7.5YR 7/3-4). Conglomerate is commonly pinkish-gray (7.5YR 7/2), clast-supported, and consists of pebbles with subordinate cobbles composed of granitic clasts 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. Unit approximately correlates to the Skull Ridge Member of Galusha and Blick (1971), and like Tta_1, has an age of 15.1 to 16 Ma. In the subsurface, this unit is as old as late Oligocene. Total thickness is approximately 250-430 m.

$Ttas_1$ **Gradational zone between the lower units of lithosomes A and S, mostly like lithosome A (middle Miocene)** — Unit shares characteristics of Tta_1 and Tts_1 but is mostly like Tta_1. See the descriptions for those individual units.

$Ttsa_1$ **Gradational zone between the lower units of lithosomes S and A, mostly like lithosome S (middle Miocene)** — Unit shares characteristics of Tts_1 and Tta_1 but is mostly like Tts_1. See the descriptions for those individual units.

Ttm_1 **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. Sand is well sorted and subangular to subrounded. Sand composition differs from unit Tta_1 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. Unit correlates to the Skull Ridge Member of Galusha and Blick (1971) and to unit *Ttms1* of Koning (2002), which lies above White Ash #4 of the Skull Ridge Member but below the Road Ash of Izett and Obradovich (2001), indicating a depositional age between 15.4 and 15.1 Ma. Unit is interpreted to represent a basin floor floodplain immediately adjacent to a piedmont flanking the Sangre de Cristo Mountains and is now largelycovered by Quaternary alluvium. Approximate thickness is 140-150 m.

Units Depicted In Cross-Sections But Not Shown On Map

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 (Tta_1 and Tta_2). *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 Tts_1 and Tts_2.

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).

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). By 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). Unit probably underlies most of the quadrangle; moderately to well consolidated; 640-910 m thick.

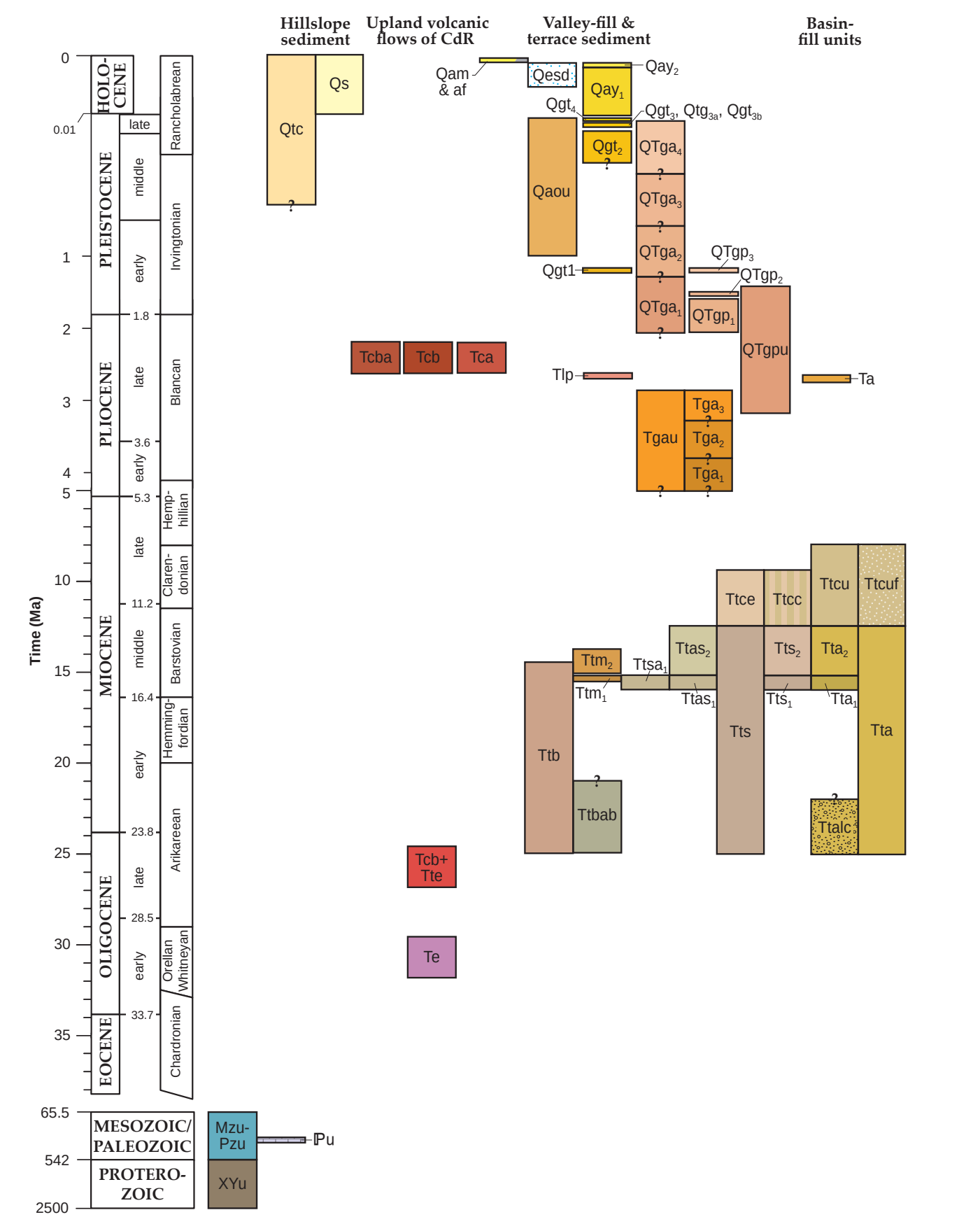
Te **Espinaso Formation (Oligocene)** — White to light gray, tuffaceous, silty-clayey sandstone and sandstone, with subordinate gray, pebbly volcaniclastic sandstone and pebble to boulder conglomerate. Unit correlates with the Bishop's Lodge Member of the Tesuque Formation, but work by Smith (2000b) 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.

Mzu-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).

ℙu **Pennsylvanian strata, undifferentiated (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.

CORRELATION OF MAP UNITS



GEOLOGIC CROSS SECTIONS