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# GEOLOGIC MAP OF THE SANTA ANA PUEBLO QUADRANGLE, SANDOVAL COUNTY, NEW MEXICO

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The Bernalillo NW quadrangle is located in the northern part of the Albuquerque basin, which is the largest basin or graben within the Rio Grande rift. The quadrangle is underlain by poorly consolidated sedimentary rocks of the Santa Fe Group. These rocks are best exposed in the southwestern part of the quadrangle in the Rincones de Zia, a badland topography cut by northward-flowing tributary arroyos of the Jemez River. The Jemez River flows through the northern half of the quadrangle; extensive fluvial and eolian deposits cover bedrock units along the river. The structural fabric of the quadrangle is dominated by dozens of generally north striking, east and west-dipping normal faults and minor folds associated with the Neogene Rio Grande rift.

The geology of the Bernalillo NW quadrangle was mapped as part of the USGS Middle Rio Grande Basin project to explore the geologic framework of water resources in the region.

This publication consists of a map sheet and a geospatial database. The map sheet includes the principal map, one cross section, a diagram showing stratigraphic correlation of map units, a description of map units, discussion, list of references, an index map that shows the location of the study area within the State of New Mexico, and one small table. The description of map units, discussion, table, and list of references are included with this text-only file.

## DISCUSSION

The Santa Ana Pueblo quadrangle is located in the northern part of the Albuquerque basin, which is the largest basin or graben within the Rio Grande rift in New Mexico. The quadrangle is underlain by poorly consolidated sedimentary rocks of the Santa Fe Group and is dominated by Santa Ana Mesa, a volcanic tableland underlain by basalt flows of the San Felipe volcanic field. The San Felipe volcanic field is the largest area of basaltic lavas exposed in the Albuquerque basin (Kelley and Kudo, 1978).

### STRUCTURE

The structural fabric of the quadrangle is dominated by dozens of generally north striking, east- and west-dipping normal faults associated with the Neogene Rio Grande rift. Many of these faults form resistant fault scarps where they offset basalt flows underlying Santa Ana Mesa, but most faults in the underlying Santa Fe Group sedimentary rocks are poorly expressed. Exceptions are the Santa Ana fault and an unnamed fault in the northwestern part of the quadrangle, where prominent ridges mark the surface expression of the fault due to enhanced silica and (or) calcium carbonate cementation in the footwall.

Another major fault is the down-to-the-east Tamaya fault, herein informally named after the local term for the nearby old Santa Ana Pueblo. This fault was not previously identified, but rather was mapped as a contact between contrasting subunits of Santa Fe Group rocks (Soister, 1952; Spiegel, 1961; Smith and others, 1970; Kelley, 1977). The Tamaya and Santa Ana faults are related en echelon structures; the Santa Ana fault dies out in the adjacent Bernalillo NW quadrangle (Koning and Personius, 2002), just south of a complex fault stepover with the Tamaya fault. The Tamaya fault can be traced in numerous exposures southward to the Jemez River and is mapped continuously beyond the southern quadrangle boundary on the basis of a prominent anomaly in high-resolution aeromagnetic data (U.S. Geological Survey and SIAL Geosciences, Inc., 1997). The Tamaya fault is exposed in a roadcut along U.S. Highway 550, where it has been erroneously mapped as the Luce fault (Kelley, 1977; Pazzaglia and others, 1999; Connell and others, 2000). The Tamaya fault has the most offset of any fault in the quadrangle, although absence of correlative units exposed across the structure prevent measurement of total throw. The fault may also cut Quaternary deposits, because it coincides with a 5-m-high, east-facing scarp in old arroyo alluvium (unit Qalo) about 500 m north of the Jemez River. The age of this alluvium is unknown, but probably is middle Pleistocene or younger, because the deposit underlies a fan that covers old deposits of the Jemez River (unit Qaj1) that probably are younger than deposits containing the ≈640-ka (Lanphere and others, 2002) Lava Creek B ash in the headwaters of the Jemez River (Rogers, 1996; Rogers and Smartt, 1996).

Other prominent structures in the quadrangle are the Luce and Algodones faults, which form the western and eastern margins, respectively, of the San Felipe fault zone (Kelley, 1954) or San Felipe graben (Kelley, 1977). These faults are part of a series of faults that offset the basalt flows underlying Santa Ana Mesa. There appears to be little net throw across the San Felipe graben, although the Luce fault has apparent down-to-the-east offset of 90–120 m (Soister, 1952; Kelley, 1977) and the Algodones fault has apparent down-to-the-west offset of 50–60 m (Personius and others, 1999). These relatively large offsets in the 2.4- to 2.6-Ma (Bachman and Mehnert, 1978; Smith and Kuhle, 1998) basalts of the San Felipe volcanic field indicate a history of recurrent movement that may have extended into the early Pleistocene (Wong and others, 1995; Machette and others, 1998; Personius and others, 1999). However, displacements on some or all of the faults on Santa Ana Mesa may be related to volcano-tectonic processes (Personius and others, 1999); the narrowing of the fault zone near the center of the volcanic field supports this inference (for example, van Wyk de Vries and Merle, 1996). If most of the displacement on faults in the San Felipe graben is related to basalt eruption, then earthquakes associated with these faults may have smaller magnitude than those associated with tectonic faults (Smith and others, 1996). Numerous eruptive centers (unit Tbc) in the volcanic field are aligned in northerly patterns that mimic the fault strikes, but these features do not appear to be controlled by mapped faults and thus may be related to older structures (Kelley and Kudo, 1978).


## ACKNOWLEDGMENTS

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## DESCRIPTION OF MAP AND SUBSURFACE UNITS

[Surficial units are shown on map only if estimated to be at least 1 m thick. Colors of unconsolidated sediment are based on visual comparison of dry samples with Munsell soil color charts (Munsell Color, 1994). Soil-horizon designations and descriptive terms follow those of Birkeland and others (1991) and Birkeland (1999)]

Qf **Artificial fill (historic)—**Locally derived and imported aggregate materials used for construction purposes. Used for highway fills along access road to old Santa Ana Pueblo, for a dike protecting old Santa Ana (Tamaya) Pueblo from Jemez River, and to divert an arroyo that previously flowed through eastern part of old Pueblo. Includes engineered fill at Jemez Canyon Dam and overflow spillway to south of dam. Unvegetated to sparsely vegetated to revegetated; no soil development. Thickness 1–30 m

### ARROYO ALLUVIUM

Qalh **Active channel alluvium (historic)—**Light-yellowish-brown to brown (10YR 6–7/4), fine to coarse sand, silty sand, pebbly sand, and less common sandy pebble, cobble, and boulder gravel; poorly to moderately sorted, massive to well bedded, with local crossbedding; sand is poorly sorted to well sorted, fine to coarse grained, subrounded, and lithic and feldspathic in composition. Gravel clast compositions reflect local geologic units exposed in drainage area. Commonly forms channel fills and bars. Confined to present arroyo channel floors and bed of Jemez River. Unit commonly includes small areas of young eolian sand (unit Qesy). Sparsely vegetated (seasonal inundation) to unvegetated; no soil development. Thickness 1 to >5 m

Qaly **Younger arroyo alluvium (Holocene)—**Light-yellowish-brown to light-gray (10YR 6–7/4), fine to coarse sand, mud, silty sand, pebbly sand, and sandy pebble, cobble, and boulder gravel; poorly to moderately sorted, massive to well bedded, with local crossbedding. Gravel clast compositions reflect local geologic units exposed in drainage area; clasts are chiefly reworked from underlying Santa Fe Group rocks, which primarily are derived from source areas to northwest (Sierra Nacimiento and Jemez Mountains); common lithologies include Precambrian pink granitic rocks, petrified wood, Pedernal Chert Member of Abiquiu Formation, Paleozoic chert and limestone, Mesozoic sandstone, and intermediate to mafic volcanic rocks. Gravels commonly form 0.5- to 1-m-thick, channel-shaped or lenticular beds. Unit underlies low terraces along major arroyos and Jemez River, 2–8 m above adjacent channels. Unit commonly includes small areas of younger eolian sand (unit Qesy). Sparsely vegetated. Some low terraces along major arroyos contain charcoal-rich hearth sites. Soil development is minimal, usually with only minor oxidation, thin A horizons, and stage I Bk horizons. Thickness 1–5 m

Qalo **Older arroyo alluvium (Holocene to lower(?) Pleistocene)—**Light-brown to light-gray (10YR 6/4–6), fine to coarse sand, silty sand, pebbly sand, and sandy pebble, cobble, and boulder gravel; poorly to moderately sorted, massive to well bedded, with uncommon crossbedding. Gravel clast compositions reflect local geologic units exposed in drainage area; in deposits south of Jemez River, clasts are chiefly reworked from underlying Santa Fe Group rocks, which primarily were derived from outcrops to northwest (Sierra Nacimiento and Jemez Mountains); common lithologies include pink granite, petrified wood, Paleozoic limestone and brown chert, Mesozoic sandstone, Pedernal Chert Member of Abiquiu Formation, basalt, intermediate volcanic rocks, and fragments of petrocalcic soil; clasts north of Jemez River are chiefly basalt. Unit underlies fan surfaces and terraces along major arroyos, 8–70 m above adjacent channels. Most deposits are thin and overlie straths cut in underlying bedrock, but some deposits along larger drainages form 10- to 20-m-thick fills. Unit commonly includes small areas of eolian sand (units Qesy and Qeso). Deposits at mouths of major arroyos interfinger with and (or) overlie deposits of Jemez River (units Qaj1–Qaj6). Soil development is variable, but stage I through stage III Bk horizons are common in lower deposits, and Bt horizons and stage III to IV Bk horizons are common in older, higher deposits. Correlative with unit Qvd of Personius and others (2000) in the Loma Machete quadrangle. Thickness 1–20 m

EOLIAN DEPOSITS

Qesy **Younger eolian sand (Holocene)—**Very pale brown to light-yellowish-brown (10YR 6–7/4), massive to horizontal to wavy crossbedded, moderately sorted to well sorted, subrounded to subangular, very fine to coarse feldspathic sand. Primarily deposited as thin sheets, coppice dunes, and small dune fields along Jemez River and downwind (east) of large arroyos and in areas underlain by poorly consolidated bedrock of unit Tzcc. Soil development is minimal, usually with only minor oxidation, but may contain stage I Bk horizons. Thickness 1–5 m

Qeso **Older eolian sand (Holocene to middle Pleistocene)—**Light-brown to light-brownish-gray (7.5 YR 6/4 and 10YR 6/2), massive to horizontal to crossbedded, moderate- to well-sorted, very fine to coarse sand. Primarily deposited as sheets and small dune fields on broad upland surfaces throughout map area. Commonly overlies fan surfaces of older arroyo alluvium (unit Qalo). Extensive deposits, such as those east of Santa Ana fault and on Santa Ana Mesa, commonly consist of multiple deposits separated by buried soils. Surface and buried soils are characterized by extensive bioturbation and oxidation, and the formation of stage II-III Bk and Btk horizons. Thickness 1 to >5 m

COLLUVIUM AND LANDSLIDES

Qls **Landslide deposits (upper to lower Pleistocene)—**Large-scale slumps ("toreva blocks") of basalt and underlying Santa Fe Group rocks formed below basalt-capped margin of Santa Ana Mesa. Primarily found in southeastern part of quadrangle, where mesa margin has been oversteepened by erosion along Rio Grande and Jemez River. Thickness 5–70 m

Qcb **Basalt-rich colluvium (upper to lower Pleistocene)—**Sandy pebble, cobble, and boulder gravel; unsorted and unstratified. Consists of heterogeneous mixture of reworked Santa Fe Group sand and gravel and boulders of basalt (unit Tb). Deposits mantle steep hillslopes below basalt-capped Santa Ana Mesa. Locally includes small slump blocks and basalt-rich deposits that have slumped and remobilized as debris flows. Most deposits are characterized by strongly developed (stage III and IV) calcic soils. Thickness 1–5 m

## JEMEZ RIVER ALLUVIUM

Jemez River alluvial deposits were mapped concurrently in the Santa Ana Pueblo and Bernalillo NW (Koning and Personius, 2002) quadrangles. Seven map units were identified in these two quadrangles, but all units are not present in both quadrangles. Alluvial units from both quadrangles are included in the "Correlation of Map and Subsurface Units" to aid in unit correlation between quadrangles. To aid in regional correlation, table 1 includes probable correlations with Jemez River alluvial units mapped by others upstream from the Santa Ana Pueblo quadrangle

Qaj6 **Alluvium 6 of Jemez River (Holocene)—**Light-yellowish-brown (10YR 6/4) fine sand, including pale brown (10YR 6/3), 10-cm-thick interbeds of sandy silt and rare pebbly zones. Deposits underlie fill terrace 4 m above modern channel 2 km west of Jemez Canyon Dam, but probably also underlie extensive 4- to 6-m-high terraces covered with eolian sand (unit Qesy) on south side of Jemez River. Correlative with units Qt7, Qt8, and Qt9 of Rogers (1996) and Rogers and Smartt (1996), with units Qt5 and Qt6 of Formento-Trigilio and Pazzaglia (1996, 1998), Formento-Trigilio (1997), Pazzaglia (1998), and Pazzaglia and others (1998), and with units Qaj6a and Qaj6b of Koning and Personius (2002), mapped upstream of quadrangle. Thickness >4 m

Qaj5 **Alluvium 5 of Jemez River (upper to middle(?) Pleistocene)—**Varicolored sand, pebbly sand, pebble and cobble gravel, and silty clay. Upper part consists of about 15 m of yellowish-brown, fine to medium sand and pebbly sand, interbedded with moderately sorted to well sorted pebble and cobble gravel in channel fills 1–2 m thick, and minor thin (10-cm-thick) beds of red and green silty clay. Gravel clasts are subangular to round and well imbricated, show south-southeast (140°–180°) transport directions, and are chiefly pink granite, petrified wood, Paleozoic limestone, Mesozoic sandstone, Pedernal Chert Member of Abiquiu Formation, and intermediate to mafic volcanic rocks, consistent with source areas to northwest. Contains a few charcoal fragments and reworked pumice pebbles in pebbly sand beds near base of upper part; pumice is chemically correlated with 1.6-Ma (Izett and Obradovich, 1994) lower Bandelier Tuff (sample locality MRGB–17–BNW; A. Sarna-Wojcicki, written commun., 1998) in adjacent Bernalillo NW quadrangle. Lower part consists of at least 3 m of mottled red and green silty clay in beds 10–50 cm thick; lower unit contains common crystals of authigenic gypsum as much as 20 cm in length. Well-developed bedding, clast lithologies, rounding, and sorting indicate deposition by Jemez River. Exposures are conformably overlain in places by 1–2 m of basalt-rich cobbly arroyo alluvium (unit Qalo) containing stripped, stage II–III Bk horizons; lower contact is not exposed but extends at least to present level of Jemez River channel. Preserved as irregular remnants underlying arroyo fan surfaces north of Jemez River. Correlative with unit Qaj5 in adjacent Bernalillo NW quadrangle (Koning and Personius, 2002); no clearly correlative alluvial deposit has been described upstream of Bernalillo NW quadrangle (Formento-Trigilio and Pazzaglia, 1996, 1998; Rogers 1996; Rogers and Smartt, 1996; Pazzaglia, 1998; Pazzaglia and others, 1998), although the unit may be correlative with a minor strath terrace fill (unit Qt5 of Rogers, 1996, and Rogers and Smartt, 1996; unit Qt4a of Formento-Trigilio, 1997, and Formento-Trigilio and Pazzaglia, 1998) in the upper Jemez River drainage (F.J. Pazzaglia, oral commun., 2001). Thickness >15 m

Qaj3 **Alluvium 3 of Jemez River (middle Pleistocene)—**Pebbly sand and sandy pebble and cobble gravel; moderately sorted, moderately to well bedded. Clasts are subangular to round and well imbricated, show southeast (110°–120°) transport directions, and are chiefly pink granite, petrified wood, Paleozoic limestone, Mesozoic sandstone, Pedernal Chert Member of Abiquiu Formation, and intermediate to basic volcanic rocks, consistent with source areas to northwest. Unit well preserved as 4- to 10-m-thick fill deposits underlying prominent terrace remnants north of Jemez River in adjacent Bernalillo NW quadrangle, but in Santa Ana Pueblo quadrangle unit is restricted to a 2-m-thick deposit along west edge of quadrangle. Deposit overlies a bedrock strath about 30 m above present channel of Jemez River and is in turn overlain by 4 m of basalt-rich, angular cobble and boulder gravel (unit Qalo) derived from Santa Ana Mesa. Correlative with unit Qt4 deposits of Rogers (1996), Rogers and Smartt (1996), Formento-Trigilio and Pazzaglia (1996, 1998), Formento-Trigilio (1997), Pazzaglia (1998), and Pazzaglia and others (1998), and with unit Qaj3 of Koning and Personius (2002), mapped upstream of quadrangle. Thickness 2 m

Qaj1 **Alluvium 1 of Jemez River (middle Pleistocene)—**Sandy pebble and cobble gravel; moderately sorted and moderately to well bedded. Clasts are subangular to round and well imbricated, show southeast transport directions, and are dominated by rocks attributable to Sierra Nacimiento and Jemez Mountains source areas to northwest. Unit poorly preserved as 1- to 2-m-thick deposits in small hills and beneath fans and remnants of basalt-rich, angular cobble and boulder gravel (unit Qalo) north of Jemez River. Deposits overlie bedrock straths about 75 m above present channel of Jemez River. Probably correlative with unit Qt2 deposits of Rogers (1996), Rogers and Smartt (1996), Formento-Trigilio and Pazzaglia (1996, 1998), Formento-Trigilio (1997), Pazzaglia (1998), and Pazzaglia and others (1998), mapped upstream of quadrangle; unit Qt2 deposits are inset 25-50 m below unit Qt1 deposits that contain Lava Creek B ash, so unit Qaj1 deposits are inferred to be younger than the ≈640-ka tephra age (Lanphere and others, 2002) attributed to these higher, older deposits. Preserved thickness 1–2 m

## BEDROCK

### Tertiary volcanic rocks

Tb **Basalt of San Felipe volcanic field (upper Pliocene)—**Dark-gray olivine basalt; forms single and multiple flows that cap Santa Ana Mesa (Kelly and Kudo, 1978); K/Ar and Ar/Ar dating of these rocks in various locations yield ages of 2.4-2.6 Ma (Bachman and Mehnert, 1978; Smith and Kuhle, 1998). In most places unit is covered by 0.5–2 m of eolian sand (units Qesy and Qeso). Thickness best expressed around rim of Santa Ana Mesa or in fault scarps; individual flows are 6–10 m thick along western and southern margins of the mesa. Thickness much greater near eruptive centers along San Felipe graben in central part of mesa

Tbc **Basalt cinder and intrusive centers, San Felipe volcanic field (upper Pliocene)—**Vent-related basaltic cinder, spatter, scoria, and dikes. Forms cinder cones, small shield volcanoes, depressions, and ring dikes and plugs at eruptive centers; after Kelley and Kudo (1978). Cones form an elongate array that trends north-south, in general alignment with numerous normal faults that offset the surface of Santa Ana Mesa (Kelley and Kudo, 1978). Thickness unknown

### Santa Fe Group

Significant revisions of the Santa Fe Group have recently been proposed by Connell and others (1999) in the northern Albuquerque basin. However, this nomenclature is preliminary, and other recent studies have suggested alternative terminology (for example, Chamberlin and others, 1999; Pazzaglia and others, 1999; Tedford and Barghoorn, 1999). Herein I retain some of the proposed stratigraphic revisions of the Santa Fe Group of Connell and others (1999) because the reference sections are located nearby, but such usage should not be interpreted as an endorse-ment of this stratigraphic terminology outside of the Santa Ana Pueblo quadrangle

Tc **Cochiti Formation (Pliocene to upper Miocene)—**Very pale brown, fine to coarse sandstone and sandy pebble, cobble, and local boulder conglomerate; poorly indurated; poorly to moderately well sorted. Massive to moderately bedded. Clasts are subangular to subrounded and primarily consist of volcanic rocks derived from Jemez Mountains to north; pumice-rich zones and obsidian clasts ("Apache tears") are common. A preliminary $^{40}Ar/^{39}Ar$ analysis on one pumice bed (sample SPT9/15/97–4) yielded an age of 7.01±.06 Ma (M.J. Kunk, oral commun., 1999), indicating these tephra are probably reworked from Peralta Tuff (Bailey and others, 1969), which has been dated at ≈6.75–7.0 Ma elsewhere in the region (Smith and others, 1991; McIntosh and Quade, 1995). Sparse clast orientation measurements indicate southerly (140°–215°) transport directions. Poor exposure prevents accurate determi-nation of conglomerate-to-sandstone ratios, but conglomerate probably makes up less than 10 percent of lower section, and is greater than 70 percent in some places near upper part of section below rim of Santa Ana Mesa in better exposures north of Santa Ana Pueblo quadrangle. As mapped herein, unit is consistent with redefinition of Cochiti Formation proposed by Smith and Lavine (1996). Unit interfingers with northwest-derived sandstone and conglomerate of unit Tou; some beds of unit Tou conglomerate are included in unit Tc. Exposures are confined to northwest corner of Santa Ana Pueblo quadrangle and adjacent Loma Creston quadrangle (Chamberlin and others, 1999), but deposits are probably present beneath northern rim of Santa Ana Mesa throughout quadrangle. Time-correlative with Upper Buff Member of Santa Fe Formation of Bryan and McCann (1937), Ceja member of Santa Fe Formation of Kelley (1977), Sierra Ladrones Formation of Machette (1978), upper Santa Fe Group units of Personius and others (2000) in Loma Machete quadrangle, Cochiti Formation of Smith and Lavine (1996) and Chamberlin and others (1999), and Ceja and Loma Barbon Members of Arroyo Ojito Formation of Connell and others (1999). Previously mapped as Bodega Butte member of the Santa Fe Formation by Soister (1952), as pumicious upper part of lower member of lower unnamed formation of Santa Fe Group by Spiegel (1961), as Cochiti Formation by Smith and others (1970), and as undivided Santa Fe Formation by Kelley (1977). Faulting complicates estimation of unit thickness but probably is maximum of 200 m at northern margin of quadrangle and pinches out to south

$Tc_c$ **Cochiti Formation, cemented (Pliocene to upper Miocene)—**Very pale brown, fine to coarse volcaniclastic sandstone and sandy pebble, cobble, and local boulder conglomerate; pervasively cemented with silica and (or) calcium carbonate in footwall of fault in northwestern part of quadrangle. Exposed thickness 30 m

Tfr **Fluvial deposits of ancestral Rio Grande (Pliocene to upper Miocene)—**Pinkish-white, medium to coarse sandstone and sandy pebble and sparse cobble conglomerate; poorly indurated, moderately well sorted. Clasts are subround to round and primarily consist of gray quartzite and rhyolitic volcanic rocks. Sorting and clast lithologies suggest a northeasterly ancestral Rio Grande source. Very poorly exposed in one location directly beneath basalt (unit Tb) near southern end of Algodones fault in southeast corner of quadrangle, but outcrops to east and northeast indicate similar pebbly sand interfingers with units Tou and Tc (Cather and Connell, 1998; Smith and Kuhle, 1998). Time-correlative with Upper Buff Member of Santa Fe Formation of Bryan and McCann (1937), Ceja member of Santa Fe Formation of Kelley (1977), Sierra Ladrones Formation of Machette (1978), axial facies of Sierra Ladrones Formation (Smith and Kuhle, 1998), upper Santa Fe Group units of Personius and others (2000) in the Loma Machete quadrangle, and Ceja and Loma Barbon Members of Arroyo Ojito Formation of Connell and others (1999). Previously mapped as Cochiti Formation by Smith and others (1970), but mostly nonvolcanic clast assemblage suggests different nomen-clature is appropriate (Smith and Lavine, 1996). Also mapped as Santa Ana member of the Santa Fe Formation by Soister (1952), as red (upper) member of lower unnamed formation of Santa Fe Group by Spiegel (1961), and as undivided Santa Fe Formation by Kelley (1977). Exposed thickness about 15 m

**Arroyo Ojito Formation**

Tou **Ceja and Loma Barbon Members of Connell and others (1999), undivided (Pliocene to upper Miocene)—**Light-gray to pale-brown to red sandstone and sandy pebble and minor cobble conglomerate; poorly indurated; poorly to moderately well sorted. Massive to moderately bedded. Clasts are subangular to subrounded and primarily consist of rocks derived from northwestern New Mexico (Sierra Nacimiento and Jemez Mountains) sources; common lithologies include pink granite, petrified wood, Paleozoic limestone, Mesozoic sandstone, Pedernal Chert Member of Abiquiu Formation, and intermediate to mafic volcanic rocks. Largest clasts are generally 20–30 cm long, although boulders 50 cm or longer are present locally. Sparse clast orientation measurements indicate easterly to east-southeasterly (75°–120°) transport directions. Also contains minor thin (2–10 cm) beds of light red silt. Thin beds (5–20 cm) of reworked rhyolitic pumice are common in the lower part of section. Preliminary $^{40}Ar/^{39}Ar$ analyses on two samples from one pumice bed (sample site SPT8/27/97–1) yielded indistinguish-able ages of 7.09±0.04 and 7.08±0.04 Ma (M.J. Kunk, oral commun., 1999), indicating these tephra are probably reworked from the Peralta Tuff (Bailey and others, 1969), which has been dated at ≈6.75–7.0 Ma elsewhere in the region (Smith and others, 1991; McIntosh and Quade, 1995). Unit contains less con-glomerate and more silt near base, which is not exposed; exposures of a distinctive 20- to 30-cm-thick, fissile, gray, very fine sandstone near the base of unit aids in mapping in the southern part of sec. 4, T. 14 N., R. 3 E. in northwestern part of quadrangle. Unit interfingers with volcaniclastic sandstone and conglomerate of Cochiti Formation (unit Tc) in northwestern part of quadrangle and is in fault contact with units Ton and Tzcc along Tamaya fault in west half of quadrangle. Poor exposure prevents accurate determination of conglomerate-to-sandstone ratios, but conglomerate probably makes up less than 10 percent of lower section and is greater than 50 percent in upper part of section in places below rim of Santa Ana Mesa. Upper part of section contains several well developed, 1-m-thick buried stage III and IV calcic soils representing periods of landscape stability and hiatuses in deposition. Deposited by shallow, east-southeasterly flowing streams of ancestral Jemez River drainage, with only minor input from south-flowing ancestral Jemez Mountains drainages. Time-correlative with Upper Buff Member of Santa Fe Formation of Bryan and McCann (1937), Ceja member of Santa Fe Formation of Kelley (1977), Sierra Ladrones Formation of Machette (1978), upper Santa Fe Group units of Personius and others (2000) in Loma Machete quadrangle, and Ceja and Loma Barbon members of Arroyo Ojito Formation of Connell and others (1999) in Bernalillo NW quadrangle (Koning and Personius, 2002). Previously mapped as Cochiti Formation by Smith and others (1970), but mostly non-volcanic clast assemblage suggests different nomenclature is appropriate (Smith and Lavine, 1996). Also mapped as Santa Ana member of Santa Fe Formation by Soister (1952), as red (upper) member of lower unnamed formation of Santa Fe Group by Spiegel (1961), and as undivided Santa Fe Formation by Kelley (1977). Faulting complicates estimation of unit thickness, but exposed thickness is about 300 m and correlative rocks are >420 m thick in adjacent Bernalillo quadrangle (Connell and others, 2000)

Ton **Navajo Draw Member of Connell and others (1999) (Miocene)—**Pink (5YR 7/3), very pale brown (10YR 8/2) to light-gray (10YR 7/1), fine to medium sandstone, containing minor pale red (2.5 YR 7/3) to red (2.5 YR 5/6) siltstone and claystone, and rare thin pebble to cobble beds of pumice and rhyolitic nonwelded tuff; poorly indurated. Also contains several poorly sorted, poorly to moderately bedded sandy pebble and cobble conglomerate beds, 0.5–2 m thick. Conglom-erate beds are less well bedded, are more poorly sorted, and have higher percentages of volcanic clasts than conglomerates in overlying unit Tou. Deposits are highly variable along strike and are preserved only in a structurally complex zone between the Santa Ana and Tamaya fault zones in northwestern part of quadrangle. Most of unit was deposited as fluvial (overbank) sediment by sluggish, south- and (or) southeast-flowing streams, but large-scale (sets 0.5–1 m high), crossbedded eolian sand deposits are locally present. Probably correlative with upper part of Middle Red Member of the Santa Fe Formation of Bryan and McCann (1937) and Kelley (1977), lower member of lower unnamed formation of Santa Fe Group of Spiegel (1961), upper and middle parts of middle Santa Fe Group units of Personius and others (2000), and Navajo Draw Member of Arroyo Ojito Formation of Connell and others (1999) in Bernalillo NW quadrangle (Koning and Personius, 2002). Mapped as Chamisa Mesa Member of Santa Fe Formation by Soister (1952) and as Zia Member of Santa Fe Formation by Kelley (1977); also mapped as Cochiti Formation by Smith and others (1970), but mostly nonvolcanic clast assemblage suggests different nomenclature is appropriate (Smith and Lavine, 1996). In fault contact with overlying unit Tou at Tamaya fault. Mostly in fault contact with underlying unit Tzcc at Santa Ana fault and at west-northwest-trending fault zone in sec. 3 and 4, T. 14 N., R. 3 E., east of southern end of prominent exposure of Santa Ana fault. Faulting and poor exposure complicate estimation of unit thickness, but exposed thickness probably <200 m

Tsfu **Santa Fe Group, undivided (Pliocene(?) to Miocene)—**Sedimentary rocks correlative with Santa Fe Group, mapped where surface access was restricted in southwestern part of quadrangle. Probably consists of Loma Barbon Member of Arroyo Ojito Formation (unit Tou) east of Tamaya fault and Navajo Draw Member of Arroyo Ojito Formation (unit Ton) and Cerro Conejo Member of Zia Formation (unit Tzcc) west of Tamaya fault. Thickness unknown

**Zia Formation**

Tzcc **Cerro Conejo Member of Connell and others (1999) (Miocene)—**Pale-brown to yellowish-red, fine- to medium-grained, parallel bedded sandstone; light-gray to very pale brown, lithic-rich, fine- to coarse-grained eolian crossbedded sandstone; and brown and red siltstone and claystone; unit weakly indurated. Sandstone is moderately to well sorted; eolian crossbedded sandstone in large (1- to 2-m-high) sets; parallel bedded sandstone in beds 0.5–2 m thick, interbedded with rare thin (5–10 cm) granule pebble gravel beds. Mudstones generally thin (2–20 cm), but some as much as 1–1.5 m thick. One thin (≤10 cm), discontinuous ash bed is mapped in footwall of Tamaya fault just north of Jemez River. Mapped as Chamisa Mesa member of Santa Fe Formation by Soister (1952), as lower member of lower unnamed formation of Santa Fe Group by Spiegel (1961), as Santa Fe Formation by Smith and others (1970), and as Zia member of Santa Fe Formation by Kelley (1977). Probably correlative with unnamed member of Zia Formation of Tedford (1982) and Tedford and Barghoorn (1997), lower part of middle Santa Fe Group unit of Personius and others (2000), and Cerro Conejo Member of Zia Formation of Connell and others (1999) in Bernalillo NW quadrangle (Koning and Personius, 2002). In fault contact with unit Ton at Santa Ana fault and with unit Tou at Tamaya fault. Poor exposure and faulting complicates estimation of unit thickness, but apparent exposed thickness about 600 m

$Tzcc_c$ **Cerro Conejo Member of Connell and others (1999), cemented (Miocene)—** Undivided very pale brown (10YR 8/2) fine- to medium-grained, cross-bedded, well-sorted sandstone, pervasively cemented with silica and calcium carbonate in footwall of Santa Ana fault in northwest corner of quadrangle. Exposed thickness 35 m

Tzl **Chamisa Mesa and Piedra Parada Members, undivided (lower Miocene)—**Shown on cross section only. Consists of red, yellow, and buff, quartzose fluvial and eolian sandstone and siltstone, interbedded with green silty sandstone of Chamisa Mesa member, and pink, gray, and yellow, fine- to coarse-grained, quartzose eolian sandstone and minor muddy interdune sandstone of Piedra Parada member, mapped elsewhere in the region (Galusha, 1966; Gawne, 1981; Koning and others, 1998; Pazzaglia and others, 1998, 1999). Thickness about 700 m in Santa Fe Pacific #1 well, located about 5 km southwest of southwest corner of map area in adjacent Loma Machete quadrangle (Personius and others, 2000), but may thin to east

## Older bedrock

TKu **Lower Tertiary and Cretaceous rocks, undivided (Eocene and Cretaceous)—**Shown on cross section only. Sedimentary rocks of Eocene Galisteo Formation, upper Cretaceous Menefee Formation, Point Lookout Sandstone, and Mancos Shale. Penetrated in Santa Fe Pacific # 1 well, located about 5 km southwest of southwest corner of map area in adjacent Loma Machete quadrangle; total thickness of interval in well is 595 m (Black and Hiss, 1974)

**Contact—**Dashed where approximately located

**Fault—**Bar and ball on downdropped side (where known); tic indicates amount and direction of dip. Dashed where approximately located, dotted where concealed

**Aeromagnetic anomaly—**Analysis by authors of high-resolution aeromagnetic data from U.S. Geological Survey and SIAL Geosciences, Inc. (1997); linear anomalies mark probable locations of faults buried by surficial deposits (Grauch and Millegan, 1998; Grauch, 1999)

**Strike and dip of inclined bedding**

**Thin surficial deposit (upper symbol) covering older unit**

**Chronological sample locality—**Number referenced in text
**Tephra deposit**

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**Table 1.** Correlation chart for alluvial deposits of the Jemez River (upstream is to left), indicated by map unit symbols. Bold units are found on this map.

[Units in bold type shown on this map. Leaders (--) indicate deposit not mapped in quadrangle]

| Ponderosa quadrangle[1] | Jemez Pueblo and San Ysidro quadrangles[2] | Bernalillo NW quadrangle[3] | **Santa Ana Pueblo quadrangle** |
|---|---|---|---|
| Qt9 | Qt6 | Qaj6b | **Qaj6** |
| Qt7, Qt8 | Qt5 | Qaj6a | **Qaj6** |
| Qt5? | Qt4a? | Qaj5 | **Qaj5** |
| Qt5? | Qt5a, Qt4a? | Qaj4 | **--** |
| Qt4 | Qt4 | Qaj3 | **Qaj3** |
| Qt3 | Qt3 | Qaj2 | **--** |
| Qt2 | Qt2 | -- | **Qaj1** |

[1]Sources: Rogers (1996) and Rogers and Smartt (1996)
[2]Sources: Formento-Trigilio and Pazzaglia (1996; 1998), Formento-Trigilio (1997), Pazzaglia (1998), and Pazzaglia and others (1998)
[3]Source: Koning and Personius (2002)