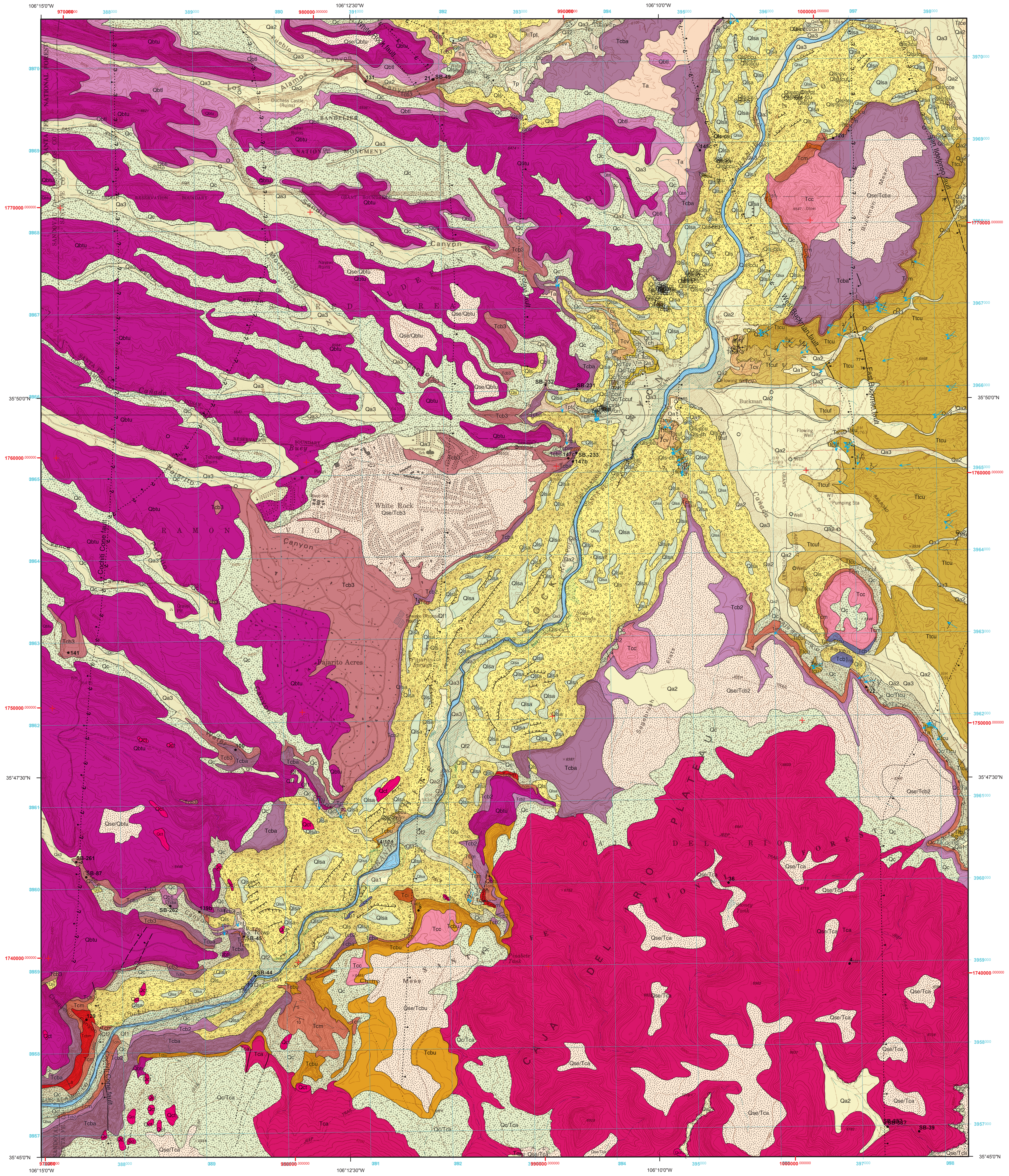
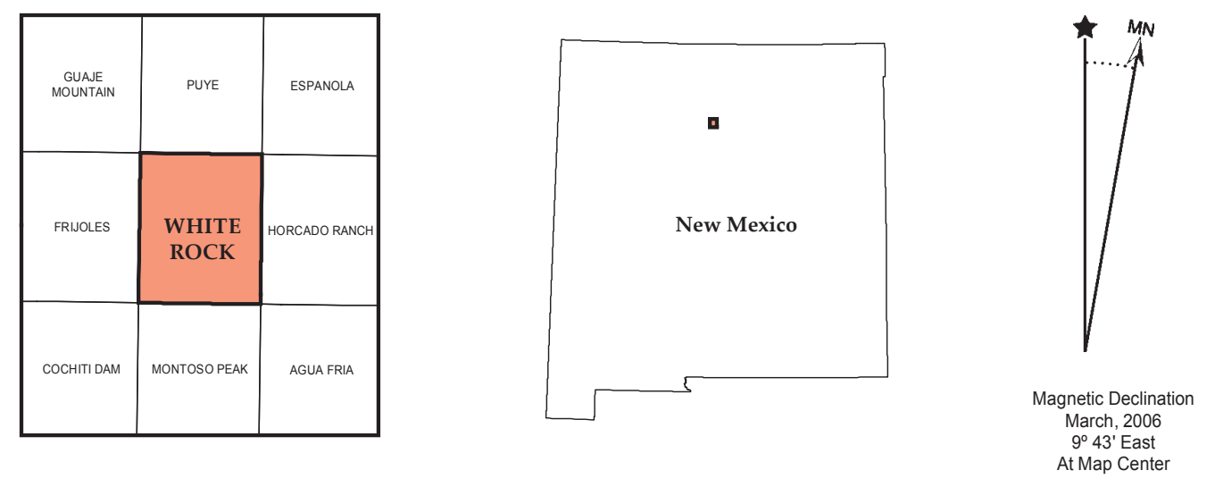
NMBGMR Open-File Geologic Map 149
Last Modified March 2018



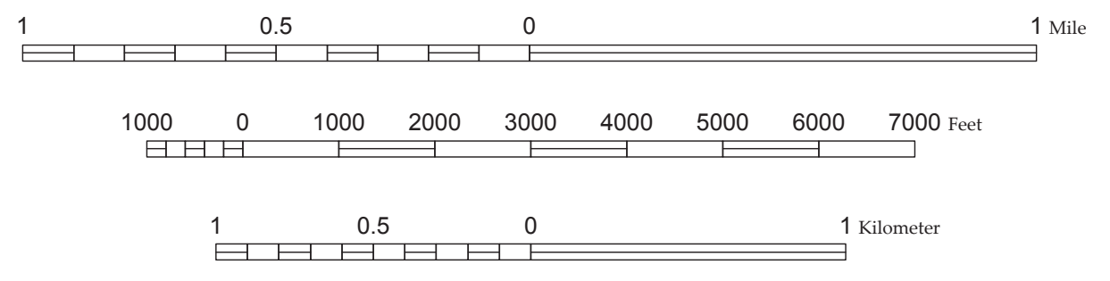
Base from U.S.Geological Survey 1984, from aerial photographs taken 1976. Field checked 1978. Map edited 1984.
1927 North American datum, Universal Transverse Mercator Projection
1000- meter UTM grid ticks, zone 13, shown in red



Magnetic Declination
March, 2006
9º 43' East
At Map Center

Quadrangle Location

1:24,000



This draft geologic map is preliminary and will undergo revision. It was produced from either scans of hand-drafted originals or from digitally drafted original maps and figures using a wide variety of software, and is currently in cartographic production. It is being distributed in this draft form as part of the bureau's Open-file map series (OFGM), due to high demand for current geologic map data in these areas where STATEMAP quadrangles are located, and it is the bureau's policy to disseminate geologic data to the public as soon as possible.

After this map has undergone scientific peer review, editing, and final cartographic production adhering to bureau map standards, it will be released in our Geologic Map (GM) series. This final version will receive a new GM number and will supercede this preliminary open-file geologic map.

DRAFT

Digital layout and cartography by the NMBGMR Map Production Group:
Phil L. Miller
David J. McCraw
Elizabeth H. Roybal

New Mexico Bureau of Geology and Mineral Resources

Open-file Geologic Map **149**

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*).

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

Geologic Map of the White Rock Quadrangle, Santa Fe, Sandoval, and Los Alamos Counties, New Mexico

May 2007

by
David P. Dethier[1] and Daniel J. Koning [2].

[1]*Department of Geosciences, Williams College, 947 Main Street, Williamstown, MA 01267*

[2] *NMBGMR, New Mexico Tech, 801 Leroy Place, Socorro, NM 87801-4796*

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 may be based on any of the following: 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.

Cross sections are constructed based upon the interpretations of the author made from geologic mapping, and available geophysical, 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.

The map has not been reviewed according to New Mexico Bureau of Geology and Mineral Resources standards. The contents of the report and map should not be considered final and complete until reviewed and published by the New Mexico Bureau of Geology 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.

Description of Map Units

▨ 01-01-00-00-00—unit—Qa3—Alluvial deposit (Holocene)—Cross-bedded to planar-bedded sand and pebbly sand and thin beds of silty sand exposed along the Rio Grande, along active channels of tributary arroyos, and on adjacent low (<4 m; <13 ft) surfaces. Beds generally <0.5 m (<1.5 ft) thick. Includes areas of late Pleistocene deposits in uplands west of the Rio Grande. Exposed thickness 2-4 m (6.5-13 ft). Actual thickness probably >10 m (>33 ft) along the Rio Grande and Cañada Ancha. Base not exposed. Soils thin (<0.5 m; <1.5 ft) with A/C or Bw horizons on low terraces west of the Rio Grande; stage II carbonate in the eastern part of the area.

▨ 01-02-00-00-00—unit—Qa2—Alluvial deposit (Holocene and late Pleistocene)—Well-sorted cobble to boulder gravel, cross-bedded sand, and thin-bedded sand and silty sand beneath terraces along the Rio Grande; cobble gravel along Los Alamos Canyon and other steep tributaries; sand and silty sand near Cañada Ancha; and gravelly sand and eolian silt on upland parts of the Cerros del Rio. Lies beneath surfaces 5-20 m (16-66 ft) above present drainages. Thickness probably 4-15 m (13-50 ft). Overlies and truncates rocks of the Santa Fe Group, landslide deposits, and older alluvium. Soils are 0.5-1.0 m (1.5-3 ft) thick and display stage II or stage III carbonate at dry sites and Bw or Bt horizons at wetter sites.

▨ 01-03-00-00-00—unit—Qa1—Alluvial and lacustrine(?) deposit (middle? Pleistocene)—Well-sorted cobble to boulder gravel and rhythmically bedded fine sand, silt, and silty clay exposed beneath terrace remnants 25-45 m (80-150 ft) above the Rio Grande. Contact relations best exposed near the mouth of Cañada Ancha, where 15 m (50 ft) of gravelly deposits fill channels cut into the Santa Fe Group (Section E of Dethier, 1997). Laminated to thin-bedded sediment 15-20 m (50-66 ft) thick lies over the gravel. Thickness mainly 10-30 m (33-100 ft). Overlies and truncates Santa Fe Group and landslide deposits. One surface west of Chino Mesa is overlain by El Cajete tephra (~50-60 ka; Reneau et al., 1996). Soil at that locality is 0.8-1.3 m (2.5-4 ft) thick and contains weak stage IV carbonate; soils on other remnants are thinner, and carbonate development is stage III.

▨ 01-04-00-00-00—unit—Qf2—Alluvial-fan deposit (Holocene and late Pleistocene)—Cross-bedded, poorly sorted cobble to boulder gravel deposited mainly along White Rock Canyon by high-gradient, ephemeral channels. Includes debris flows along channels that drain Bandelier Tuff. Most small fan deposits west of the Rio Grande are mapped as Qa3 or Qc. Thickness 4-8 m (13-26 ft). Generally overlies landslide deposits. Interfingers with and merges laterally with alluvial deposits. Soils are thin to absent on active areas of fans and <0.8 m (<2.5 ft) thick with stage II or weak stage III carbonate elsewhere.

▨ 01-05-00-00-00—unit—Qf1—Alluvial-fan deposit (late to middle Pleistocene)—Cross-bedded, poorly sorted cobble to boulder gravel and poorly sorted, matrix-rich debris-flow deposits that form remnants 5-15 m (16-50 ft) above adjacent Qf2 deposits. Thickness 4-15 m (13-50 ft), but most contacts obscured by colluvium. Overlies landslide deposits and Santa Fe Group. Overlain by El Cajete tephra (~50-60 ka; Reneau et al., 1996) along Water Canyon. Soils poorly exposed but locally thicker than 1.0 m (3 ft), exposing stage III or weak stage IV carbonate.

▨ 01-06-00-00-00—unit—Qc—Colluvial deposit (Holocene to middle Pleistocene)—Rockfall, debris-flow, and poorly sorted alluvial deposits at the bases of cliffs, particularly along White Rock Canyon. Texture and clast lithology are variable. Includes thin (<2 m; <6.5 ft) alluvial deposits west of the Rio Grande and, in places, El Cajete tephra (~50-60 ka; Reneau et al., 1996). Thickness generally 4-10 m (13-33 ft) but locally along White Rock Canyon exceeds 25 m (82 ft). Overlies Bandelier Tuff west of White Rock; elsewhere overlies basaltic flows, phreatomagmatic deposits, and landslides. Soils thin (<0.5 m; <1.5 ft) and weakly developed at most locations, but lenses of El Cajete tephra, strong Bt (west of Rio Grande) or K horizons (White Rock Canyon and east), and buried soils (Birkeland, 1999) demonstrate that deposits are polygenetic and locally older than late

▨ 01-07-00-00-00—unit—Qse—Thin sheetflood and eolian deposit (Holocene to late Pleistocene)—Light yellowish-brown to pale brown to brownish-yellow, silt and very fine- to medium-grained sand mixed with varying amounts of coarser sand and gravel. This thin unit caps high-level surfaces. The underlying unit is also shown. Weakly to moderately consolidated. Qse is less than 4 m-thick.

▨ 01-08-00-00-00—unit—Qls—Landslide deposit (Holocene to late Pliocene)—Massive slumps and debris flows rich in basaltic-boulder gravel mainly exposed along White Rock Canyon, north of Chaquehui Canyon, and along Cañada Ancha. Most slides are inactive. Deposits consist of massive slump blocks with coherent internal stratigraphy near canyon rims and progressively deformed slumps and debris flows closer to the Rio Grande. Dips in massive slump blocks range from 8° to 70° toward head scarps. Failures occurred along (1) steeply dipping planes rooted in the Santa Fe Group, (2) subhorizontal planes in clayey silt layers found at several levels of Pliocene fluvial and lacustrine deposits (Ta), and (3) steep walls of maars. Limited areas of autochthonous rocks are included in areas mapped as Qls. Slide material overlies rocks of the Santa Fe Group at most sites. At several locations undisturbed late Pliocene deposits lie stratigraphically above landslide deposits (Section H of Dethier, 1997). Morphology of most failures and inclusion of Bandelier Tuff in some suggest that slides were active in early to middle Pleistocene time but that many became stable in the middle to late Pleistocene. El Cajete tephra (~50-60 ka; Reneau et al., 1996) lies on landslide deposits south of the White Rock area. Soils are generally 0.8-1.4 m (2.5-4.5 ft) thick. Carbonate morphology (Birkeland, 1999) is stage IV at some sites, but stage III carbonate is present in most exposures. Cation ratios in rock varnish (Dethier et al., 1988) at two sites suggest that those landslides stabilized >250 ka.

▨ 01-09-00-00-00—unit—Qlsa—Alluvium, eolian deposits, and colluvium on the upper surfaces of landslides (Holocene to upper Pleistocene)—Flat to gently sloping areas on the upper surfaces of slumps that are sites of active fluvial and colluvial processes (near Pajarito Springs and southwest of Otowi Bridge, for example). These areas are covered with >4 m (>13 ft) of fluvial, eolian, and colluvial deposits.

▨ 03-01-00-00-00—unit—Ta—Ancha Formation (upper Pliocene)—Brownish-yellow to light-yellowish-brown sand and gravel under the Cerros del Rio volcanic flows (units Tcba and Tcb2) and phreatomagmatic deposits (Tcm); unit is also interlayered with these volcanic flows. Overlies the Puye Formation (Tp) and local basalt flows near the Rio Grande; to the east, the Ancha Formation unconformably overlies Miocene-age Cuarteles Member deposits of the Tesuque Formation (Koning and Maldonaldo, 2001; Koning et al., 2002). At a description site near the eastern quadrangle boundary (UTM coordinates: 3,960,550N, 398,125S, ± 20 m; zone 13, NAD 27), the sediment is gravelly sand with very thin to thin, planar to lenticular beds. The gravel here is generally poorly sorted pebbles with 5-20% cobbles; clast composition is: 1-5% quartzite, trace amphibolite, locally trace basalt or andesite clasts, and 95-99% granite. Cobbles and coarse to very coarse pebbles are commonly rounded to subrounded, and very fine to medium pebbles are subrounded to subangular. Sand is generally coarse to very coarse, subangular to subrounded, poorly to moderately sorted, and arkosic (with 15% lithics that include 0.5% volcanic and olivine grains). At a description site near Caja del Rio Canyon (UTM coordinates: 3,962,350 N, 397,150 S, ± 20 m; zone 13, NAD 27), the sediment has 15-25% thin to thick channel-fills of sandy pebbles to pebbly sand, and the gravel consists of clast-supported, granitic pebbles; the non-channel sediment is comprised primarily of slightly silty very fine- to very coarse-grained sand in thin to thick, tabular beds, or otherwise massive. Sediment is weakly to moderately consolidated, and generally non-cemented except for the bases of some channels. Unit locally includes silty and clayey lacustrine sediment near the Rio Grande. The unit also includes thin-bedded silt and silty sand, and beds of phreatomagmatic deposits and debris flows exposed along Cañada Ancha and north of Water Canyon, west of the Rio Grande. Paleocurrent directions measured on channels and gravelly crossbeds range from 180° to 270° and average about 220°. The unit is correlated with the Ancha Formation in the Santa Fe embayment to the south (Koning et al., 2002; Koning and Maldonado, 2001) 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. Also correlates with older alluvium of Griggs (1964). The unit contains lenses of dacitic tephra along Cañada Ancha. Manley (1976) reported an age of 2.7 Ma of one lense some 8 km (5 mi) east of Caja del Rio Canyon. Age elsewhere is likely Pliocene considering stratigraphic relations with Pliocene-age Cerros del Rio volcanic flows and phreatomagmatic deposits. The thickness of 1-30 meters (commonly less than 5 m, although generally not mapped where it is this thin).

▨ 03-02-00-00-00—unit—Tp—Puye Formation fanglomerate (Pliocene; Griggs, 1964)—Weakly lithified pebble to boulder gravel, boulder-rich debris flows, massive to planar-bedded sand, thin (<1 m; <3 ft) beds of dacitic tephra and pumiceous alluvium, and beds of fine sand and silt. Exposed west of the Rio Grande except for an isolated outcrop south of the mouth of Cañada Ancha (Section F of Dethier, 1997). Gravel beds generally 0.5-3.0 m (1.5-10 ft) thick. Debris flows range from 0.3 m (1 ft) to about 5.0 m (16 ft) thick. Clast and matrix lithology mainly dacite derived from the Tschicoma Formation of the Jemez Mountains, but Precambrian material composes >30% of some fluvial units. Thickness 5-30 m (16-100 ft). Fills channels cut in rocks of the undivided Santa Fe Group and, along with Los Alamos Canyon, into cobble gravel of the Puye Formation, Totavi Lentil (Griggs, 1964). Exposed beneath quartzite-rich cobble gravel (Totavi Lentil) or phreatomagmatic deposits at most locations. Paleocurrent directions measured on channels, gravelly crossbeds, and imbricated cobbles range from about 90° to 200°and average about 150°, slightly south of the trend of present canyons. Faulted locally near the mouth of Ancho Canyon; otherwise undeformed. Pumiceous Puye gravel 8 km (5 mi) north-northwest of Otowi Bridge gave a fission-track age of 2.9 Ma (Table 1 of Dethier, 1997). Turbeville et al. (1989) report that the upper part of the Puye Formation may be as young as 1.7±0.1 Ma northwest of the White Rock quadrangle.

▨ 03-03-00-00-00—unit—Tpt—Puye Formation, ancestral Rio Grande facies (Pliocene; Totavi Lentil of Griggs, 1964)—Slightly lithified pebble to cobble gravel-rich in clasts of Precambrian rock, sand, and thin beds of silty sand west of the Rio Grande and at one outcrop south of the mouth of Cañada Ancha, east of the Rio Grande (Section F of Dethier, 1997). Coarse units are 0.5-3.0 m (1.5-10 ft) thick, cross-bedded, and locally planar bedded. Clasts generally >80% quartzite and other resistant lithologies from northern New Mexico, but clasts from the southern Sangre de Cristo Range are common locally. Thickness 5-45 m (16-150 ft). Maximum thickness and most extensive exposures in Sandia and Mortandad Canyons (Section D of Dethier, 1997). Fills channels in and locally interbedded with Puye fanglomerate except along Los Alamos Canyon, where it overlies Santa Fe Group. Lies beneath landslide deposits, Pliocene alluvium, or phreatomagmatic deposits at most exposures. Paleocurrent directions measured on channels, gravelly crossbeds, and imbricated cobbles range from 160° to 220° and average about 180°. Mainly undeformed. Near the mouth of Ancho Canyon (Section J of Dethier, 1997) lies under a basaltic flow (Tcb2) reported by Bachman and Mehnert (1978) to have an age of about 2.6 Ma (Table 1 of Dethier, 1997).

▨ 04-01-00-00-00—unit—Qct—El Cajete tephra (late? Pleistocene)—Pumiceous lapilli of rhyolitic composition. Forms surface layer in isolated outcrops as thick as 40 cm in southwest part of map area and <5 cm in northeast part of map area. Most exposures have been reworked by slope processes. Derived from the El Cajete vent in the Valles caldera; previously thought to be about 150,000 yrs old (Self et al., 1988) but may be as young as 50 ka (Reneau et al., 1996).

▨ 04-02-00-00-00—unit—Qbtu—Bandelier Tuff, upper part (early Pleistocene)—Slightly welded pyroclastic flows (Tshirege Member) and a thin (<1 m; <3 ft) pumiceous fall unit (Tsankawi Pumice Bed), both of rhyolitic composition. Dominates surfaces west of the Rio Grande and forms one prominent outcrop east of the Rio Grande (Section H of Dethier, 1997). Two to five pyroclastic flows separated by pumice concentrations or thin, sorted partings are present along deep canyons west of the Rio Grande. Thickness generally <60 m (<200 ft) but about 90 m (300 ft) east of the Rio Grande. As mapped, may include exposures of lower Bandelier Tuff, which it lies above. Paleoflow direction to the east. Derived from the Valles caldera west of the map area. Age 1.2 Ma (Izett and Obradovich, 1994).

▨ 04-03-00-00-00—unit—Qbtl—Bandelier Tuff, lower part (early Pleistocene)—Slightly welded pyroclastic flows (Otowi Member) of pumiceous rhyolite and a compound pumiceous fall unit (Guaje Member) as thick as 6 m (20 ft), also of rhyolitic composition. Best exposed in deep canyons west of the Rio Grande, particularly in Los Alamos (Section A of Dethier, 1997) and Sandia Canyons. One or two thick flows overlie the Guaje Member, which is absent at many exposures. Maximum thickness about 50 m (165 ft). Lies beneath upper Bandelier Tuff. Fills canyons as deep as 50 m (165 ft) cut into tholeiitic olivine basalt (Tcb3), basaltic andesite (Tcba), and phreatomagmatic deposits. Derived from the Valles caldera west of the map area. Age is 1.6 Ma (Izett and Obradovich, 1994).

▨ 04-04-00-00-00—unit—Tcdrv—Cerros del Rio Volcanic Field Rocks, undivided (Pliocene; cross section only)—Composed mainly of tholeiitic olivine basalt flows, pillow basalt, and palagonitic breccia (unit Tcb3) that overlie olivine-hypersthene basaltic andesite, andesite, and hawaiite (unit Tcba). Other volcanic rock units of this volcanic field (e.g., Tcc, Tcm, Tcbm, Tcbu) may also be present.

▨ 04-05-00-00-00—unit—Tcc—Cinder cone deposits of the Cerros del Rio volcanic field (Pliocene)—Oxidized cinders, agglomerate, and minor areas of phreatomagmatic deposits composed of olivine basaltic andesite and basalt. Contains 2-8% quartz xenocrysts. Exposed mainly along the Rio Grande and at the Caja del Rio Canyon. Granular surface deposits, dissected cinder cones, and slightly lithified exposures in canyon walls; best exposed near La Mesita (Section C of Dethier, 1997). Massive to planar bedded, locally rich in lava and accidental bombs <0.2 m (<0.5 ft) in diameter. Maximum thickness about 60 m (197 ft). Lies above phreatomagmatic deposits at many exposures. Age not closely bounded but probably late Pliocene.

▨ 04-06-00-00-00—unit—Tcm—Phreatomagmatic deposits of the Cerros del Rio volcanic field (Pliocene)—Bedded to massive fall, surge, and flow deposits composed of basaltic tuff and cinders and accidental fragments of the Santa Fe Group. Thickest exposures along the Rio Grande and Cañada Ancha (Section G of Dethier, 1997). Fall beds, 0.3-3.0 m (1-10 ft) thick, are composed mainly of ash and lapilli containing sparse bombs of accidental fragments and basaltic fragments. Surge beds are planar and cross-bedded, locally rippled, coarse silt to pebbly sand, generally 0.1-0.4 m (0.3-1.3 ft) thick. Flow deposits are mainly matrix-rich pebble to boulder gravel in discontinuous beds 1-4 m (3-13 ft) thick. Near maars, the concentration of accidental fragments decreases upsection. Locally sheared, slumped, or brecciated. As much as 60 m (200 ft) thick near maars such as La Mesita (Section C of Dethier, 1997), "Buckman maar" (Section G of Dethier, 1997; Aubele, 1978), and "Montoso maar" (Aubele, 1978). Generally lies above Puye Formation, undivided Santa Fe Group, and interlayered basalt and phreatomagmatic deposits. Lies beneath flows of basaltic andesite, basalt, or cinder, and agglomerate deposits. In Ancho Canyon (Section J of Dethier, 1997), lies on Tcb2, which gave an age of 2.6 Ma (Table 1 of Dethier, 1997), but stratigraphic relations suggest deposits along Cañada Ancha may be somewhat older. Minimum age not well known.

▨ 04-07-00-00-00—unit—Tcbm—Basalt and interlayered phreatomagmatic deposits of the Cerros del Rio volcanic field (Pliocene)—Thin (<10 m; <33 ft) basaltic flows interlayered with phreatomagmatic basaltic rocks, mainly surge and flow deposits, and mapped in the southern part of the map area near the Rio Grande. Multiple baked layers exposed in Chaquehui Canyon (Section K of Dethier, 1997) and along the north margin of Chino Mesa (Section I of Dethier, 1997). Maximum thickness of 50 m (165 ft). Lies on phreatomagmatic deposits and Santa Fe Group. Lies beneath phreatomagmatic deposits and basalt flows. One flow in Chaquehui Canyon gave an age of 2.78±0.04 Ma (Table 1 of Dethier, 1997).

▨ 04-08-00-00-00—unit—Tci—Basaltic intrusion of the Cerros del Rio volcanic field (Pliocene)—Olivine, pyroxene basaltic andesite containing quartz xenocrysts. Forms fine-grained dikes and small, shallow intrusions, with sharp chilled margins, associated with maars and cinder cones along the east margin of White Rock Canyon. Most prominent intrusion is a small plug capped with agglomerate at the west edge of Chino Mesa. Aubele (1978) suggested that a sill lies beneath cinders and agglomerate along the west margin of Sagebrush Flats, and the andesitic exposure in Water Canyon (location 100) may be intrusive. Dikes generally vertical and <10 m (<33 ft) wide. Unit intrudes phreatomagmatic or cinder-cone deposits. Not dated but probably middle or

▨ 04-09-00-00-00—unit—Tca—Andesite of the Cerros del Rio volcanic field (early Pleistocene? and late Pliocene)—Massive, steep-sided flows, agglomerate, and domes of hypersthene andesite (Table 2) exposed in the southeast part of the map area. Strongly sheeted near flow surface; brecciated at bases. The thickness of flows >20 m (>66 ft). Total thickness unknown but likely exceeds 150 m (500 ft) in the southeast map area. Lies above basaltic andesite and hawaiite and lies beneath Quaternary Guaje Pumice Bed (Qbtl). Manley (1976) reported an age of about 2 Ma (Table 1 of Dethier, 1997) from an andesite flow 5 km (3 mi) east of the eastern edge of the map area. Age of youngest domes unknown.

▨ 04-10-00-00-00—unit—Tcb3—Basalt of the Cerros del Rio volcanic field (late Pliocene)—Tholeiitic olivine basalt flows, pillow basalt, and palagonitic breccia exposed west of the Rio Grande north of Chaquehui Canyon. Flows thin (<10 m; <33 ft) with sharp to rubble-rich contacts. Subaerial thickness <30 m (<100 ft); maximum thickness ~80 m (~260 ft) in Mortandad Canyon (Section D of Dethier, 1997). The unit overlies lacustrine or sandy fluvial sediment (Ta) north of White Rock and older basaltic flows to the south (Section J of Dethier, 1997). Thin (<3 m; <10 ft) fluvial and lacustrine deposits separate the basalt from overlying lower Bandelier Tuff at some sites (Sandia Canyon, for instance). Flow directions measured on foreset deposits of pillow basalt in Los Alamos, Sandia, Mortandad, Buey, and an unnamed canyon range from about 70° to 150° (average about 110°). Topset-foreset contacts in deltas of basaltic debris at 6,200±25 ft elevation suggest that a lake dammed near Chaquehui Canyon persisted in White Rock Canyon during the eruption of much of the basalt. Basalt originated from vents buried by Bandelier Tuff west and northwest of the map area. A sample from the basalt exposed near the intersection of Pueblo and Los Alamos Canyons (Section A) in the northwest map area gave an Ar/Ar age of 2.33±0.08 Ma (Table 1 of Dethier, 1997), and flows capping Ancho Canyon and underlying White Rock gave ages between 2.5 and 2.4 Ma.

▨ 04-11-00-00-00—unit—Tcba—Basaltic andesite and related flows of the Cerros del Rio volcanic field (Pliocene)—Massive flows of olivine-hypersthene basaltic andesite, andesite, and hawaiite, containing as much as 7% quartz, exposed along the Rio Grande. Forms thick (>30 m; >100 ft locally) flows with brecciated bases and cooling joints 4 m (13 ft) in diameter. As much as 170 m (560 ft) thick along the Rio Grande at the south end of the map area. Fills canyons as deep as 40 m (130 ft) southwest of Otowi Bridge (Section B of Dethier, 1997), where flows lie on top of phreatomagmatic deposits (Tcm) and the Puye Formation (Tp and Tpt) and lie beneath fluvial and lacustrine sediment (Ta). The unit overlies basalt (Tcb2), phreatomagmatic deposits and agglomerate, and the Puye Formation south of Water Canyon west of the Rio Grande (Sections J and K of Dethier, 1997) and south of Sagebrush Flats east of the Rio Grande. Outcrop pattern and channel orientation suggest that lava flowed mainly southwest and south from vents near La Mesita, on Sagebrush Flats between Water and Ancho Canyons, and probably in the vicinity of Chino Mesa (Aubele, 1978). The Otowi flow of Galusha and Blick (1971) gave an age of 2.57±0.02 Ma (location 145a), and a massive flow probably derived from La Mesita (location 145c) gave an age of 2.55±0.02 Ma. The flow between Water and Ancho Canyons gave an Ar/Ar age of 2.3±0.3 Ma. Age bracketed by the 2.6±0.4 Ma age of stratigraphically lower Tcb2 near Ancho Canyon (Table 1 of Dethier, 1997) and the 2.33 Ma age of overlying Tcb3 along Los Alamos Canyon (Table 1 of Dethier, 1997).

▨ 04-12-00-00-00—unit—Tcb2—Basalt flows of the Cerros del Rio volcanic field (Pliocene)—Thin (<10 m; <33 ft) flows of olivine basalt (hawaiite, see Table 2 of Dethier, 1997) containing <5% quartz xenocrysts and exposed mainly beneath large areas of Sagebrush Flats (Sections F and G of Dethier, 1997) and along the east boundary of White Rock quadrangle. Brecciated and sparse baked zones between flows. The unit's maximum thickness is ~70 m (~230 ft) near Chino Mesa. The unit overlies phreatomagmatic deposits (Tcm) and Pliocene alluvial deposits (Ta) along Cañada Ancha, at the White Rock Overlook, and in Pajarito Canyon. A latite-andesite flow (Baldridge, 1979) is included with Tcb2 lies above the Totavi Lentil (Tpt) in Ancho Canyon. Andesite and basaltic-andesite flows (Tca, Tcba) and Quaternary alluvium lie above hawaiite in the Sagebrush Flats area, whereas Tcb2 flows lie beneath basaltic andesite (Tcba) or olivine basalt (Tcb3) at most exposures west of the Rio Grande. Probable vent areas are marked by cinder and agglomerate deposits from Sagebrush Flats south to Chino Mesa; younger basaltic and andesitic flows probably cover other vents. A flow exposed on the south rim of Caja del Rio Canyon (location 122) gave an age of 2.49±0.03 Ma (Table 1 of Dethier, 1997). An age of about 2.6 Ma (Table 1 of Dethier, 1997) was obtained by Bachman and Mehnert (1978) in Ancho Canyon.

▨ 04-13-00-00-00—unit—Tcb1—Basaltic flows of the Cerros del Rio volcanic field (Pliocene?)—Olivine basalt flows and more evolved rocks exposed within 20 m (66 ft) of the present level of the Rio Grande and Cañada Ancha. Flows are thin to massive and include a lava lake (Caja del Rio Canyon) and some poorly exposed outcrops along the Rio Grande from Water Canyon to Chaquehui Canyon. Thickness 20-95 m (66-310 ft). The latter flows lie above deformed phreatomagmatic deposits (Tcm) and beneath cinders and agglomerate (Tcc). Sources of the flows are buried, probably diverse (Table 2 of Dethier et al., 1997), and may lie in a stratigraphic position similar to subsurface volcanic rocks reported by Griggs (1964), some as old as middle Miocene (WoldeGabriel et al., 1996). A flow near the mouth of Water Canyon gave an age of 2.50±0.04 (Table 1 of Dethier,

▨ 04-14-00-00-00—unit—Tcbu—Basalt, undivided, of the Cerros del Rio volcanic field (Pliocene)—Olivine basalt, hawaiite, and basaltic andesite containing 2-8% quartz xenocrysts and exposed in the southern part of the map area (Section I of Dethier, 1997). Thin to massive flows. Thickness from 20 m to >150 m (from 66 ft to >490 ft) in the southern map area. The unit lies above phreatomagmatic deposits (Tcm). Generally lies beneath Tcba and may be equivalent, in part, to basalt mapped as Tcb2. Montoso maar (Aubele, 1978) was the probable source for much of this unit. Age unknown but probably middle to late Pliocene.

▨ 05-01-00-00-00—unit—Tmb—Tertiary mafic basalt (late Miocene; cross section only)—Gray to dark-gray, variably vesicular basalt that is olivine- ± plagioclase-phyric and commonly coarse-grained. Variable alteration to clays. Multiple flows present. Described using cuttings reported from well PM-4 (WoldeGabriel et al., 2006), R-10 (David Broxton and David Vaniman, written commun., 2006), and R-22 (Ball et al., 2002). Dated fragments of this unit from wells near White Rock (PM-4 and R-9) have returned ages ranging from 8.5-10.0 Ma (WoldeGabriel et al., 2001; 2006; Broxton et al., 2001).

▨ 05-02-00-00-00—unit—Tcvwp—Chamita Formation, Vallito Member interbedded with western piedmont deposits (upper Miocene)—Only found in outcrop at the mouth of Ancha Canyon. Light-brown to reddish-yellow (7.5YR 6/4-6) silt, very fine- to fine-grained sandstone, and minor clay intercalated with ~25% coarse-grained channel fills. The channel-fills are >10 m wide, 1 to 2 m thick, and consist of pebbly sand with lesser sandy pebble conglomerate. The sand is commonly planar-laminated. Pebbly beds are thin to medium and planar to lenticular. Pebbles are subrounded to rounded, poorly to moderately sorted, and clast-supported. Gravel is composed of felsic to intermediate volcanic rocks with 0.5–1% quartzite; the volcanic rocks have a large number of monolithic dacites presumed to be derived from the Jemez Mountains. Channel-fill sand is fine- to very coarse-grained and moderately to poorly sorted. Deposits are non- to weakly cemented. Greater than 30 m-thick.

▨ 05-03-00-00-00—unit—Ttcuf—Tesuque Formation, fine-grained Cuarteles Member east of Rio Grande (Upper Miocene)—Pink to light-brown to reddish-yellow to light-yellowish brown, silty very fine- to fine-grained sandstone, siltstone, and mudstone. Coarse channel-fills of pebbly sandstone and sandy-pebble-conglomerate comprise about 3–25% of the unit. Fine-grained sediment outside of coarse-grained channel-fills is in very thin to thick, tabular beds that may be internally laminated. 1–5% muscovite flakes locally are present. Sparse cross-laminations up to 40 cm-tall may possibly represent eolian dunes. Sand is generally very fine- to medium-grained, an arkose, well sorted, and subangular to subrounded. There is 0.5–1%, very thin to thin, brown to light-brown (7.5YR 5-6/4) claystone beds. Coarse-grained channel-fills are scattered, lenticular to ribbon-shaped, and up to 10–100 cm-thick; locally they these channel-fills are stacked as to form thicker complexes. The internal bedding of the channels is very thin to thin, and planar to lenticular to cross-stratified. The pebbles are moderately to poorly sorted, subangular to subrounded, and granitic (with trace to 1% yellowish Paleozoic siltstone and limestone, quartzite, and gneiss). Channel-fill sand is fine- to very coarse-grained, subangular to subrounded, poorly to well sorted, and an arkose. Individual channels are up to 35 cm-deep and have westward-orientated paleoflow indicators. Channels-fills may fine-upward from pebbly to sandy sediment; sorting may become better upwards as well. Very thin to medium, lenticular, isolated channels also are present within the fine-grained sediment (generally 3–10% of the volume). Isolated channels tend to be strongly to moderately cemented, whereas laterally extensive and thick channel complexes are generally not as cemented. The finer, non-channelized sediment of the unit is moderately to well consolidated and weakly cemented by calcium carbonate. Unit possesses 1–3% weakly developed paleosols with reddish Bw horizons 20–30 cm thick. Interpreted to represent a generally low-energy alluvial environment where the distal alluvial slope transitioned to the flat basin floor. This unit grades eastward and upward into coarser-grained Cuarteles Member. In the subsurface, this unit interfingers westward with the Cejita Member (Tesuque Formation) and the Vallito Member (Chamita Formation). Unit progrades westward over the Vallito Member. Up to 50 m-thick.

▨ 05-04-00-00-00—unit—Tccuf—Chamita Formation, fine-grained Cuarteles Member west of the Rio Grande (Upper Miocene)—Strata are similar to that of the fine-grained Cuarteles Member of the Tesuque Formation but are located west of the Rio Grande. Here, the Cuarteles Member interfingers westward with Vallito Member and the Hernandez Member of the Chamita Formation.

▨ 05-05-00-00-00—unit—Ttcu—Tesuque Formation, Cuarteles Member (Upper Miocene)—Sandy pebble-conglomerate and pebbly sandstone comprising coarse channel-fill complexes, with subordinate slightly clayey-silty sand containing <5% pebbles that were deposited by lower-energy flow outside of confined channels—the latter is referred to below as the “finer sediment” of this unit. Interbedded within this unit are sparse beds of coarse black ash and white coarse ash-lapilli, which are described below. Channel-fill complexes may be up to ~ 2 m thick and commonly very pale brown to light yellowish brown to pink in color. Bedding within the channel-fill complexes (from most to least common) is lenticular, planar, U-shaped, and cross-stratified (up to 20 cm-thick foresets), and generally the beds are very thin to medium (with internal planar-laminations); bedding becomes more planar westward where this unit grades into Ttcuf. Margins of individual channels are up to 90 cm tall but commonly 20–40 cm tall. Channel complexes may fine-upwards from gravel- to sand-dominated sediment. Pebble conglomerate is clast-supported and has 0–5% cobbles (average size of largest clasts are 11 x 8 cm). Pebbles are poorly to moderately sorted and mostly subangular (some subrounded). Clasts are composed of granite with trace to 1% yellowish Paleozoic limestone and siltstone, trace quartzite, trace chert, 0.5–2% gneiss, and trace amphibolite. Channel sand ranges from fine- to very coarse-grained but mostly is medium- to very coarse-grained, angular to subangular (mostly subangular), poorly to moderately sorted, and an arkose. 1–15% of individual channel complexes are strongly to moderately cemented by calcium carbonate; the rest is weakly to non-cemented. The non-cemented to weakly cemented channel sediment may locally have up to 5–8%(visual estimate) clay in the gravel and sand interstices, and is generally weakly to moderately consolidated; where clay is present, channel-fills have a reddish yellow color.
clayey-silty to clayey-silty (visual estimate of 1–10% clay + silt) sand with <10% scattered pebbles.
[illegible] sediment is reddish-yellow to light brown to pink. This sediment is generally massive but may locally be very thinly to thickly, tabular-bedded (bedding is poor) or planar-laminated. The sand is very fine- to very coarse-grained but mostly very fine- to medium-grained, poorly to moderately sorted, subangular to subrounded, and an arkose. This sediment is weakly to well consolidated. Within this sediment is 1–15% very thin to thin, lenticular beds of medium- to very coarse-grained, arkosic sandstone and granitic pebble-conglomerate. Locally, there are sparse beds of pale brown (10YR 6/3), silty very fine- to medium-grained sand that is well-sorted and arkosic. These deposits locally grade laterally into coarse deposits similar to those seen in channels, but buttress margins with older channel deposits have not been observed. The finer sediment may represent small aggradational lobes deposited on the alluvial slope at the mouths of channels. They are commonly scoured and inset by the coarse channel complexes.
of this unit and commonly are preserved at or near the top of the finer sediment; less commonly,
[illegible] coarse channel deposits. These soils are characterized by a reddish yellow (5YR 6/6), 10–30 cm-thick Bw or Bt horizons with a sharp upper contact and a gradational lower contact (over 2–6 cm). Locally, these reddish horizons are underlain by whitish to pinkish Bk horizons 10–50 cm-thick possessing Stage I carbonate morphology. On the south end of Buckman Mesa, the abundance of soils increases up-section from 1–5% of total sediment volume.
300–400 m thick.
Unit overlies and grades westward into unit Tccuf, so it is of equivalent age or younger.

▨ 05-07-00-00-00—unit—Ttce—Cejita Formation, Tesuque Formation (middle to upper Miocene)—Only exposed on the northeast slope of Buckman Mesa, where it grades upward into fine-grained Cuarteles Member of the Tesuque Formation. Here, the Cejita Member consists of sandy and gravelly channel-fills that are extensive, very thinly to thinly cross-stratified (up to ~ 1m-thick foresets) within 1–2 m-thick channel-fills of pebbly very fine- to very coarse-grained sand and sandy pebble-cobble conglomerate. Clast lithologic types 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 from the east). There may be 10–90% pink-gray dacites and rhyolites together with light gray dacites-andesites(?), probably representing mixing and interfingering with the Vallito Member to the west. Clast imbrication is approximately due south (+/- 25°). Subsurface data also indicates that the Cejita Member grades westward into the Vallito Member (Chamita Formation) and eastward into the Cuarteles Member (Tesuque Formation). Age of base is ca, 13.2 Ma (Koning et al., 2005). The exposed thickness of 40–45 m; subsurface thickness of 125–135 m.

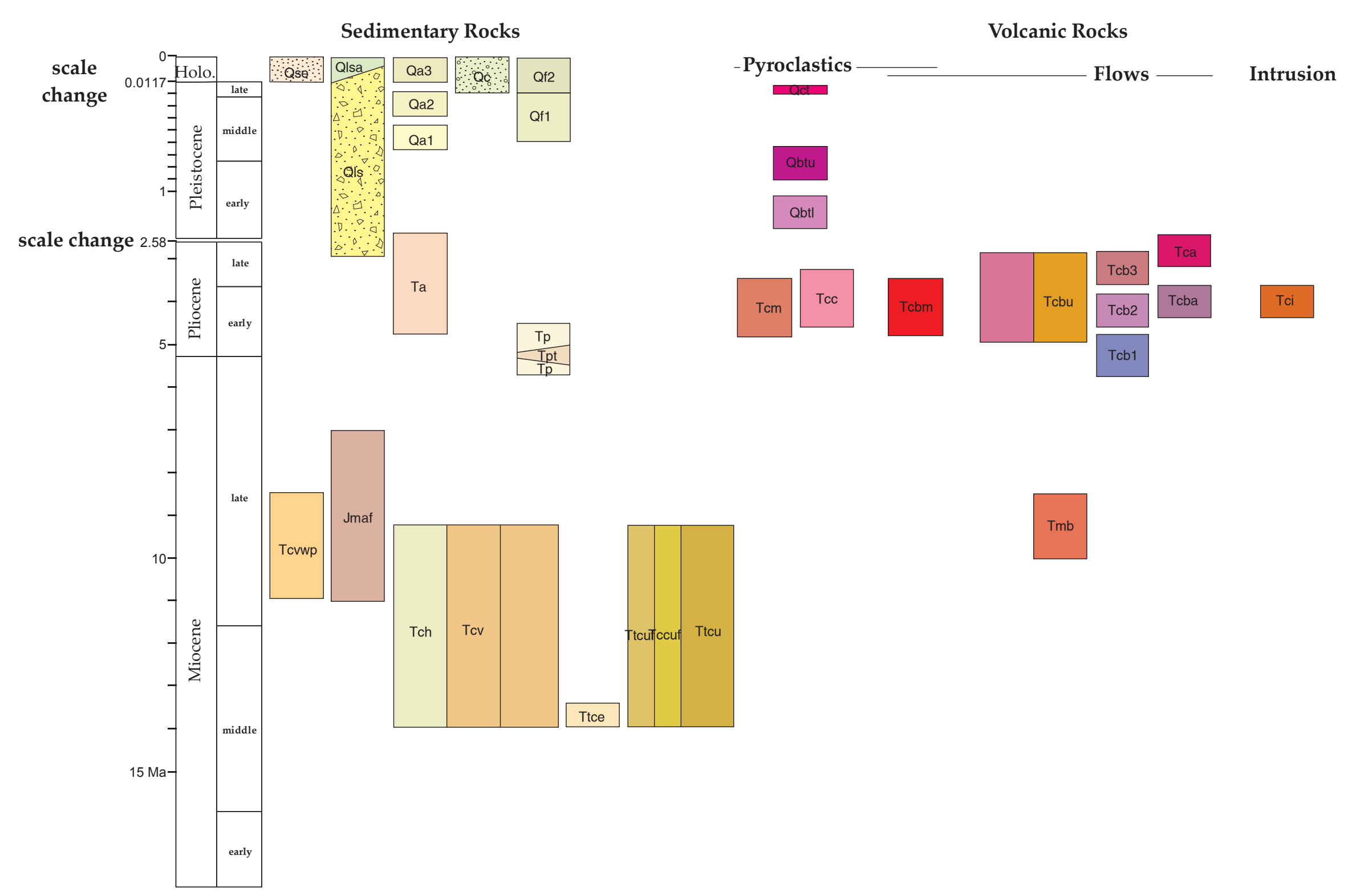
▨ 05-08-00-00-00—unit—Tch—Chamita Formation, Hernandez Member (middle to upper Miocene)—Light gray channel-fills with subordinate finer-grained floodplain deposits. Amalgamated channel-fills form packages as much as 18 m-thick. These channel-fills locally fine-upwards into horizontal-bedded floodplain deposits of clay, silt, and clayey-silty very fine- to fine-grained sand. The coarse-grained channel-fills are marked by a variety of bed forms, ranging from planar to lenticular to cross-stratified. Gravels include very fine to very coarse pebbles and cobbles that are subrounded to rounded, very poorly sorted, and commonly clast-supported. Lithologic types include a high amount of gray to dark gray to greenish gray to brown dacites to andesites, with minor amounts of rhyolite, welded tuff, and less than 15% quartzite in our study area (Table 1). Locally, there is less than 10% Paleozoic sedimentary clasts and minor granitic detritus. The sand fraction has low amounts of the frosted quartz and rounded, red-brown chert and volcanic(?) sand grains observed in the Vallito Member (generally less than 15% of the sand fraction). The sand mostly contains subangular to subrounded, relatively clear quartz and plagioclase, with less than 15% orange-stained quartz + potassium feldspar, 1-15% mafics, <2% chert, <5% green quartz grains, and 3-50% volcanic grains similar in composition to the gravel fraction. In outcrops, reddish brown to brown to pale yellow floodplain deposits are minor to very minor compared to the coarse-channel-fills, but locally floodplain deposits are abundant in wells R-10 and R-16.
Member interfingers eastward with the Vallito Member. Locally, such as at the base of the west slope
[illegible] Canyon directly across from the Buckman well field, the Hernandez Member directly interfingers eastward with the Cuarteles Member. The Hernandez Member is 27 m thick in the Upper Buckman stratigraphic section and attains unknown, but probably much higher, thickness values to the west.

▨ 05-09-00-00-00—unit—Tcv—Chamita Formation, Vallito Member (middle to upper Miocene)—Broad channel-fills (typically >10s of meters wide) consisting of sand-dominated sediment in horizontal to cross-stratified, laminated to very thin to medium beds. Stacked channel-fills form amalgamated packages as much as 12 m-thick. The pebble fraction rarely exceeds 40 mm in diameter; clasts are moderately sorted, subrounded, and consists largely of volcanic clasts having similar composition as the volcanic sand grains together with minor amounts of quartzite, granite, and Paleozoic sedimentary clasts (mostly sandstone, but also local limestone and siltstone). Pebbles are generally insufficient to produce clast-supported gravel beds. Basalt lithologic types are unique to the Vallito Member only in the subsurface east of the Rio Grande but are locally present in exposures west of the Rio Grande. Sand is very pale brown to pink to light gray, fine- to coarse-grained, and consists of subrounded (with subordinate rounded and subangular), locally frosted quartz grains. There is typically trace to 3% red to brown, rounded chert and possible volcanic grains, 1-8% mafics, and 5-20% orange-stained quartz grains together with minor potassium feldspar. Up to ~25% volcanic grains are also present, ranging from welded tuff, other tuff, rhyolite, basalt, and dacite (dacite being the most common). Other lithic grains include <5% quartzite and Paleozoic sedimentary grains. Floodplain deposits consist of very fine- to fine-grained sand and silty sand, silt, and clay in various proportions. Locally, the Vallito Member contains intervals of extensively cross-stratified sand with ~20 cm-thick foresets; these are possibly eolian deposits. Non- to weakly cemented, with only minor strong cementation. In the Buckman area, the lower contact of the Vallito Member is placed at the lowest occurrence of thick sand beds characterized by fine to coarse, subrounded to rounded, locally frosted quartz with minor rounded, red-brown chert or volcanic grains and orange-stained quartz.
Cuarteles Member, and locally with the Cejita Member of the Tesuque Formation. The Vallito
[illegible] Member in a broad zone that includes much mixing between the two members (as much as 7 km wide). East of the Rio Grande, the Vallito Member, is gradationally overlain by the Cuarteles Member of the Tesuque Formation. West of the Rio Grande, the two are in an interfingering and mixed relation with no complete progradation of the Cuarteles Member over the Vallito Member. The base of this member is coeval with the lower Cejita Member of the Tesuque Formation (see cross-section), and thus is ca. 13.2 Ma. In R-10, this member extends up to the basalt flow that likely correlates to 8.5-9.0 Ma flows to the west. The unit is over 900 m-thick, including where it is mixed with Hernandez Member detritus (cross-section).

▨ 05-09-01-00-00—subunit—Tcv-Tch—Chamita Hernandez and Vallito Members undivided (middle to upper Miocene; cross section only)—Chamita Hernandez and Vallito Members undivided (cross section only)

▨ 05-10-00-00-00—unit—Jmaf—Jemez Mountains alluvial fan deposits (late Miocene)—Sand, gravel, and silt deposited on a piedmont slope flanking the eastern margin of the Jemez Mountains volcanic field. Gravel is subangular to subrounded and composed mainly of porphyritic dacite with subordinate basalt, andesite, and rhyolite. Sand is grayish-brown to brown, fine- to very coarse-grained, and subangular to rounded. Described using well cuttings (Ball et al., 2002; Broxton et al., 2012).

Correlation of Map Units



Explanation of Map

<all other	6.2 Inclined
1.1.1 Contact—Identity and existence certain, location	6.33 Approximate orientation of inclined
1.1.2 Contact—Identity or existence questionable, location	2.11.9 Inclined fault (2nd
1.1.25 Unconformable contact—Identity and existence certain, location	12.5 Fluvial transport
1.1.3 Contact—Identity and existence certain, location	19.3.25 Drill hole for mineral
1.1.4 Contact—Identity or existence questionable, location	26.1.1 Water well, type
1.1.7 Contact—Identity and existence certain, location	31.21 Sample locality—Showing sample
17.12 Head scarp of landslide-Active, sharp, distinct, and accurately	31.10 Cross section
2.1.1 Fault (generic; vertical, subvertical, or high-angle; or unknown or unspecified orientation or sense of slip)—Identity and existence certain, location accurate	2.11.16 General right-down fault (in cross section)—Arrows show a relative right-down orientation along the fault.
2.1.7 Fault (generic; vertical, subvertical, or high-angle; or unknown or unspecified orientation or sense of slip)—Identity and existence certain, location concealed	2.11.17 General left-down fault (in cross section)—Arrows show a relative left-down orientation along the fault.
2.2.1 Normal fault—Identity and existence certain, location	31.02.25 Well location—Showing in cross section the location and depth of a well used to establish the unit stratigraphy.
2.2.3 Normal fault—Identity and existence certain, location	31.02.26 Well location—Showing in cross section the projected location and depth of a well used to establish the unit stratigraphy.
2.2.4 Normal fault—Identity or existence questionable, location	
2.2.7 Normal fault—Identity and existence certain, location	
2.2.8 Normal fault—Identity or existence questionable, location	
1.2.1 Key bed—Identity and existence certain, location	
17.12 Head scarp of landslide-Active, sharp, distinct, and accurately	

Geologic Cross Section A–A'