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Prepared in cooperation with the National Park Service

Geologic Map of the Montoso Peak Quadrangle, Santa Fe and Sandoval Counties, New Mexico

Pamphlet to accompany

Scientific Investigations Map 3179

U.S. Department of the Interior
U.S. Geological Survey

Cover: View to the northeast of eroded cinder cone of Twin Hills, from northeast rim of Cerro Rito. Photograph by Ren A. Thompson, 1996. Insert: U.S. Forest Service twelve hundred water well.

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KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2011

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Map Sheet

Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)

Divisions of Quaternary, Neogene, and Paleogene time used in this report[1]

Period or Subperiod	Epoch		Age
Quaternary	Holocene		0—11.7 ka
	Pleistocene	late	11.7—132 ka
		middle	132—788 ka
		early	788 ka—2.59 Ma
Neogene	Pliocene		2.59—5.33 Ma
	Miocene		5.33—23.0 Ma

[1]Ages of time boundaries are those of the U.S. Geological Survey Geologic Names Committee (2010) except those for the late-middle Pleistocene and middle-early Pleistocene boundaries, which are those of Richmond and Fullerton (1986). Ages are expressed in ka for kilo-annum (thousand years) and Ma for mega-annum (million years).

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Introduction

The Montoso Peak quadrangle is underlain by volcanic rocks and associated sediments of the Cerros del Rio volcanic field in the southern part of the Española Basin (figs. 1–3) that record volcanic, faulting, alluvial, colluvial, and eolian processes over the past three million years. The geology was mapped from 1997 to 1999 and modified in 2004 to 2008. The geologic mapping was carried out in support of the U.S. Geological Survey (USGS) Rio Grande Basins Project, funded by the USGS National Cooperative Geologic Mapping Program. The primary mapping responsibilities were as follows:Thompson and Hudson mapped the volcanic deposits and faults and prepared the digital compilation of the geologic map, Shroba mapped the surficial deposits, Mark R. Hudson and Scott A. Minor mapped surface exposures of faults, Hudson conducted paleomagnetic studies for stratigraphic correlations, and David A. Sawyer assisted with unit correlations with exposures on the adjoining Tetilla Peak quadrangle to the south (Sawyer and others, 2002).

The mapped distribution of units is based primarily on interpretation of 1:16,000-scale, color aerial photographs taken in 1992, and 1:40,000-scale, black-and-white, aerial photographs taken in 1996. Most of the contacts on the map were transferred from the aerial photographs using a photogrammetric stereoplotter and subsequently field checked for accuracy and revised based on field determination of allostratigraphic and lithostratigraphic units. Determination of lithostratigraphic units in volcanic deposits was aided by geochemical data, $^{40}Ar/^{39}Ar$ geochronology, aeromagnetic and paleomagnetic data (Thompson and others, 2006). Supplemental revision of mapped contacts was based on interpretation of USGS 1-meter orthoimagery. This version of the Montoso Peak quadrangle geologic map uses a traditional USGS topographic base overlain on a screened shaded relief base generated from 10-m digital elevation model (DEM) data from the USGS National Elevation Dataset (available at *http://ned.usgs.gov/*); sun illumination is from the northwest at 45° above the horizon.

Faults are identified with varying confidence levels in the map area (fig. 4). Recognizing and mapping faults developed near the surface in young, brittle volcanic rocks is difficult because (1) they tend to form fractured zones tens of meters wide rather than discrete fault planes, (2) the youth of the deposits has allowed only modest displacements to accumulate for most faults, and (3) many may have significant strike-slip components that do not result in large vertical offsets that are readily apparent in offset of sub-horizontal contacts. Those faults characterized as “certain” either have distinct offset of map units or had slip planes that were directly observed in the field. Faults classed as “inferred” were traced based on linear alignments of geologic, topographic and aerial photo features such as vents, lava flow edges, and drainages inferred to preferentially develop on fractured rock. Lineaments defined from magnetic anomalies form an additional constraint on potential fault locations.

Description of Map Units

[Color of units from Munsell Color, 1973]

Surficial Deposits

The surficial map units on this map are informal allostratigraphic units of the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983), whereas the other map units are informal lithostratigraphic units. For this reason, subdivisions of stratigraphic units use time terms “late” and “early” where applied to surficial units, but use position terms “upper” and “lower” where applied to lithostratigraphic units. The mapped surficial deposits (Qba and younger) are known or estimated to be at least 1 m thick. Most of these deposits are poorly exposed. Thin (< 50 cm), discontinuous sheetwash deposits (Qsw) locally mantle gently sloping map units. We did not map deposits that are (1) of limited extent (less than about 25 m wide), (2) exposed in steep cuts, and (3) fill material (unit af) that was not observed on aerial photographs or orthoimagery.

Age assignments for surficial deposits are based chiefly on the (1) relative degree of modification of their original surface morphology, (2) relative heights above modern stream channels, and (3) degree of soil development. Soil-horizon

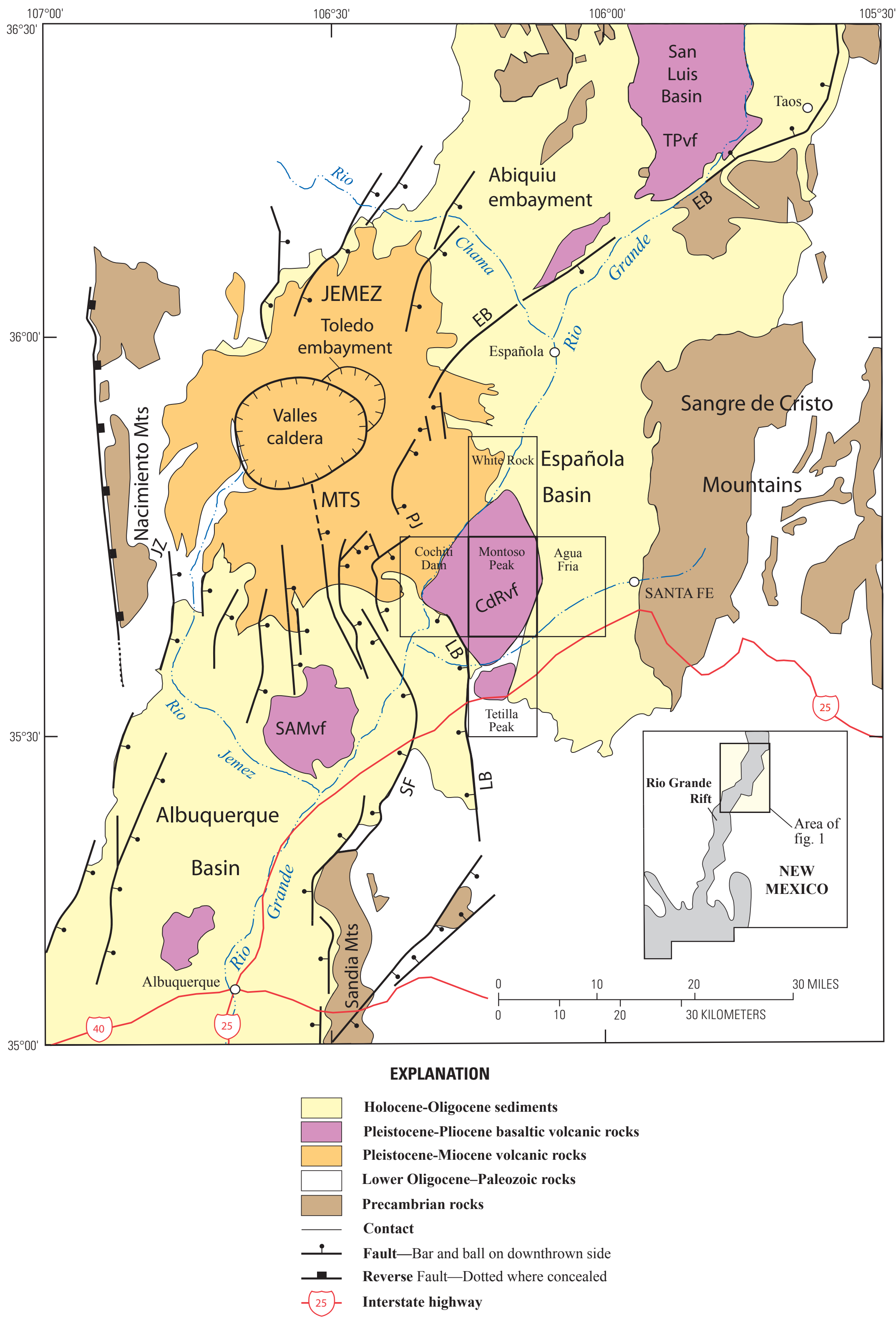
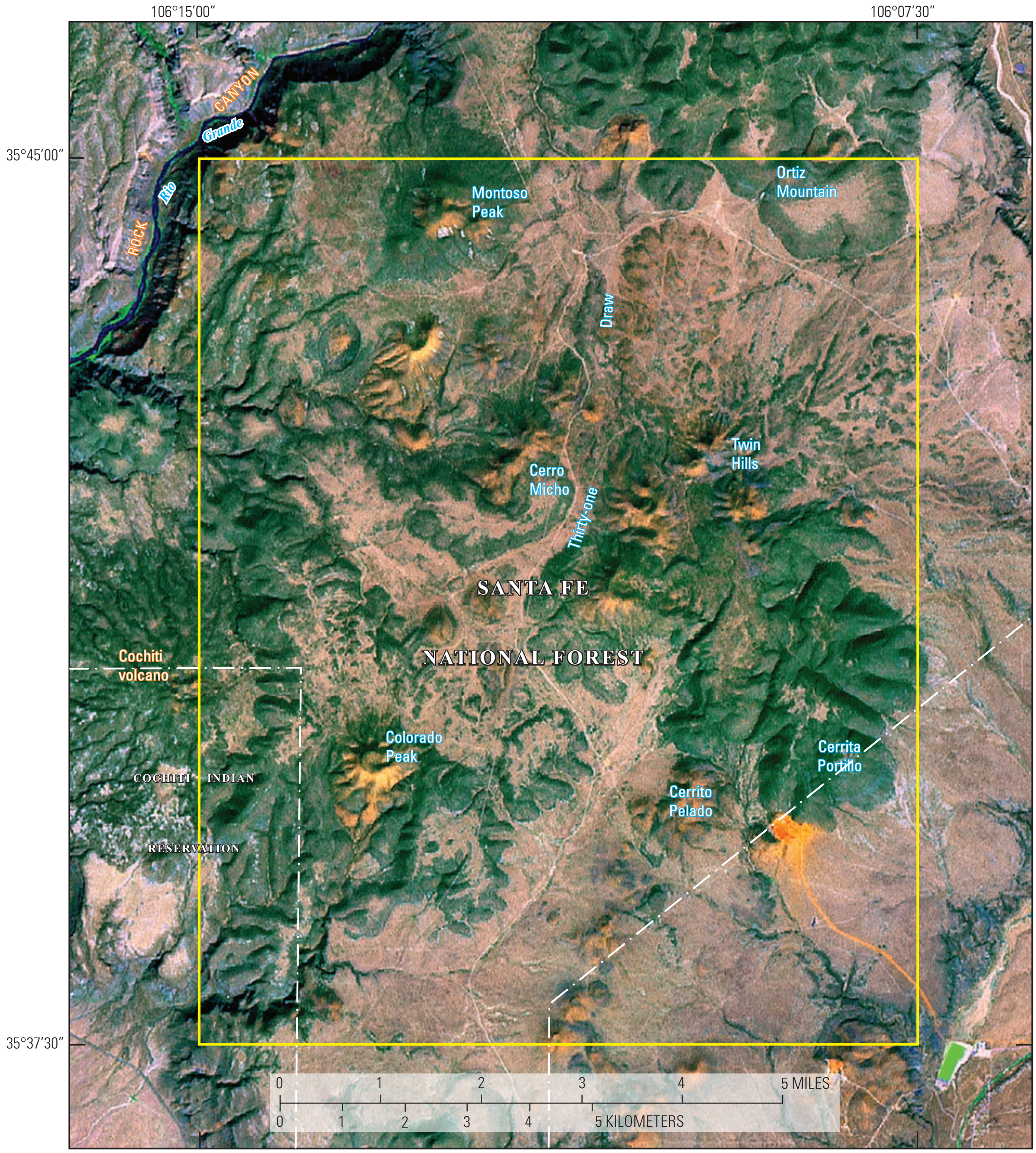


Figure 1. Location map and general geology of the Española Basin, adjacent basin, and volcanic fields of the Rio Grande rift. Geology modified from Smith and others (2001, fig. 3). Approximate location of the Toledo caldera (Toledo embayment) is modified from Gardner and Goff (1996). Volcanic fields: CdRvf, Cerros del Rio volcanic field; SAMvf, Santa Ana Mesa volcanic field; TPvf, Taos Plateau volcanic field. Faults: EB, Embudo fault, JZ, Jemez fault; LB, La Bajada fault; PJ, Pajarito fault; SF, San Francisco fault.



Boundaries modified from U.S. Geological Survey, Montoso Peak, NM, 1:24,000-scale map, 2002.

Figure 2. Landsat 7 satellite image (30-m band 7-4-2 merged with 15-m band 80 acquired on October 14, 1999, of Cerros del Rio, New Mexico area (image clip from Sawyer and others, 2004), showing geologic features and select geographic names. Volcanic rocks and sediments of the Cerros del Rio volcanic field are visible throughout the image, dark-blue river in the northwest part of the image is the Rio Grande, light-orange area and linear feature in the southeast part of the image are a cinder quarry and haulage road, light-green area in the southeast corner of the image is a recreation area. Yellow rectangle is the boundary of the Montoso Peak 7.5-minute quadrangle.

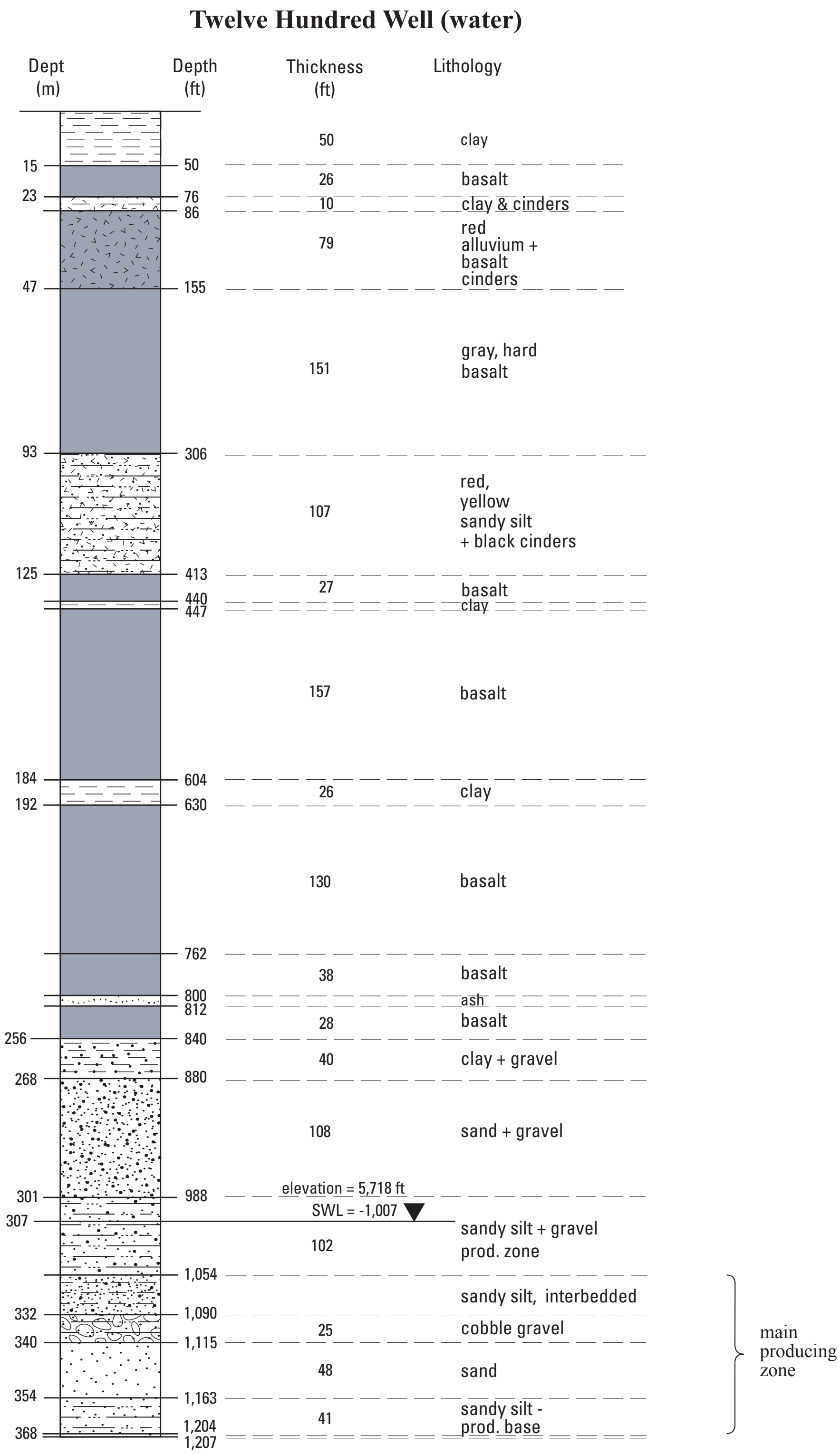


Figure 3. Interpreted lithologic column from U.S. Forest Service Twelve Hundred well driller's log (modified from Sawyer and Minor, 2006). Eight horizons identified as basalt represent lava flows, flow packages and associated pyroclastic deposits. Interbedded clastic rocks and fine-grain deposits are relatively minor except for the drilling interval 93–125 m. Interpreted penetration of Santa Fe Group sediments occurred at 256 m depth, static water level (SWL) occurs at a depth of 307 m.

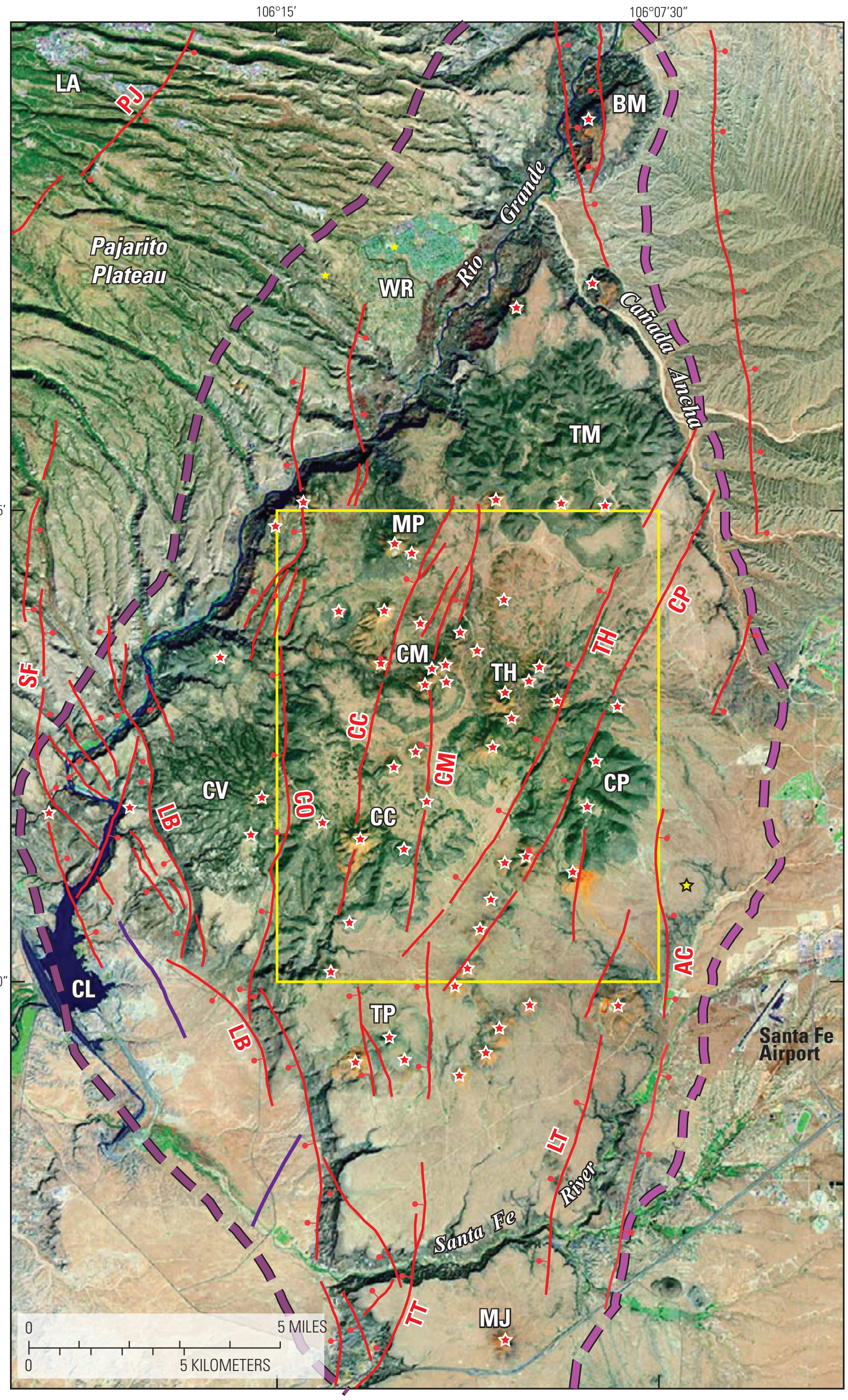


Figure 4. Landsat 7 image (30-m band 7-4-2 merged with 15-m band 80 acquired on October 14, 1999; image clip from Sawyer and others, 2004) of Cerros del Rio volcanic field showing approximate eruptive extent as purple dashed line, mapped vent areas as red stars, and presumed buried vents based on aeromagnetic data as yellow stars. Geographic abbreviations: LA, Los Alamos; WR, White Rock; CL, Cochiti Lake; BM, Buckman Mesa; OM, Ortiz Mountain; MP, Montoso Peak; CM, Cerro Micho; TH, Twin Hills; CP, Cerro Portillo; CC, Cerro Colorado; CV, Cochiti Volcano; TP, Tetilla Peak; MJ, Mesita de Juana. Major mapped faults and lineaments are shown in red and aeromagnetic lineaments related to buried faults are shown in purple. Fault abbreviations: PJ, Pajarito fault; SF, San Francisco fault; LB, La Bajada fault; TT, Tetilla fault; CM, Cerro Micho fault; CC, Cerro Colorado fault; CO, Cochiti fault; TH; Twin Hills fault; CP, Cerro Portillo fault; LT, Las Tetillitas fault; AC, Arroyo Calabasas fault. Quadrangle outline in yellow.

designations are based on those of Guthrie and Witty (1982), Birkeland (1999) and the Soil Survey Staff (1999). Some of the surficial deposits contain secondary calcium carbonate of pedogenic (soil) origin. Stages of secondary calcium carbonate morphology (referred to as stages I through III in Bk, Bkb, Btkb, K, and Kb soil horizons) are from Gile and others (1966) and Machette (1985). Thin (less than 1 m) deposits of volcanic rubble that locally overlie basaltic and andesitic lava flows commonly are cemented by calcium carbonate having stage IV morphology.

In this report, the terms “alluvium” and “alluvial” refer to material transported by running water confined to channels (stream alluvium), whereas those deposited by running water not confined to channels are referred to as sheetwash. The terms “colluvium” and “colluvial” refer to material transported on slopes chiefly by mass-wasting (gravity-driven) processes—such as creep, debris flow, and rock fall—aided by running water not confined to channels (sheetwash) (Hilgard, 1892; Merrill, 1897). Surficial map units that include debris-flow deposits probably also include hyperconcentrated flow deposits. These latter deposits are intermediate in character between stream-flow and debris-flow deposits. The term “plastic” in the descriptions of sheetwash unit (Qsw) refer to the extent to which moist sediment changes shape continuously under the influence of an applied stress and that retain the impressed shape on the removal of the stress (Soil Survey Staff, 1951).

Grain or particle sizes of surficial deposits are based on field estimates, using the modified Wentworth scale (American Geological Institute, 1982). In the descriptions of surficial map units, the term “clasts” refers to particles larger than 2 mm in diameter, whereas the term “matrix” refers to particles smaller than 2 mm in diameter. Most of the clasts in surficial deposits within the map area are angular and subangular fragments derived chiefly from basaltic and andesitic lava flows and pyroclastic deposits.

Colors of the surficial deposits were determined by comparison of dry matrix with Munsell Soil Color Charts (Munsell Color, 1973). These colors generally are similar to those of the sediment and volcanic rock from which they were derived. The colors of the surficial deposits commonly range from white (2.5*Y* 8/1) to light reddish brown (7.5*YR* 6/4).

Artificial-Fill Deposits

af **Artificial fill (latest Holocene)**—Uncompacted mine tailings and storage piles composed of dark red (10R about 3/6), cinder, spatter, and agglutinate excavated from basaltic pyroclastic deposits at Cerrito Pelado, near the southeastern corner of the map area. Locally may include in-place pyroclastic depositis. Estimated thickness less than 15 m

Alluvial Deposits

Qg **Gravelly alluvium (Holocene? and late Pleistocene)**—Small, scattered deposits of gravelly stream alluvium that form small low hills along and near Arroyo Tetilla in the southern part of the map area. Unit contains deposits of pebbly and cobbly sandy gravel and pebbly and cobbly silty sand. The top of the unit is capped by a gravelly lag that is about 5 m or less above the adjacent channels of intermittent streams. Boulders as long as 1 m are locally present in the gravelly lag. Some deposits of Qg may be gravelly facies of Qac. Estimated thickness 5–10 m

Qsw **Sheetwash deposits (Holocene to middle? Pleistocene)**—Slightly pebbly to pebbly and cobbly, slightly silty to silty, very fine to medium sand. The matrix is slightly to moderately plastic. Some of the silt- to fine sand-size fraction in these deposits may be of eolian origin and have been transported by strong southwesterly winds that deflated sediment from former sparsely vegetated or actively aggrading alluvial deposits. Some of the silt- and clay-size fraction in Qsw may have been derived from more distant sources (Shroba and Thompson, 1998). Sediments in Qsw were deposited chiefly by unchannelized surface flow and, possibly in part, by gravity-driven slope processes. Unit Qsw locally contains rare fragments of reworked pumice from the 1.61 Ma Guaje(?) Pumice Bed of the Otowi Member of the Bandelier Tuff (Bailey and others, 1969; Izett and Obradovich, 1994) and possibly pumice (Qec) from younger eruptions in the nearby Jemez Mountains, about 25 km northwest of the map area (fig. 1). The unit also locally includes small deposits of undivided alluvium and colluvium (Qac) and basaltic alluvium (Qba). Although loess locally mantles lava flows about 50–60 ka in the Valles caldera (Wolff and others, 1996) (fig. 1) and rock-glacier deposits about 10–14 ka near Lake Peak in the Sangre de Christo Range (Shroba, 1977, 1987), loess deposits were not observed within or on Qsw. Surface soils formed in Qsw in the adjacent Agua Fria and Tetilla Peak quadrangles (Shroba and others, 2006; Sawyer and others, 2002) locally have Bw, Bt/Bk, or Btk/K horizon morphology depending in part on the age of the deposit. Bt and Btk horizons have thin clay films on ped faces. Bt horizons are 20–70 cm thick; Btk horizons are 10–45 cm thick and have stage I–II carbonate morphology. Bk horizons are as much as 80 cm thick and have stage I to II carbonate morphology. K horizons are as much as 75 cm thick and have stage III carbonate morphology. These properties suggest that some of the more strongly developed soils are formed in deposits that may be about 120–160 ka (Shroba and Birkeland, 1983; Nelson and Shroba, 1998; Birkeland and others, 2003). Although undifferentiated, younger deposits locally overlie older deposits of Qsw. Older sheetwash deposits are locally greater than 2 m thick and have upper surfaces marked by buried Bkb, Btkb, or Kb horizons greater than 30 cm thick. Presence of surface and buried soils formed on and in Qsw indicate periodic deposition followed by surface stability and soil development. The last major episode of deposition may have been associated with enhanced summer rainfall during the early Holocene (Reneau and others, 1996b). Low-lying areas of Qsw are susceptible to sheet flooding due to unconfined overland flow, and locally to stream flooding and gullying. Disturbed surface of Qsw may be susceptible to minor wind erosion. Exposed thickness 1.5–4.5 m; possibly as much as 10 m

Alluvial and Colluvial Deposits

Qac **Alluvium and colluvium, undivided (Holocene and late Pleistocene?)**—Chiefly undifferentiated flood plain and stream channel deposits, sheetwash (Qsw), and minor fan alluvium and debris-flow deposits, undivided (Qfd). Unit ranges from slightly pebbly, silty sand to poorly sorted, clast- and matrix-supported, locally bouldery, cobbly and pebbly gravel with a sandy matrix. Low-lying areas of the map unit are prone to periodic flooding and locally to debris-flow deposition. Deposits composed of moderately well sorted silty sand are prone to gullying. Thickness possibly about 1–10 m

Qfd **Fan alluvium and debris-flow deposits, undivided (Holocene to middle? Pleistocene)**—Clast-and-matrix supported, locally bouldery, pebbly and cobbly gravel with a sandy matrix, and locally pebbly and cobbly, slightly silty sand that contains gravel lenses. The unit commonly forms fan-shaped and lobate masses of sediment deposited at and below the mouths of narrow valleys. Sediments were deposited by sediment-charged, intermittent streams and debris flows. Levees that contain cobbles and boulders are locally present on debris flows. Small deposits of unmapped sheetwash (Qsw) locally overlie unit Qfd. Soils formed in younger deposits have Bk horizons; those formed in older deposits have thin (about 30 cm) K horizons with strong stage III carbonate morphology. Low-lying areas of the map unit adjacent to stream channels are prone to periodic flooding and debris-flow deposition. Maximum thickness possibly about 20 m

Colluvial Deposits

Qc **Colluvium, undivided (Holocene to middle? Pleistocene)**—Deposits of unsorted and non-stratified, mostly matrix-supported, sandy sediment and rock debris on and near steep slopes. Deposits range in size from pebbly silty sand to cobbly and bouldery rubble with a sandy matrix. Unit Qc consists chiefly of soil-creep, debris-flow, and rock-fall deposits, as defined by Varnes (1978) and Cruden and Varnes (1996). Unit locally includes deposits of sheetwash (Qsw) and alluvium and colluvium, undivided (Qac) that are too small to map separately. Unit Qc may be susceptible to continued movement or reactivation due to natural and human-induced processes. Some of the rock fragments in unit Qc are as much as 3 m in diameter; some of the sand in the unit probably was deposited as sheetwash and debris flows. Maximum thickness possibly about 20 m

Lava Flows and Related Deposits of the Cerros Del Rio Volcanic Field

The Cerros del Rio volcanic field is a predominantly basaltic to andesitic volcanic plateau along the southeast flank of the Jemez Mountains (fig. 1) of northern New Mexico. Lavas and related pyroclastic deposits of this field are locally exposed over 700 km^2 and reflect eruption of at least 120 km^3 of rift-related mafic magma, mainly between 2.7 and 1.1 Ma (table 1, see map sheet). Most of the lava flows are of Pliocene and early Pleistocene age and predate large-volume silicic caldera eruptions in the nearby Jemez volcanic field; however, late-stage eruptions from the Cerros del Rio volcanic field post-date eruption of the Tshirege Member (1.2 Ma; Valles caldera) of the Bandelier Tuff in the Jemez volcanic field. Most of the eruptive centers in the Cerros del Rio volcanic field are central-vent volcanoes ranging from low-relief shield centers to remnants of steep-sided, breached cinder cones. These lavas have from 49 to 64 weight percent SiO_2 and exhibit a strong correlation between landform and whole-rock chemistry (fig. 5; table 2, see map sheet; and table 3). The low-silica, subalkaline basaltic lavas erupted from broad shield volcanoes and formed thin (< 3–4 m) low-viscosity flows that traveled far; conversely transitional to mildly alkaline basalts and basaltic andesites formed thick (as much as 30 m) discontinuous lavas flows that erupted from high-relief, steep-sided, dissected vents. Dacitic lavas are related to late-stage dome growth and eruption of thick (as much as 50 m), even more viscous blocky lava flows that issued from one well-defined vent area at Tetilla Peak about 2 km south of the map area (Sawyer and others, 2002) and locally in tributary canyons of the Rio Grande, west of the map area (Dethier, 1997).

Volcanic deposits of the Cerros del Rio volcanic field are divided into a three-fold classification representing early, middle, and late phases of eruption that persisted from about 2.7 Ma to 1.1 Ma. Volcanic units in the map area are believed to represent products of monogenetic eruptive centers of the early (>2.7–2.59 Ma), middle (2.59–2.1 Ma) and late (1.5–1.1 Ma) volcanic phases of Thompson and others (2006). These subdivisions are based on 1:24,000-scale geologic mapping, stratigraphic studies, $^{40}Ar/^{39}Ar$ geochronology, and paleomagnetic and aeromagnetic data. Integration of these datasets results in approximate eruption ages reflected in table 1. Some geochemical data were used to identify rock lithologies within the stratigraphic subdivisions for the entire field and were incorporated in unit descriptions, where available, for volcanic deposits in the map area. Volcanic rock names are based on the standard IUGS classification scheme (Le Bas and Streckeisen, 1991); however, only root names are used in map unit description. Some volcanic units contain rocks of variable composition, spanning classification boundaries. In these cases, the dominant rock type was used for the unit name and ranges of compositions are presented in table 1. Preliminary results of new $^{40}Ar/^{39}Ar$ age determinations are presented in unit descriptions. In places, map units represent the consolidation of deposits of limited extent and are based on similar lithologic character, stratigraphic position, inferred age, aeromagnetic and paleomagnetic signatures, and aerial extent of similar or related deposits. Map-unit nomenclature for the volcanic deposits in part reflects that proposed by Aubele (1979). Colors of the lava flows and cinder deposits used in unit descriptions were determined by comparison with a Geological Society of America Rock-Color Chart (Rock-Color Chart Committee, 1995).

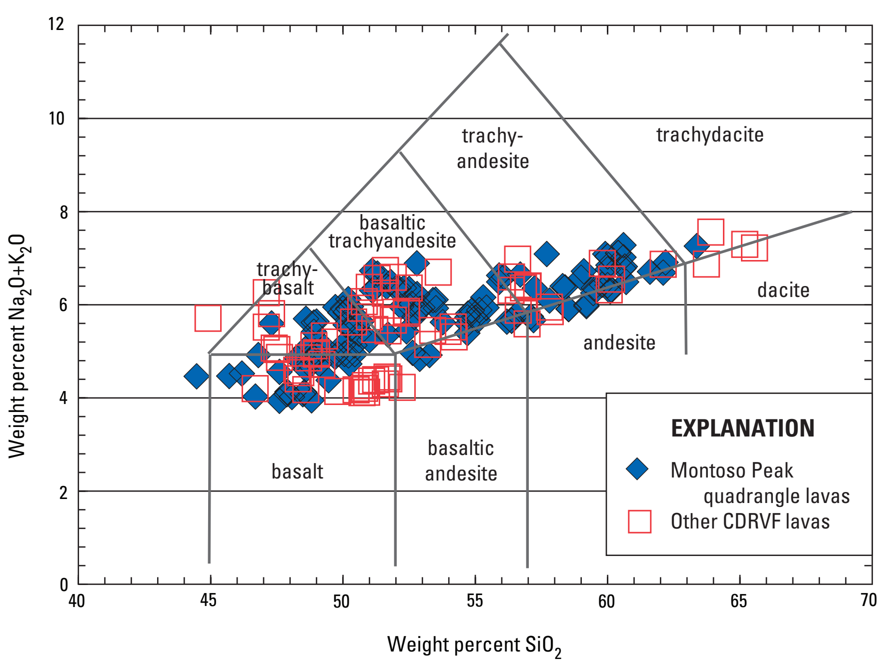


Figure 5. Total alkali vs. silica classification diagram (Le Bas and others, 1986) for volcanic rocks exposed in the map area (filled diamonds) and adjacent areas (open squares). CDRVF, Cerros del Rio volcanic field.

Table 3. Location coordinates for Cerros del Rio volcanic field samples.

[Geographic Coordinate System NAD 27 Datum]

Sample No.	Quadrangle	Map Unit	Latitude	Longitude
96TTP01	Tetilla Peak	Tat	35°36'29"	106°12'33"
04TMP23	Montoso Peak	Tcm	35°44'22"	106°14'47"
6RTCD10	Montoso Peak	Tcm	35°42'52"	106°14'50"
3MRG–1	Montoso Peak	Tbcc	35°42'56"	106°11'16"
96TMP18	Montoso Peak	Tbc	35°42'50"	106°11'01"
96DTP04	Tetilla Peak	Tbs	35°37'11"	106°08'15"
96TTH02A	Turqoise Hill	Tbs	35°37'01"	106°07'29"
02TMP02	Montoso Peak	Tayc	35°39'22"	106°10'15"
2MRG–11	Montoso Peak	Tay	35°39'02"	106°10'24"
96TMP38	Montoso Peak	Tcac	35°39'49"	106°13'10"
96TMP20	Montoso Peak	Tca	35°40'33"	106°12'47"
96TMP24	Montoso Peak	Tca	35°38'24"	106°13'49"
MP3260601	Montoso Peak	Tcp	35°41'38"	106°09'48"
96TMP04	Montoso Peak	Tcp	35°41'56"	106°09'11"
96TMP36	Montoso Peak	Tcp	35°40'01"	106°09'56"
96TMP08	Montoso Peak	Tm	35°44'10"	106°12'54"
96TMP07	Montoso Peak	Tm	35°43'50"	106°13'38"
96TMP35	Montoso Peak	Tbcl	35°39'07"	106°09'16"
04TMP21	Montoso Peak	Tbcl	35°39'03"	106°09'17"
04TMP22	Montoso Peak	Tbcl	35°39'11"	106°09'14"
96TMP27	Montoso Peak	Ttx	35°43'52"	106°09'33"
2MRG–2	Montoso Peak	Qbu	35°44'12"	106°08'22"
96TMP15	Montoso Peak	Qbu	35°44'11"	106°08'21"
4MRG–17	Montoso Peak	Qbx	35°37'46"	106°11'08"
96TMP09	Montoso Peak	Qbx	35°38'45"	106°10'10"
MP3270601	Montoso Peak	Qae	35°42'06"	106°14'24"
05TMP01	Montoso Peak	Qae	35°42'30"	106°12'50"
96TMP22a	Montoso Peak	Qbt	35°38'00"	106°13'46"
96TMP22b	Montoso Peak	Qbt	35°38'00"	106°13'46"
2MRG–5	Montoso Peak	Qcb	35°38'34"	106°13'36"
3MRG–2	Montoso Peak	Qcb	35°39'52"	106°13'45"
MP3260602	Montoso Peak	Qto	35°42'22"	106°09'52"
96TMP03	Montoso Peak	Qto	35°41'53"	106°09'09"
96TMP17	Montoso Peak	Qo	35°44'56"	106°10'30"
96TMP14	Montoso Peak	Qo	35°44'17"	106°08'25"
3MRG–8	Montoso Peak	Qtd	35°43'56"	106°11'14"
96TMP19	Montoso Peak	Qtd	35°42'22"	106°11'20"
04TMP24	Montoso Peak	Qtdc	35°42'45"	106°12'03"
96DCD01	Cochiti Dam	Qb	35°37'56"	106°16'04"
96TCD01	Cochiti Dam	Qb	35°38'03"	106°15'36"
6RTCD4	Cochiti Dam	Qcl	35°39'35"	106°18'00"
DN–96–28b	Cochiti Dam	Qcl	35°39'52"	106°17'55"
97TMP50	Montoso Peak	Qcu	35°40'32"	106°14'37"
3MRG–4	Cochiti Dam	Qcu	35°41'20"	106°16'58"

Qec **El Cajete Member of the Valles Rhyolite (late Pleistocene)**—Small scattered deposits of white, coarse sand- to small pebble-size (0.5–12 mm) pumice fragments that locally mantle hill slopes in the northern part of the map area. The pumice is about 50–60 ka and was erupted from the nearby Valles caldera (Bailey and others, 1969; Reneau and others, 1996a), about 20 km northwest of the map area (fig. 1). Some or much of Qec was redeposited by alluvial and possibly by mass-movement or eolian processes. Maximum thickness possibly about 5 m

Qba **Basaltic alluvium (early? to middle? Pleistocene)**—Several poorly exposed deposits of locally bouldery, cobbly and pebbly gravel with a sandy matrix and pebbly sand are exposed near the eastern boundary of the map area. Clasts are commonly subangular and consist of basalt, basaltic andesite, and andesite. The unit locally contains carbonate-cemented lenses composed of pumice fragments about 2 mm to 10 cm in diameter. This pumice was probably derived from the nearby Jemez Mountains. Likely sources of the pumice are the 1.22 Ma Tsankawi Pumice Bed of the Tshirege Member of the Bandelier Tuff, and the 1.61 Ma Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff (Bailey and others, 1969; Izett and Obradovich, 1994). Unit Qba is mostly stream alluvium, but also probably includes fan alluvium and debris-flow deposits as well as sheetwash deposits. Unit Qba is equivalent to the alluvium on basalt of Spiegel and Baldwin (1963). Thickness possibly about 3–10 m

Andesite of Cochiti Volcano (early Pleistocene)—Reddish brown to medium gray lava flows and oxidized cinder and spatter erupted from Cochiti Volcano, which is on the Cochiti Dam quadrangle, near the southwestern boundary of the map area. Cochiti Volcano deposits post-date down-to-west offset along the Cochiti fault, whose footwall scarp formed a topographic barrier to eastward deposition of lava flows. Unit consists of an upper and lower sequence of preserved lava flows and near vent pyroclastic material associated with the upper unit. Vent area for upper unit is coincident with eroded, conical summit of Cochiti Volcano. Maximum exposed thickness is 40 m, but deposits thicken dramatically to the west in the adjacent quadrangle

Qcuc **Upper unit, cinder deposits**—Near-vent pyroclastic deposits, predominantly scoria and spatter agglutinate and minor flow material. Deposits are only present along the western edge of the map area

Qcu **Upper unit, lava flows**—Medium to dark gray andesite lava flows (59–62 weight percent SiO_2); typically thin (3–5 m), platy and discontinuous and are everywhere overlain by near-vent deposits, predominantly cinder and lesser amounts of spatter. Sparse phenocrysts include olivine, pyroxene and plagioclase in decreasing order of abundance. An $^{40}Ar/^{39}Ar$ isotopic age of 1.51±0.05 Ma was obtained from a lava flow near the base of the section on the northwest side of Cochiti Cone in the adjacent Cochiti Dam quadrangle. These flows have reverse aeromagnetic and paleomagnectic signature

Qcl **Lower unit**—Medium to dark gray andesite lava flows (53–59 weight percent SiO_2), typically thin, less than 3 m in map area but locally thicken in adjacent Cochiti Dam quadrangle. Sparse phenocrysts include olivine, pyroxene and plagioclase in decreasing order of abundance; slightly higher proportions of olivine than in Qcu. Flows are interpreted to have reversed magnetic polarity based on aeromagnetic signature. Poorly exposed, maximum thickness 40 m, base not exposed

Basalt of Hill 7033 (early Pleistocene)—Lava flows and associated near-vent deposits erupted from small, eroded cinder and spatter cones in southeast part of map area. Part of a chain of northeast-trending vents that coincides with mapped lineament inferred to be one of several north to northeast trending faults in the map area. Exposed thickness typically 2–25 m, thicker near vent areas

Qbxc **Cinder deposits**—Dissected cinder cones composed of near vent pyroclastic deposits, predominantly scoria, spatter agglutinate and minor flow material

Qbx **Lava flows**—Thin (<3 m), medium gray basalt lava flows (47–49 weight percent SiO_2) exposed in upper reaches of Arroyo Calabasas, on the adjacent Turquoise Hill quadrangle, in the southeast part of the map area. Flows are laterally discontinuous with massive interiors and vesiculated flow tops, largely covered with sheet wash alluvium. Olivine phenocrysts (1–2 mm) are common in a fine-grained microcrystalline groundmass. An $^{40}Ar/^{39}Ar$ isotopic age of 2.03±0.35 Ma was obtained from a lava flow south of the map area on the adjacent Tetilla Peak quadrangle (Sawyer and others, 2002). Reversed paleomagnetic and aeromagnetic signature

Andesite of Ortiz Mountain (early Pleistocene)—Massive andesite lava flows composed of a lower aerially extensive, basal crystal-rich lava flow and discontinuous near-vent deposits on the upper flanks of Ortiz Mountain. Ortiz Mountain is the southernmost of a series of andesite eruptive centers of largely unknown compositional range outside of the map area in the adjacent White Rock Canyon quadrangle (Dethier, 1997)

Qoc **Cinder deposits**—Near-vent pyroclastic deposits, predominantly scoria, spatter agglutinate and minor flow material

Qo **Lava flows**—Medium-gray to black-glassy, blocky andesite lava flows (59–63 weight percent SiO_2) containing abundant phenocrysts of plagioclase and pyroxene, and locally minor olivine, hornblende and opaque minerals. An $^{40}Ar/^{39}Ar$ isotopic age of 2.32±0.06 Ma (sample 96TMP14) was obtained from near the southeastern extent of the basal lava flow. Reverse aeromagnetic and paleomagnetic signature. Maximum exposed thickness is 225 m

Basaltic andesite of Twin Hills (early Pleistocene)—Comprises three adjacent, dissected vent areas and associated lava flows in the Twin Hills and Cerro Rito areas. Flank-lava flows from the Twin Hills vent complex and the unnamed eruptive center 1 km to the south largely flowed northeast. Exposures of paleovalley-filling lavas erupted along Thirty-One Draw may include petrologically similar flows from both the Twin Hills and Cerro Rito eruptive centers. The Twin Hills and unnamed centers to the south are cut by northeast trending dikes. The Cerro Rito center is characterized by a prominent breached summit crater cut by discontinuous northwest trending dikes.

Qtoc **Cinder deposits**—Near vent pyroclastic deposits, predominantly scoria, spatter agglutinate, locally interbedded with medium gray to red oxidized lava flows

Qto **Lava flows**—Thin (<3 m) medium-gray lava flows (50–53 weight percent SiO_2) forming cliff exposures along Thirty-One Draw. Lava flows thin to the north and were likely sourced near the current head of Thirty-One Draw and were restricted to deposition in a shallow paleovalley bordered on the east by Thirty-One Draw. Flows contain olivine and clinopyroxene phenocrysts (2–3 mm) and sparse glomerocrysts of olivine + pyroxene. Thin platy fracturing is common, particularly near the base of lava flows. An $^{40}Ar/^{39}Ar$ isotopic age of 2.53±0.04 Ma (sample 2TMP01) was obtained from a northeast-trending dike on the western flank of Twin Hills. Maximum exposed thickness in the Thirty-One Draw area is 20 m. Near vent deposits are medium-gray to red oxidized vesicular lava flows and blocky erosional flow remnants intercalated with spatter agglutinate and scoria in the Twin Hills and Cerro Rito areas. Flows contains ubiquitous olivine phenocrysts (< 1 mm) and resorbed plagioclase and quartz xenocrysts (1.3 mm) in a fine-grained holocrystalline groundmass. Reversed aeromagnetic and paleomagnetic signature. Maximum exposed thickness is 175 m

Basalt of Hill 7065 (early Pleistocene)—Eroded and dissected near vent deposits and flank lava flows preserved on the northwest and southeast facing flanks of extensive lavas flows erupted from a small center marked by near vent pyroclastic deposits of an eroded cinder cone on the southeast side of Cerro Micho. These lava flows filled a west- to northwest-trending paleotopographic valley currently occupied by Arroyo Eighteen. Lavas erupted from two source areas on the northwest flank of Cerro Micho and filled a small north-trending paleovalley cut into deposits of Tcmc

Qtdc **Cinder deposits**—Near vent pyroclastic deposits, predominantly scoria, spatter agglutinate, locally interbedded with medium gray to red oxidized lava flows

Qtd **Lava flows**—Medium to dark gray basaltic foliated lava flows (50–52 weight percent SiO_2), typically 2–5 meters thick with aa bases and vesicular tops. Most flows are sparsely phyric containing small (less than 1 mm) olivine and pyroxene phenocrysts in a fine-grained intersertal to glassy groundmass. Flows thickened locally where ponded against paleotopographic barriers and thin proximal to vent areas. An $^{40}Ar/^{39}Ar$ isotopic age of 2.55±0.04 Ma (sample 5MRG-4) was obtained from a lava flow on the northwest flank of Cerro Micho. Reverse aeromagnetic and paleomagnetic signature. Maximum exposed thickness is 30–35 m in Arroyo Eighteen and thicker (up to 100 m) where comprised primarily of eroded near vent deposits northwest of Cerro Micho

Basalt of Tetilla Hole (early Pleistocene)—Lava flows and associated near-vent pyroclastic deposits near the confluence of Arroyo Tetilla and Arroyo Colorado in the southwest part of the map area. Locally, unconformably overlies deposits of Tca and is overlain by deposits of Qcb in the upper reaches of Arroyo Colorado

Qbtc **Cinder deposits**—Dissected cinder cones composed of near-vent pyroclastic deposits, predominantly scoria, spatter agglutinate and minor flow material

Qbt **Lava flows**—Massive, medium-gray, basaltic (50 weight percent SiO_2) lava flows that underlie the upper reaches of Arroyo Tetilla. Flows are thick, up to 17 m, with aa bases, vesicular tops with elongate vesicles, and minor interbedded bombs and scoria. Flow direction is to the north and flows grade laterally to the south into preserved remnants of vent area composed of cinder, scoria, bombs and agglutinate. Olivine phenocrysts and small pyroxene clots are common, groundmass is dense and fine grained. An $^{40}Ar/^{39}Ar$ isotopic age of 2.49±0.05 Ma (sample 96TMP22a) was obtained from the uppermost lava flow at Tetilla Hole. Reverse aeromagnetic and paleomagnetic signature. Maximum exposed thickness is 80 m

Basalt of Colorado Peak (early Pleistocene)—Includes erosional remnants of two volcanic centers built on the northwest and southeast flanks of Colorado Peak. Deposits include near vent pyroclastic deposits and associated flank lava flows. Erupted lavas flowed away from the paleotopographic high underlain by Tca/Tcac toward the current drainages occupied by Arroyo Tetilla to the south and Arroyo Eighteen to the north. An $^{40}Ar/^{39}Ar$ isotopic age of 2.53±0.01 Ma (sample 2MRG–5) was obtained from a lava flow near the base of the section in Arroyo Colorado. Reverse polarity based on paleomagnetic determination and aeromagnetic signature

Qcbc **Cinder deposits**—Dissected cinder cones comprised of near vent pyroclastic deposits, predominantly scoria, spatter agglutinate and minor flow material

Qcb **Lava flows**—Medium- to dark-gray, massive, basaltic (49–50 weight percent SiO_2) lava flows (3–5 m thick). Phenocrysts of olivine, typically small, less than 1 mm diameter but occur up to 4 mm in diameter, and clinopyroxene with common olivine+clinopyroxene clots up to several millimeters in a fine grained holocrystalline groundmass. Xenocrysts of resorbed quartz and plagioclase up to several millimeters in diameter are common. Maximum exposed thickness is 120 meters although the section may reflect apparent thickening due to offset along north-trending normal faults

Basaltic andesite of Arroyo Eighteen (early Pleistocene)—Lava flows and associated near-vent pyroclastic deposits erupted from small cinder cones at the head of Arroyo Eighteen. Erupted lavas flowed westward along a paleodrainage coincident with Arroyo Eighteen. An $^{40}Ar/^{39}Ar$ isotopic age of 2.56±0.02 Ma (sample 3MRG–6) was obtained from a lava flow in a tributary to Arroyo Montoso near the western edge of the map area. Reverse polarity based on paleomagnetic determination and aeromagnetic signature

Qaec **Cinder deposits**—Dissected cinder cones comprised of near vent pyroclastic deposits, predominantly scoria, spatter agglutinate and minor flow material

Qae **Lava flows**—Medium-gray, massive basaltic andesite (55–57 weight percent SiO_2) lava flows (3-5 m thick) containing sparse olivine±pyroxene phenocrysts and abundant xenocrysts of plagioclase and quartz. Maximum exposed thickness is 65 m but is locally thickened by down-to-west normal faults

Basalt of Hill 6929 (early Pleistocene)—Lava flows and near vent pyroclastic deposits from two centers, preserved in the northcentral part of the map area. Locally, near-vent deposits unassociated with any lava flows, are preserved on the southeast flank of Montoso Peak. Additional deposits occur west of Ortiz Mountain where a prominent northeast-trending dike cuts eroded cinder deposits. Lava flows abut deposits of Ttx, Qto and Tm to the southeast, south and west respectively. Reverse magnetic polarity based on fluxgate magnetometer determination

Qbzc **Cinder deposits**—Dissected cinder cones composed of near vent pyroclastic deposits, predominantly scoria, spatter agglutinate and minor flow material

Qbz **Lava flows**—Medium- to dark-gray, basaltic to basaltic andesite lava flows, proximal to associated cinder deposits are thin (2–3 m) and discontinuous. Some lava flows along the eastern and western flanks of Montoso Peak are likely derived from vent areas to the north of the map area on the White Rock quadrangle. Phenocrysts of olivine, ubiquitously altered to iddingsite, and lesser amounts of pyroxene are typical. Quartz and plagioclase xenocrysts are present locally. Maximum exposed thickness is 30 m, base not exposed

Basalt of Cañada Ancha (early Pleistocene)—Medium- to dark-gray lava flows exposed along the northeastern margin of the map area and along Cañada Ancha in the adjacent Agua Fria quadrangle (Shroba and others, 2006). Comprises three informal map units produced by discrete eruptive events from unknown source vents presumed to underlie younger deposits of the map area. Only the upper units (Qbu and Qbuc) are exposed in the map area but the nomenclature is retained for consistency with unit designation in the adjacent Agua Fria quadrangle. The basalt of Cañada Ancha is overlain by the andesite of Ortiz Mountain at the northern exposed extent

Qbuc **Cinder deposits**—Dissected cinder cones composed of near vent pyroclastic deposits, predominantly scoria, spatter agglutinate and minor flow material. Locally includes thin, isolated deposit of cinder, not necessarily reflecting near vent proximity. This deposit may reflect lava flow rafting of near-vent pyroclastic deposits away from vent areas now presumed buried beneath Qtoc in the Twin Hills area

Qbu **Lava flows**—Basalt to basaltic andesite lava flows that cap an eastward-sloping surface on the west side of Cañada Ancha. Lava flows contain moderately abundant, equant olivine phenocrysts, sparse clinopyroxene phenocrysts, and ubiquitous resorbed plagioclase xenocrysts. Lava flows are lobate and discontinuous, and vary in thickness from 1.5 to 5 m. Flows have reversed magnetic polarity based on paleomagnetic signature and overlie 2.3–2.4 Ma lava flows of unit Tbm in the Agua Fria quadrangle (Shroba and others, 2006). Maximum exposed thickness is 8 m

Basalt of Montoso Peak (Pliocene)—Basalt lava flows and near vent pyroclastic deposits forming Montoso Peak and adjacent lowlands southwest of Montoso Peak. An $^{40}Ar/^{39}Ar$ isotopic age of 2.59±0.05 Ma was obtained from a lava flow forming a prominent bench on the south side of Montoso Peak (sample 96TMP08). Normal magnetic polarity from both paleomagnetic and aeromagnetic signature. Maximum exposed thickness is 210 m

Tmc **Cinder deposits**—Dissected monogenetic cinder cone composed of near vent pyroclastic deposits, predominantly scoria, spatter agglutinate and minor flow material. Volcanic bombs are common near the summit of Montoso Peak

Tm **Lava flows**—Dark-gray to medium-gray basalt (49–52 weight percent SiO_2) lava flows, typically less than 5 m thick containing common phenocrysts of olivine, pyroxene and plagioclase, and locally xenocrysts of quartz and hornblende

Andesite of Colorado Peak (Pliocene)—Andesitic lava flows form the lower flanks of Colorado Peak and grade transitionally into predominantly near-vent pyroclastic deposits near the summit and dissected southern flank. Most flows appear to have erupted from a central vent area characterized by a conspicuous summit crater and associated ring dikes and incipient flow breccias. Summit cone area is cut by northeast- and northwest-trending dikes. An $^{40}Ar/^{39}Ar$ isotopic age of 2.60±0.10 Ma was obtained from a lava flow near the summit of Colorado Peak. Normal magnetic polarity based on paleomagnetic and aeromagnetic signature. Maximum exposed thickness is 225 m, base not exposed

Tcac **Cinder deposits**—Dissected summit cone composed of near vent pyroclastic deposits, predominantly scoria, spatter agglutinate, bombs and abundant flow material. Near-vent deposits are sparsely olivine and pyroxene phyric and contain few xenocrysts

Tca **Lava flows**—Dark-gray basaltic andesite to andesite (56–62 weight percent SiO_2) lava flows up to 15 m thick containing phenocrysts of olivine and pyroxene and abundant xenocrysts of resorbed plagioclase and sparse quartz. Lava flows are lobate in form and directed predominantly to the west and northwest but truncated to the west by offset along the down-to-west Cochiti Cone normal fault

Basaltic andesite of Thirty-One Draw (Pliocene)—Discontinuous, poorly exposed outcrops of lava flows and minor associated pyroclastic deposits forming the north flank of Twin Hills underlying Qto. Interpreted to be remnants of a larger, eroded and buried volcanic center. Normal magnetic polarity is inferred from aeromagnetic signature and is consistent with an eruption age greater than 2.59 Ma (table 1)

Ttxc **Cinder deposits**—Pyroclastic deposits, predominantly scoria and spatter agglutinate which may not represent immediate proximity to eruptive vent. Deposits are thin and discontinuous

Ttx **Lava flows**—Medium-gray to dark-gray basaltic andesite lava flows (52–53 weight percent SiO_2) underlying vegetated north slopes of Twin Hills. Lava flows are thin, (less than 3 m), vesicular, aphyric to sparsley phyric containing small olivine phenocrysts (less than 1 mm) in a fine-grained, holocrystalline groundmass. Preserved lava flow directions are to the north. Maximum exposed thickness is 50 m

Andesite of Cerrita Portillo (Pliocene)—Lava flows and associated near-vent pyroclastic deposits of Cerro Portillo volcano exposed in the central and eastern margin of the map area. An $^{40}Ar/^{39}Ar$ isotopic age of 2.60±0.10 Ma (sample 96TMP36) was obtained from a lava flow on the south flank of an eroded distal flow lobe. Normal magnetic polarity based on paleomagnetic and aeromagnetic signature. Maximum exposed thickness is 175 m

Tcpc **Cinder deposits**—Near-vent pyroclastic deposits, predominantly spatter with lesser amounts of scoria

Tcp **Lava flows**—Medium-gray massive, blocky andesite lava flows (58–61 weight percent SiO_2) erupted from vents in the central part of the map area. Lava flows form broad surfaces on lava-flow sequences as much as 100 m thick. Lava flows contain ubiquitous phenocrysts of hornblende, plagioclase, clinopyroxene, Fe-Ti oxides, and minor olivine. Resorbed plagioclase xenocrysts are commonly associated with glomerocrysts of altered pyroxene. Dominant flow directions are to the northeast, east and southeast

Basalt of Caja del Rio (Pliocene)—Lava flows and associated near-vent pyroclastic deposits associated with a northeast trending alignment of small volume eruptive centers in the southeast part of the map area. Comprised predominantly of near-vent deposits with lesser flow material erupted from lower flanks of individual cinder cones. An $^{40}Ar/^{39}Ar$ isotopic age of 2.59±0.04 Ma (sample 02TMP02) was obtained from a lava flow on the southeast flank of the largest cinder and spatter remnant. Normal magnetic polarity based on paleomagnetic and aeromagnetic signature. Maximum exposed thickness is 135 m, base not exposed

Tayc **Cinder deposits**—Multiple dissected cinder cones composed of near-vent pyroclastic deposits, predominantly scoria, spatter agglutinate, bombs and abundant flow material

Tay **Lava flows**—Thin (<4 m), medium-gray basalt to basaltic andesite (49–53 weight percent SiO_2) lava flows exposed in the uppermost reaches of Arroyo Calabasas. Sparsely phyric with olivine phenocrysts (1–2 mm) in microcrystalline groundmass. Ubiquitous, resorbed plagioclase xenocrysts are typically 2–3 mm but can be up to 0.5 cm

Tb **Basalt of La Bajada Rim (Pliocene)**—Medium- to dark-gray basaltic (48–50 weight percent SiO_2) lava flows exposed only in the lower reaches of Arroyo Tetilla in the southeast part of the map area. Includes both tholeiitic and transitional olivine basalts and locally basaltic andesites. Phenocrysts include olivine+pyroxene±plagioclase and lesser iron-titanium oxides. Locally overlies paleochannel deposits of the Rio Grande east of the map area in the Cochiti Dam quadrangle. Likely erupted from buried and (or) eroded volcanic centers overlain by Tca. Maximum exposed thickness is 40 m

Basaltic andesite of Arroyo Calabasas (Pliocene)—Medium- to dark-gray lava flows exposed along Arroyo Calabasas and three tributary arroyos in the southeastern part of the map area and in the adjacent Agua Fria quadrangle (Shroba and others, 2006). Comprises two map units produced by discrete eruptive events, the younger from an unknown source vent presumed to underlie younger surficial deposits east of the map area. Only the lower unit is exposed in the map area but the nomenclature is retained for consistency with unit designation in the adjacent Agua Fria quadrangle. An $^{40}Ar/^{39}Ar$ isotopic age of 2.53±0.20 Ma (sample 4MRG–5) was obtained from a lava flow in Arroyo Calabasas but a normal magnetic polarity based on the measured paleomagnetic signature of the same sample suggests the age must be greater than 2.59 Ma and is within the analytical error of the argon age determination. Maximum exposed thickness is 90 m at Cerrito Pelado, outflow thickness in Arroyo Calabasas is typically 25 m or less

Tbclc **Cinder deposits**—Near vent pyroclastic deposits, predominantly scoria, spatter agglutinate, bombs and abundant flow material preserved at Cerrito Pelado. Active quarry operations have removed and (or) recontoured the northeastern third of Cerito Pelado exposing interbedded flow material and pyroclastic material and lesser intrusive dikes too small to show at map scale

Tbcl **Lava flows**—Medium- to dark-gray, basaltic andesite (53–55 weight percent SiO_2) lava flows containing sparse olivine phenocrysts in a fine-grained holocrystalline groundmass. Lava flows are typically discontinuous and thin, typically less than 1.5–2 m thick. In most places the map unit represents flow lobes of a single flow or eruptive event. The source area is inferred to be the vent area of Cerrito Pelado, based on geochemical and paleomagnetic correlation with lava flows in Arroyo Calabasas

Basalt of Tsinat Mesa (Pliocene)—Interbedded flows and near-vent pyroclastic deposits erupted from vents at the northeast corner of the Tetilla Peak quadrangle (Sawyer and others, 2002). Flows are interbedded with brown to reddish-brown cinders, spatter and other undifferentiated near-vent pyroclastic deposits. Locally the cinder cone is composed of oxidized cinders, scoria, blocks and bombs, and cut by numerous dikes of fine-grained basaltic andesite. Lava flows that erupted from the cinder cone in the southeast corner of the map area flowed predominantly south and southeast and form the eastern rim of the Cerros del Rio volcanic field adjoining the village of Cieneguilla in the Turquoise Hill and Tetilla Peak quadrangles. An $^{40}Ar/^{39}Ar$ isotopic age of 2.68±0.03 Ma was obtained from a dike that locally intrudes the cinder cone on the adjacent Tetilla Peak quadrangle to the south (Sawyer and others, 2002). Cinder deposits are locally quarried for decorative landscape material. Normal magnetic polarity based on paleomagnetic and aeromagnetic signature. Exposed thickness is 30–35 m, but deposits thicken to the south

Tbsc **Cinder deposits**—Near-vent pyroclastic deposits, predominantly scoria, spatter agglutinate, bombs and abundant flow material

Tbs **Lava flows**—Medium-gray basalt to basaltic andesite (51–53 weight percent SiO_2) lava flows containing small olivine phenocrysts and common resorbed plagioclase and quartz xenocrysts. Commonly interbedded with scoria and cinders

Tbta **Basaltic tephra and Ancha Formation, undivided (Pliocene)**—Poorly exposed deposits of basaltic tephra about 15 cm to 5 m thick interstratified with sand, pebbly sand, and poorly sorted basaltic tephra-bearing sandstone of the Ancha Formation. Some of the basaltic tephra-bearing sandstone may have been deposited as hyperconcentrated flows. Mapped near the southeastern corner of the map area beneath the basaltic andesite of Arroyo Calabasas (Tbcl). Maximum exposed thickness is 20 m

Basaltic andesite of Cerro Micho (Pliocene)—Thin, discontinuous lava flows associated with two small, eroded cinder cones on the northeast flank of Cerro Micho. Locally cut by northeast trending dikes. An $^{40}Ar/^{39}Ar$ isotopic age of 2.73±0.03 Ma (sample 3MRG–1) was obtained from a lava flow interbedded with scoria on the larger of the two cinder cones. Normal magnetic polarity based on paleomagnetic and aeromagnetic signature. Maximum thickness is 115 m

Tbcc **Cinder deposits**—Near-vent pyroclastic deposits, predominantly scoria, spatter agglutinate, bombs and abundant flow material

Tbc **Lava flows**—Medium- to dark-gray, thin (<3m) basaltic andesite (52–53 weight percent SiO_2) lava flows. Contains abundant olivine and lesser pyroxene phenocrysts (< 2 mm) and ubiquitous plagioclase and quartz xenocrysts in a fine grained holocrystalline groundmass

Andesite of Cerro Micho (Pliocene)—Lava flows and associated near-vent deposits erupted from several eroded vent areas, the largest of which is preserved at Cerro Micho. Thick lava flows up to 8–10 m, underlie the eastern rim of White Rock Canyon in the northwest part of the map area. Between White Rock Canyon and Arroyo Montoso, the section is exposed in several, down-to-west fault blocks. Scattered near-vent deposits, predominantly cinders, overlie associated lava flows and are thickest along a NW-SE trending alignment of dissected cinder and spatter cones extending from the northwest corner of the map to Cerro Micho on the southeast. An $^{40}Ar/^{39}Ar$ isotopic age of 2.76±0.03 Ma (sample 3MRG–5) was obtained from a lava flow in a tributary to Arroyo Montoso. Normal magnetic polarity based on paleomagnetic and aeromagnetic signature. Maximum exposed thickness is 300 m although thickness varies considerably and likely reflects eruption of lava flows onto an irregular paleotopographic surface

Tcmc **Cinder deposits**—Near-vent pyroclastic deposits, predominantly scoria, spatter and lesser agglutinate

Tcm **Lava flows**—Medium-gray to reddish brown andesite (57–60 weight percent SiO_2) lava flows. Although variable, most lava flows characteristically contain olivine and clinopyroxene phenocrysts, sparse to abundant plagioclase phenocrysts ± resorbed plagioclase xenocrysts in a fine-grained holocrystalline groundmass

Tat **Andesite of Tetilla Peak (Pliocene)**—Massive light-gray lava flows that underlie the southern rim of Arroyo Colorado in the southwest part of map area and most of Tetilla Peak to the south in the adjacent Tetilla Peak quadrangle (Sawyer and others, 2002). Basaltic andesite and andesite lava flows (56.5–62.7 percent SiO_2) contain common plagioclase and clinopyroxene phenocrysts, sparse xenocrystic quartz, and hornblende that locally is a prominent phenocryst in upper part of lava flows at Tetilla Peak (Zimmerman and Kudo, 1979). An $^{40}Ar/^{39}Ar$ isotopic age of 3.04±0.21 Ma from a lava flow in the adjacent Tetilla Peak quadrangle. Normal magnetic polarity based on paleomagnetic and aeromagnetic signature. Individual flows range from 50 to 70 m in thickness; aggregate thickness as much as 200 m

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