

Geologic Map of the Canada Quadrangle, Sandoval County, New Mexico

By

Scott D. Lynch, Gary A. Smith, and Andrika J. Kuhle

May, 2004

**New Mexico Bureau of Geology and Mineral Resources
*Open-file Digital Geologic Map OF-GM 85***

Scale 1:24,000

This work was supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program (STATEMAP) under USGS Cooperative Agreement 06HQPA0003 and the New Mexico Bureau of Geology and Mineral Resources.



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

The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government or the State of New Mexico.

Geology of the Canada 7.5' Quadrangle, Sandoval County, New Mexico

Scott D. Lynch

New Mexico Institute of Mining and Technology, Socorro NM 87801

Gary A. Smith and Andrika J. Kuhle

Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque,
NM 87131

Introduction

A geologic map of the Canada 7.5' quadrangle was completed as a project of the New Mexico Bureau of Geology and Mineral Resources geologic mapping program. The map is a compilation of work from various mappers (fig.1). Gary Smith and Andrika Kuhle of the University of New Mexico mapped the southern half of the quadrangle between 1997 and 2002. Scott Lynch mapped the northwest corner during 2003 as a contract geologist with the New Mexico Bureau of Geology and Mineral Resources. The northeast corner was compiled from mapping by Goff et al. (1990), Lavine (1995), and from new reconnaissance mapping by Gary Smith. The area known as the Cochiti mining district in upper Colle Canyon was compiled from mapping by Stein (1983) along with new mapping by Scott Lynch. All mapping was done at a scale of 1:24,000, with the exception of Stein (1983) who mapped at 1:6,000. The map area is located in the southern Jemez Mountains, approximately 25 miles due west of Santa Fe, New Mexico. This report summarizes the regional geologic setting and discusses the major geologic features of the quadrangle.

Geologic Setting

The Canada quadrangle is located at the boundary between the southern Jemez volcanic field and northern Santo Domingo Basin, and on the western edge of the Rio Grande rift. The Santo Domingo Basin is an accommodation zone within the rift that is filled primarily with Santa Fe Group sediments (Smith and Kuhle, 1998). The Jemez volcanic field is at the intersection between the rift and the northeast-trending Jemez lineament. These structures are characteristically expressed in the Jemez Mountains as northerly and northeasterly trending normal faults. Miocene to Pleistocene lavas and pyroclastics ranging in composition from basalt to rhyolite make up the volcanic field, and its development culminated with the formation of the Valles Caldera and associated 1.22 Ma eruption of the Bandelier Tuff. The southeastern margin of the Valles Caldera is about 10-15 km northwest of the Canada quadrangle.

In the southern Jemez volcanic field, the Bandelier Tuff erupted over a rugged terrain of volcanic rocks known as the Keres Group (Bailey et al., 1969). The group was refined by Gardner et al. (1986) and consists of Canovas Canyon Rhyolite, Paliza Canyon Formation, and Bearhead Rhyolite. Paliza Canyon Formation dominates Keres Group, and consists of voluminous andesitic to dacitic, with some basaltic, lavas and associated volcanic breccias (Gardner et al., 1986). Canovas Canyon Rhyolite flows and tuffs typically underlie Paliza Canyon andesites and dacites, but are intercalated locally. Most

of the Canovas Canyon and Paliza Canyon volcanic rocks were erupted 8-10 Ma (Gardner et al., 1986; Goff et al., 1990; Lavine et al., 1996; Chamberlin et al., 1999). Overlying the Paliza Canyon Formation is the Bearhead Rhyolite, which consists of rhyolite intrusions, lava flows and domes, and the associated pyroclastic and sedimentary strata of the Peralta Tuff member. Bearhead rhyolite erupted between 6-7 Ma (Gardner et al., 1986).

Description and Discussion of Rock Units in the Canada Quadrangle

The northern half of the Canada quadrangle is Keres Group rocks and Bandelier tuff, and the southern half is primarily volcanoclastic basin-fill sediments and pediment gravels of the Santa Fe Group. The Keres Group rocks form prominent highlands along the northwestern and northeastern sides of the quadrangle, with Bandelier Tuff capping the mesas in between. Keres Group rocks are also present in the deeply incised canyons between the mesas of Bandelier Tuff.

Galisteo Formation

The oldest rocks in the map area are blocks of non-volcanoclastic arkosic sandstone (Tg) present within diorite and monzonite stocks (Tpid). These blocks are present only in a small area near the northern quadrangle boundary in Colle Canyon. They are typically massive, well sorted, coarse-grained, and consist of sub-rounded quartz and feldspar grains. The thickest block is about 100 meters. Stein (1983) and Smith (2001) interpret these blocks as roof pendants within the stocks. They are tentatively correlated to the Eocene Galisteo Formation by Smith (2001) based on lithologic similarities, but precise stratigraphic assignment is uncertain. Outcrops of Galisteo Formation are found just outside the Canada quadrangle, less than 10 km to the east of the pendant blocks.

Keres Group

Canovas Canyon Rhyolite

The oldest Keres Group rocks in the map area are scattered outcrops of Canovas Canyon Rhyolite tuffs (Tct), domes, flows, and a few intrusions (Tcc). The tuffs are lithic-rich, bedded ash-flow tuffs with a maximum composite thickness of about 20 meters. Tcc is commonly flow banded, up to 100 m thick, and contains sparse phenocrysts of quartz, sanidine, and biotite. K-Ar ages of four domes and flows range from 9.24 ± 1.50 Ma to 12.4 ± 2.0 Ma (Goff et al., 1990).

Paliza Canyon Formation - intrusive rocks (Tpi)

North of Bearhead Peak there is mostly hypabyssal rocks of the Cochiti mining district. The area is in the footwall of a NE-trending fault zone, including the major Bland fault (Stein, 1983). Uplift and erosion of these blocks has exposed the feeder system of the Keres Group volcanic rocks, a depth of exposure seen nowhere else in the Jemez volcanic field. The rocks are primarily dikes and stocks of the Paliza Canyon Formation that are intruded by Bearhead Rhyolite dikes and stocks. The dikes commonly

are near vertical and strike north to northeast, coincident with fault orientations in the area.

The rocks in the Cochiti mining district are hydrothermally altered and intensely fractured. Faults and fractures in the district are commonly filled with N-S and NE-SW trending, gold and silver bearing epithermal quartz veins up to 1 meter wide. The rocks are variably chloritized, silicified, and argillized. WoldeGabriel and Goff (1989) dated hydrothermal illite and determined this alteration occurred between 5.9-6.5 Ma and may thus be associated with Bearhead Rhyolite magmatism.

The oldest of these hypabyssal rocks in the Canada quadrangle is a single, continuous outcrop of a gabbro stock (Tpig). It has diabasic texture with plagioclase, augite, and olivine. Andesite dikes (Tpia) intrude the gabbro. Tpia consists of basaltic andesite, andesite, and dacite dikes and stocks. The basaltic andesite contains sparse phenocrysts of plagioclase, augite, and olivine; the andesite contains few phenocrysts of plagioclase and augite; and the dacite is composed of plagioclase, orthoclase and quartz. Diorite and monzonite dikes and stocks (Tpid) locally intrude both Tpig and Tpia. Dikes range between 1 cm and 30 m thick. They contain phenocrysts of plagioclase and augite set in a fine-grained phaneritic to aphanitic groundmass of plagioclase, orthoclase, quartz, and augite. Sandstone xenoliths are common in Tpid,

Paliza Canyon Formation-extrusive rocks and volcanoclastic deposits

Paliza Canyon andesites are voluminous and widespread in the southern Jemez Mountains. Thick sequences of andesite flows, domes, and minor intrusions (Tpa) exist along the northwest margin of the Canada quadrangle. They contain 1-5% phenocrysts of plagioclase, clinopyroxene, and lesser amounts of hypersthene, and they have an observed composite thickness of 140 meters with no exposed base. East of these exposures the andesites are down-dropped by down-to-the-east normal faults and buried by a thick sequence of Peralta Tuff. Tpa "reappears" east of the down-to-the-west Medio Dia fault beneath coarsely porphyritic andesite domes and flows (Tppa) of similar mineralogy. Olivine andesite domes and flows (Tpoa) are found beneath Tpa east of the Medio Dia fault. They contain plagioclase, clinopyroxene, hypersthene, and olivine phenocrysts.

Paliza Canyon dacite domes and flows overlie the andesites along the northwest margin of the quadrangle. Dacite domes, flows, and minor intrusions are also present from Bland Canyon eastward -- a similar distribution to the andesites. Hornblende dacite (Tphd) has a maximum observed thickness of about 60 meters and contains phenocrysts of plagioclase, hornblende, minor clinopyroxene, \pm biotite. Of greater abundance is biotite dacite (Tpbd), which overlies the hornblende dacite in Sanchez Canyon and has a maximum observed thickness of about 150 meters. It contains phenocrysts of plagioclase, biotite, \pm clinopyroxene, \pm hornblende, \pm quartz.

Volcanoclastic deposits (Tpv) in the Canada quadrangle consist of breccias, conglomerates, and sandstones that are locally interbedded with Paliza Canyon Formation lava flows. They are primarily debris-flows and fluvial deposits consisting of reworked flow-breccia blocks and tephra. Also included in Tpv are localized primary and slightly reworked andesitic, dacitic, and rhyodacitic tephra. Outcrops in Cochiti and Sanchez Canyons include monolithologic breccias with sparse radially jointed blocks that

may be block-and-ash-flow deposits. The stratigraphy, volcanology, and sedimentology of these deposits described by Lavine (1995).

Bearhead Rhyolite

Phenocryst-poor rhyolite intrusions, domes, flows and tuffs intrude and overlie the Paliza Canyon Formation in the southeastern Jemez Mountains. The Peralta Tuff Member of the Bearhead Rhyolite is typically overlain and intruded by the domes, flows, and intrusions, but locally they are intercalated or the Peralta Tuff buries the lava.

As much as 500 meters of Peralta Tuff is present in Peralta, Colle, and Bland Canyons. It thins eastward from Bland Canyon and thins westward up Peralta Canyon. It consists of pyroclastic-fall, flow, and surge deposits interbedded with sandy gravel. Pyroclastic deposits are typically lithic-rich and contain <3% phenocrysts of quartz, sanidine, biotite, and plagioclase. Sedimentary strata are thickest near the base of the unit in Bland Canyon, and are only present between Peralta and Bland Canyons. The Peralta Tuff erupted between about 6.2-7.0 Ma (Smith, 2001).

Bearhead rhyolite domes and flows (Tbf), and dikes and stocks (Tbi) contain 1-3% phenocrysts of quartz, sanidine, biotite, \pm minor plagioclase. They are commonly strongly banded with vitrophyre near their margins. Domes and intrusions are commonly distributed along and at the intersection of N-S and NE-SE striking faults. A thickness of ~370 meters is observed near the type locality of Bearhead Peak.

Tewa Group

Bandelier Tuff fills paleotopographic lows in the Canada quadrangle. A nice example of thick Bandelier tuff abruptly pinching out against a major fault scarp is seen in Colle Canyon. The Otowi Member (Qbo) of the Bandelier Tuff is commonly found beneath the Tshierge Member (Qbt) in the map area. Qbo reaches a thickness of up to 100 meters, and locally features a basal pumice-fall deposit up to 2 meters thick. It is non-welded, lithic-rich, and commonly forms slopes and tent rocks. A 1-3 m thick alluvial gravel and sand deposit (Qoa) is locally found beneath the Otowi member. Both Qbo and Qbt contain abundant phenocrysts of euhedral quartz and iridescent sanidine. Qbt is typically non-welded to slightly welded, but is densely welded locally. Qbt is up to 150 meters thick and locally includes a basal pumice fall deposit up to 2 meters thick. Qbt forms the conspicuous orange cliffs that cap the mesas in the southern Jemez Mountains. Qbo erupted ~1.22 Ma and Qbt ~1.61 Ma.

El Cajete pumice deposits (Qec) are present in the Canada quadrangle as discontinuous sheetwash and fluvially reworked rhyolite pumice-fall deposit, typically less than 5 m thick. It also includes poorly to moderately sorted primary deposits that occur along the Pajarito fault zone and in Bland Canyon. Pumice clasts contain less than 2% phenocrysts of quartz, sanidine, biotite, and rare clinopyroxene and hornblende. Qec erupted approximately 60 ka from the El Cajete crater in southern moat of Valles caldera. The maximum thickness of the deposit is about 10 meters, and it is quarried in many locations.

Santa Fe Group

Gradationally overlying the Peralta Tuff are volcanic sands and gravels of the Cochiti Formation (QTc), which is present in poorly sorted, tabular beds in the southern half of the Canada quadrangle. Clasts consist of Keres Group volcanic rocks with a distinct upward increase in the abundance of devitrified and altered rhyolite at the expense of vitric rhyolite. The basal contact at Tent Rocks is located about 10 m above a 6.79 ± 0.05 Ma pyroclastic deposit (McIntosh and Quade, 1995). A 6.16 ± 0.07 Ma (W. McIntosh, personal communication, Oct. 1997) rhyolitic tephra is present in lower beds of the formation at Tent Rocks. East of Tent Rocks, the lower Pleistocene Bandelier Tuff (*Qbo*) is present within the uppermost Cochiti Formation.

Ancestral Rio Grande gravels of the Sierra Ladrões Formation (QTslg) are interbedded with Cochiti Formation in the southeastern corner of Canada quadrangle, but are also found as clasts in Peralta Tuff at Tent Rocks, and in fault gouge along Pajarito fault on west side of Bland Canyon. QTslg contains about 35-40% quartzite, 20% granitic and metamorphic rocks and the remainder mostly volcanic rocks. Clasts of Oligocene pedernal chert comprise 1 to 5% of most outcrops. At Tent Rocks, rhyolitic hydromagmatic deposits dated at 6.90 ± 0.06 Ma (McIntosh and Quade, 1995; Smith, 2000) contain accessory clasts derived from axial gravel deposits. Tephra, apparently reworked from the lower Bandelier Tuff, and dated at 1.62 ± 0.01 Ma (W. . McIntosh, personal communication, Feb. 1997) is present approximately 20 m below the top of the Sierra Ladrões Formation in the Santa Fe River valley immediately upstream of Cochiti Dam in the Santo Domingo Pueblo quadrangle (Smith and Kuhle, 1998). These dates limit the age of the Sierra Ladrões Formation outcrops in the Santo Domingo from late Miocene to early Pleistocene, although outcrops on this quadrangle are all of late Miocene age.

A broad pediment surface cut primarily on Cochiti Formation in the southwestern part of the quadrangle is overlain by cobble and boulder gravels of the Gravel of Lookout Park (Tglp). The gravel is inset below basalt of Santa Ana Mesa dated at 2.41 ± 0.03 Ma, on the Santo Domingo Pueblo Southwest quadrangle (Smith and Kuhle, 1998), and underlies lower Bandelier Tuff (1.61 Ma) indicating deposition during a short period of the late Pliocene. Remnants of a stage IV calcic soil horizon are present at the surface in some places. This older soil was stripped and then the gravel was largely buried in eolian sand and silt (*Qe*) in which a new soil has formed with a stage II-stage III calcic horizon evident in various places.

Quaternary surficial deposits

Fill and strath piedmont-stream terraces (Qt_1 - Qt_4) in the Canada quadrangle are primarily associated with Peralta, Bland, and Cochiti Canyons and are gravels composed of variably altered andesitic and rhyolitic clasts and, in Peralta Canyon, Bandelier Tuff fragments. Eolian sand and silt (*Qe*) form 0.5-3 m thick deposits primarily on top of the ancient geomorphic surface that is underlain by the gravel of Lookout Park. Landslides (*Qls*) are common along steep slopes in the northern Canada quadrangle, and alluvium (*Qal*) and colluvium (*Qc*) are present throughout the quadrangle.

Stratigraphy

A 12.4 Ma Canovas Canyon Rhyolite flow (Tcc) and an underlying tuff (Tct) are exposed in Sanchez Canyon and are the oldest volcanic units in the Canada quadrangle. The flow is overlain by intercalated Paliza Canyon Formation andesite and dacite flows, domes, and volcanoclastic deposits. The lower part of this sequence is intercalated with Canovas Canyon Rhyolite domes, flows, and tuffs as young as 9.2 Ma (Gardner and Goff, 1984). There is no compositional progression in this sequence of rocks (Goff et al., 1990). The sequence is overlain by Peralta Tuff, which is overlain by a Bearhead Rhyolite dome.

In the western part of the quadrangle, Paliza Canyon Formation andesite flows (Tpa) and intrusive rocks (Tpi) are the oldest volcanic units exposed. Paliza Canyon Formation biotite dacite flows (Tpbd) overlie andesite flows (Tpa) along the western quadrangle margin. A Paliza Canyon Formation hornblende dacite flow (Tphd) is present beneath Peralta Tuff (Tbp) and apparently above andesite flows (Tpa). It is a single exposure in the northwest corner of the quadrangle and its stratigraphic relationship with the biotite dacite (Tpbd) is unknown.

Bearhead Rhyolite is stratigraphically above Paliza Canyon Formation in the Canada quadrangle. The Peralta Tuff Member (Tbp) is typically overlain and intruded by Bearhead Rhyolite domes, flows, and intrusions (Tbf/Tbi), but in Peralta Canyon they are intercalated or the Peralta Tuff buries the lava. Bandelier Tuff (Qbo/Qbt) overlies Bearhead Rhyolite and Keres Group.

The Cochiti Formation (QTc) gradationally overlies the Peralta Tuff Member in the southern part of Canada quadrangle and is interbedded with the Sierra Ladrones Formation (QTslg) near the southeastern corner. Bandelier Tuff (Qbo) is present within the uppermost Cochiti Formation east of Tent Rocks.

Structure

The Jemez volcanic field is at the intersection of the north-trending Rio Grande Rift and the northeast-trending Jemez lineament. High-angle normal faults trending north, north-northwest and northeast are numerous in the Canada quadrangle. Most of these faults dip between 65°-75° to the east or southeast. A notable exception is the major Medio Dia fault, which is down to the west. They are well exposed in the Keres Group volcanics, commonly with fault gouge, breccias, slicks, alteration zones, and in some places quartz veins. The displacement in Keres Group rocks is greater than 170 meters where the Peralta fault enters Peralta Canyon and juxtaposes Peralta Tuff against Paliza Canyon andesite (Tpa). The Bland fault juxtaposes hypabyssal Keres Group rocks in the footwall against Peralta Tuff in the hanging wall. Several faults also offset upper Pliocene pediment gravels (Tglp) in the southern part of the quadrangle by as much as 70 m, and a few displace the 1.22 Ma Bandelier Tuff (Qbt) in the northern part by typically less than 30 m.

The Pajarito fault zone is a major north to northeast trending structure in the Jemez Mountains. In the Canada quadrangle it has a record of movement in the middle Pleistocene. Between Bland and Cochiti Canyons it displaces the Bandelier Tuff by 90 meters. In Bland Canyon it also cuts middle Pleistocene terrace gravel (Qt₃), which is in

fault contact with Peralta Tuff. Goff et al. (1990) estimate a maximum displacement of 300 m in the Keres Group rocks along the Pajarito fault between Bland and Cochiti Canyons.

Many of the Keres Group magmas intruded and erupted along faults in the southern Jemez volcanic field (Gardner et al. 1986). In the Canada quadrangle, several Bearhead Rhyolite stocks and domes are found at the intersection between N-S trending and NE-SW trending faults. In the northwest corner of the quadrangle, Bearhead Rhyolite vents are aligned along N-S trending faults, which are intruded by rhyolite dikes. The intermediate and rhyolitic dikes in the Cochiti mining district very commonly trend N-S and NE-SW.

The Bearhead basin accommodates the 500 m thick, west-tilted section of Peralta Tuff between Peralta and Medio Dia Canyons (Smith, 1999). The fault zone of Peralta Canyon forms the western stepped margin of the basin, with the Peralta fault forming its far western edge. The Peralta tuff thins against the western margin, and is abruptly truncated by the Peralta fault. The down to the west Medio Dia fault zone forms the eastern margin of the Bearhead basin. The southeastern margin of the basin is partly uplifted in the footwall of the Pajarito fault. This uplift, along with possibly greater displacement along the Peralta fault zone than the Medio Dia fault zone, accounts for the westward tilt of the Bearhead basin. The basin is about 8 km wide near its southern end. It tapers to the north between northeast trending faults and the northwest trending Medio Dia fault. It is about 2.5 km wide near the northern quadrangle boundary, where northeast trending, down to the southeast faults form its northern margin. The thick section of Peralta Tuff Member and overlying Cochiti Formation is absent east and west of the Bearhead basin, indicating deposition during basin subsidence (Smith, 1999).

References Cited

- Bailey, R.L., Smith, R.L., and Ross, C.S., 1969, Stratigraphic nomenclature of volcanic rocks in the Jemez Mountains: U.S. Geological Survey Bulletin 1274-P, 19 p.
- Chamberlin, R.M., Pazzaglia, F.J., Wegmann, K.W., and Smith, G.A., 1999, Preliminary geologic map of the Loma Creston 7.5-min. quadrangle, Sandoval County, New Mexico, New Mexico Bureau of Mines and Mineral Resources, Open-file Geologic Map OF-GM 25, scale 1:24,000.
- Gardner, J.N., Goff, F., Garcia, S., and Hagan, R.C., 1986, Stratigraphic relations and lithologic variations in the Jemez volcanic field: *Journal of Geophysical Research*, v.91, p. 1763-1778.
- Gardner, J.N., and Goff, F., 1984, Potassium-argon dates from the Jemez volcanic field: implications for tectonic activity in the north-central Rio Grande rift, New Mexico Geological Society, Guidebook 35, p. 75-81.
- Goff, F., Gardner, J.N., and Valentine, G., 1990, Geology of St. Peter's Dome area, Jemez Mountains, New Mexico: New Mexico Bureau of Geology and Mineral Resources Geologic Map GM-69, 2 sheets, scale 1:24,000.
- Lavine, A., 1995, Sedimentologic and temporal relations between volcanic and volcanoclastic rocks of the Keres Group, Jemez Mountains: Implications for the physical and volcanic evolution of Keres Group composite volcanoes [M.S. thesis]: Albuquerque, University of New Mexico.

- Lavine, A., Smith, G.A., and Goff, F., 1996, Volcaniclastic rocks of the Keres Group: insights into mid-Miocene volcanism and sedimentation in the southeastern Jemez Mountains: New Mexico Geological Society 47th Field Conference Guidebook, p. 211-218.
- McIntosh, W.C., and Quade, J., 1995, $^{40}\text{Ar}/^{39}\text{Ar}$ geochronology of tephra layers in the Santa Fe Group, Española basin, New Mexico: New Mexico Geological Society, Guidebook 46, p. 279-287.
- Smith, G.A., 2001, Development of a pyroclastic apron adjacent to rhyolite domes in a subsiding basin: Upper Miocene Peralta Tuff, Jemez Mountains, New Mexico, in *Volcanoes of New Mexico*, L. Crumpler and S.G. Lucas, editors: New Mexico Museum of Natural History and Science Bulletin 18, p. 85-96.
- Smith, G.A., McIntosh, W.C., and Kuhle, A.J., in press, Sedimentologic and geomorphic evidence for teeter-totter subsidence of the Santo Domingo accommodation-zone basin, Rio Grande rift, New Mexico: Geological Society of America Bulletin.
- Smith, G.A., 1999, Tectonics and volcanism of the late Miocene Bearhead magmatic episode in the southeastern Jemez Mountains, New Mexico: New Mexico Geology, v. 21, p. 37-38.
- Smith, G.A. and Kuhle, A.J., 1998, Geology of the Santo Domingo Pueblo and Santo Domingo SW 7.5' quadrangles, Sandoval County, New Mexico, New Mexico Bureau of Mines and Mineral Resources, Open-file Geologic Map OF-GM 15 and 26, scale 1:24,000.
- Stein, H.J., 1983, Geology of the Cochiti mining district, Jemez Mountains, New Mexico [M.S. thesis]: University of New Mexico, Albuquerque, 122 p.
- WoldeGabriel, G., and Goff, F., 1989, Temporal relations of volcanism and hydrothermal systems in two areas of the Jemez volcanic field, New Mexico: Geology, v. 17, p. 986-989.