Geologic Map of the Laguna Cañoneros 7.5-minute Quadrangle, Cibola and McKinley Counties, New Mexico

By

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June 2014

New Mexico Bureau of Geology and Mineral Resources
Open-file Digital Geologic Map OF-GM 244

Scale 1:24,000

This work was supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program (STATEMAP) under USGS Cooperative Agreement G13AC00186 and the New Mexico Bureau of Geology and Mineral Resources.

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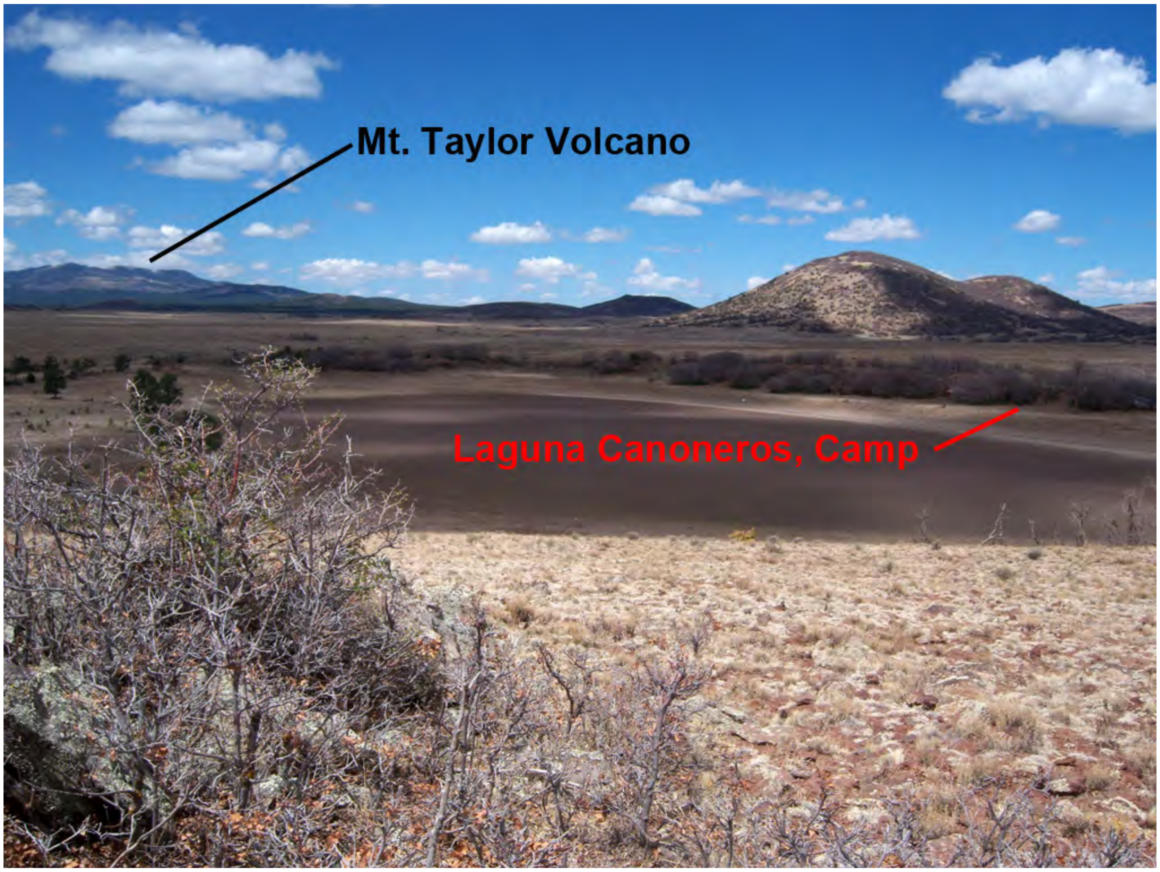

View southwest across Laguna Cañoneros maar and barren basaltic plains of southern Mesa Chivato, May 2013. Mount Taylor composite volcano (11,300 ft, 3445 m) rises in far left and the trachyte dome of Cerro Chivato (8920 ft, 2720 m) looms to right. "Camp" marks location of small houses, cabins, and stables of a previous cattle ranch that is now part of the extensive Floyd Lee Ranch. The "camp" served as our northern base during the second season of mapping operations. Photo by F. Goff.

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INTRODUCTION

Laguna Cañoneros quadrangle lies on the northeast flank of Mount Taylor, an extinct composite volcano in west central New Mexico (Hunt, 1938), and is located roughly 50 km northeast of Grants, New Mexico (Fig. 1). The landscape is dominated by the barren lava-covered plateau of Mesa Chivato to the northeast and by a tree-covered highland of scoria cones and lava flows to the southwest. Maximum elevation is the summit of Cerro Redondo (8,976 ft) near the southwest edge of the quadrangle, whereas minimum elevation (7,250 ft) occurs in the bottom of Seboyeta Canyon on the southeast edge of the quadrangle (see geologic map). Access to the quadrangle is tedious. The U.S. Forest Service owns the land in the northwest corner of the quadrangle accessible on Forest Service road 555. The northern ¾ of quadrangle land belongs to the extensive Floyd Lee Ranch (San Mateo, NM), which is only accessible by permission through the gate at the east end of FS 555 near the west margin of the quadrangle. The southern quarter of quadrangle lands belongs to the Elkins Ranch (southwest), the Silver Dollar Ranch (south), the Seboyeta Land Grant (upper Seboyeta Canyon) and the Lobo Ranch (southeast). Each of these landholdings is reached by permission on separate dirt roads from the south through Laguna Pueblo and the village of Seboyeta. Most lands on the quadrangle are used for cattle ranching, hunting and minor recreation. Lobo Ranch contains an extensive wind farm that generates electricity. We found scant evidence that pre-Columbian inhabitants lived on the quadrangle.

Hunt (1938) produced the first geologic map of the region and pointed out the spatial association between the Mount Taylor stratovolcano and surrounding mafic lavas and scoria cones. Sears et al. (1941) described transgressive-regressive depositional relations in Upper Cretaceous sedimentary rocks beneath Mount Taylor. Geologic mapping of 1:24,000 quadrangles began in the 1960s, mainly supporting the regional uranium boom (e.g., Moench, 1963; Moench and Schlee, 1967; Lipman et al., 1979). Crumpler (1980a, 1980b) mapped a portion of Mesa Chivato north of Laguna Cañoneros quadrangle and analyzed many of the lavas, cones and domes. Crumpler (1982, fig. 4) also published a geologic sketch map of the summit of Mount Taylor. Perry et al. (1990) published a more detailed geologic map of the summit and southwest flank of the volcanic complex. Dillinger (1990) produced a 1:100,000-scale map of the region to support coal investigations. Because of their unusual mineralogy and xenoliths, the geochemistry and age of Mount Taylor and Mesa Chivato volcanic products has been investigated in numerous reports (Baker and Ridley, 1970; Lipman and Moench, 1972; Crumpler, 1982; Perry et al., 1990; Hallett et al., 1997; Shackley,

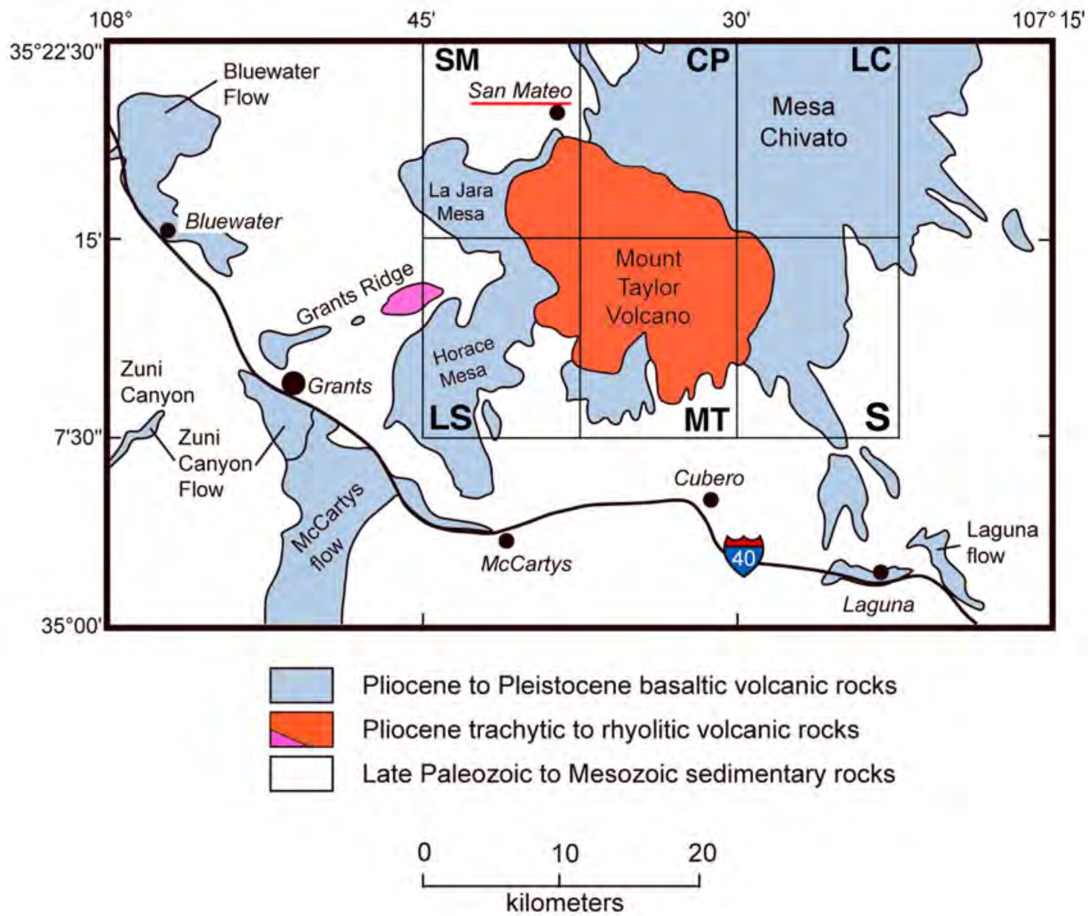

Figure 1. Location map of Laguna Cañoneros quadrangle (LC) and other mapped quadrangles (CP=Cerro Pelon, LS=Lobo Springs, MT=Mount Taylor, S=Seboyeta, SM=San Mateo).

1998; Fellah, 2011; Goff and Goff, 2013; Goff et al., 2013a, 2013b). Five other quadrangles have been recently mapped in the Mount Taylor region: Lobo Springs (Goff et al., 2008), Mount Taylor (Osburn et al., 2010), San Mateo (McCraw et al., 2009), Cerro Pelon (Goff et al., 2012), and Seboyeta (Skotnicki et al., 2012).

ACKNOWLEDGEMENTS

Harry Lee, Jr. (Fernandez Company, San Mateo) graciously provided access to the Lee Ranch. We are indebted to the staff of Laguna Pueblo for allowing us access to their lands on the Silver Dollar Ranch. Special thanks go to Jed Elrod, Ranch Manger (now retired) and Robert Alexander, Range Specialist, Laguna Pueblo. Kelley D'Amato (Everest Holdings, Scottsdale, AZ) and Shawn Pit (Red Mesa Wind, LLC, Seboyeta, NM) gave us permission to map the Lobo Ranch. We are grateful to Lee Maestas, past President, Seboyeta Cattle Association, for granting us access to upper Seboyeta Canyon. Buddy Elkins (Grants, NM) kindly allowed us to map the Elkins Ranch. The State Map Program jointly supported by the U.S. Geological Survey and the New Mexico Bureau of Geology and Mineral Resources funded this geologic map. We thank J. Michael Timmons (NMBG&MR) for logistical and tactical support and Larry Crumpler (New Mexico Natural History Museum) for discussions on the volcanology. David McCraw produced the final map. Fieldwork was conducted by standard procedures on all lands (topographic maps, air photography, binoculars, rock hammers, hand lenses, GPS devices, brunton compasses, portable flux gate magnetometer, four-wheel drive trucks, and boot leather). Chemical analyses of volcanic rocks (Appendix 1) were analyzed by John Wolff (Washington State University) and purchased from ALS USA, Inc. (Reno, NV). Selected thin sections (Appendix 2) were made by Dave Mann (High Mesa Petrographics, Los Alamos, NM). Ar/Ar dates were provided by William McIntosh and Lisa Peters (NMBG&MR).

GEOLOGY

The Laguna Cañoneros quadrangle is underlain by a thick, widespread sequence of slightly folded, domed and faulted upper Cretaceous rocks of the southern Colorado Plateau (Figs. 2, 3) having an aggregate thickness of 1070 m (3500 ft). Our mapping utilizes the style and terminology of Hunt (1938) and Lipman et al. (1979). The upper Cretaceous section (Fig. 3) is a regressive sequence, recording a gradual transition from open marine conditions (Mancos Shale) to a marginal marine (Gallup Sandstone, Stray and Dalton Sandstone members of the Crevasse Canyon Formation) and deltaic setting (Dilco and Gibson Coal members of the Crevasse Canyon Formation). The Point Lookout Sandstone, exposed in Seboyeta Canyon, was deposited during a marine transgression. The Satan Tongue of the Mancos Formation overlies the Point Lookout and underlies a variety of lava flows capping southwestern Mesa Chivato (Skotnicki et al., 2012). The upper Cretaceous sequence in the Mount Taylor region was folded, uplifted and eroded in early to mid-Tertiary time forming part of the greater Colorado Plateau. During the last 25 Myr, a structural transition zone has developed between the Colorado Plateau and an extensional zone called the Rio Grande rift. Cretaceous rocks were partially eroded during a period of base level stability and pedimentation in west central New Mexico that lasted from approximately 4 to 2.5 Ma. The Mt. Taylor volcanics were erupted onto this pediment surface. Bryan and McCann (1938) suggested that the erosion surface underlying Mt. Taylor was correlative with the Ortiz surface located in the Rio Grande rift. Beginning in the

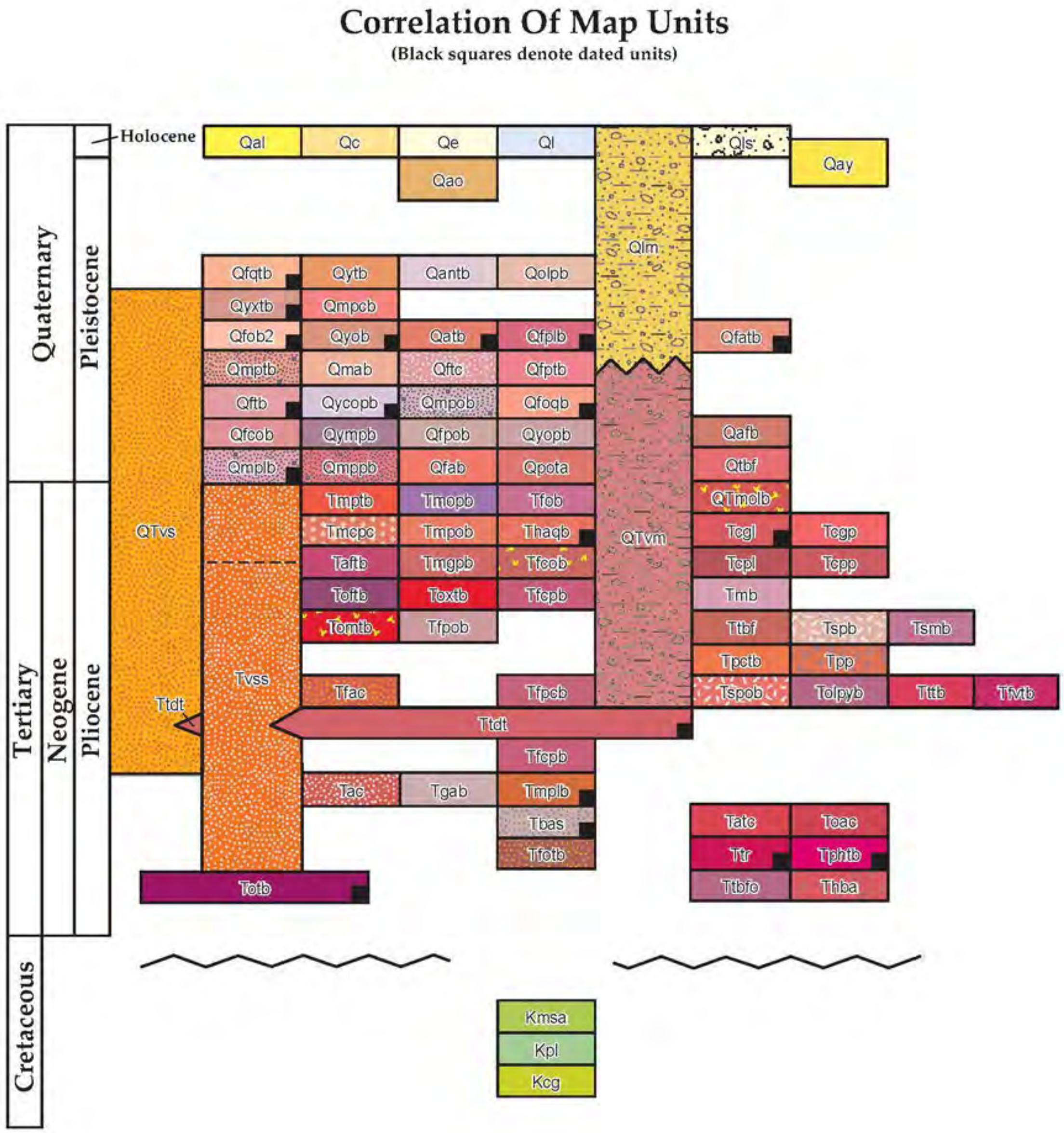

Figure 2. Correlation chart of geologic units mapped during this investigation.

early Pliocene (roughly 3.8 Ma), volcanism ensued in the region eventually forming a composite intermediate composition stratovolcano at Mount Taylor, flanked by mesas covered with basaltic lavas and scoria cones. This volcanism more or less ceased at about 1.25 Ma. Since that time, erosion has cut broad basins and shallow canyons into the terrain. The regional Pliocene pediment surface is preserved only where it is capped by basalt flows, such as on Mesa Chivato.

The magmatic evolution of the Mount Taylor volcanic field (MTVF) and Mesa Chivato has been described most recently by Crumpler (1980a, 1980b) and Perry et al. (1990). Volcanism in the Laguna Cañoneros quadrangle apparently commenced with emplacement of Cerro Chivato trachyte dome and older basaltic lava flows such as the hornblende-bearing trachyte near the north margin of the quadrangle. The ages of these units and older lavas on adjacent quadrangles span 3.5 to 3.0 Ma (Osburn et al., 2009; Goff et al., 2012; Skotnicki et al., 2012). These earliest volcanic rocks were then flooded and buried by successive eruptions of basaltic lavas from about 3.0 to 1.5 Ma. One eruption of light colored, slightly porphyritic trachydacite pumice is documented as several thin beds interlayered with basaltic flows within the eastern part of the quadrangle. These pumice beds resemble one dated at 2.700 ± 0.002 Ma to the south on adjacent Seboyeta quadrangle (Skotnicki et al., 2012; see also Dunbar et al., 2013 and Kelley et al., 2013). The youngest eruptions that we have documented to date on this quadrangle are the peridotite-bearing trachybasalt flows erupted from a scoria cone east of the quadrangle (1.85 ± 0.06 Ma, Goff et al, 2012) and trachybasalt lava flows erupted from Cerro Ortiz scoria cone (1.56 ± 0.17 Ma, Lipman and Mehnert, 1979) on the southwest edge of the quadrangle.

Volcanic rocks in the Mount Taylor area are slightly alkalic (Fig. 4). Few units contain primary quartz, although many of the mafic lavas contain quartz xenocrysts (Appendix 2). Previous workers in this region have variously classified the majority of volcanic rocks as basalt-andesite-rhyolite to hawaiite-latite-trachyte-rhyolite (e.g., Baker and Ridley, 1970; Lipman and Moench, 1972; Crumpler, 1980a; 1980b; Perry et al., 1990). For this map, we are using the widely accepted classification scheme of La Bas et al. (1986) and previously published chemical analyses to rename the volcanic units (Fig. 4). Thus, the alkali basalts (hawaiites) are called trachybasalts, basaltic andesites (muegerites) are called basaltic trachyandesites, andesites (latites) are named trachyandesites, and quartz latites are called trachydacite. The only volcanic rocks with no name changes are the rhyolites, trachytes and basanites.

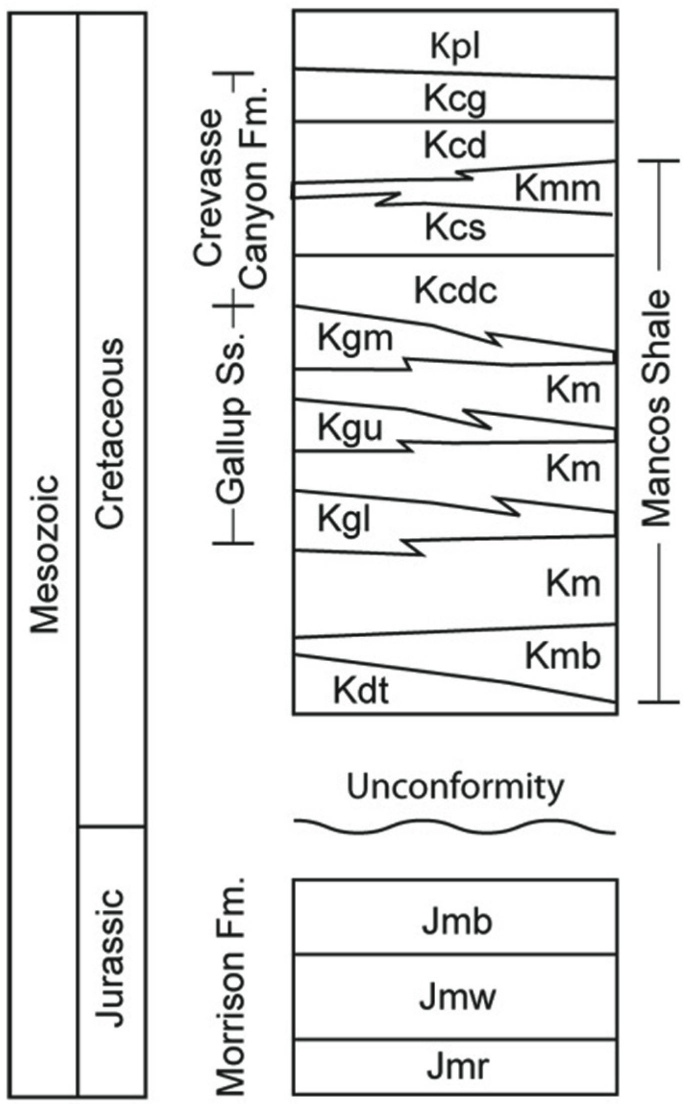

Figure 3. Stratigraphy beneath Laguna Cañoneros quadrangle from Cretaceous Point Lookout Sandstone down to Jurassic Morrison Formation (see rock descriptions; modified from Goff et al., 2012).

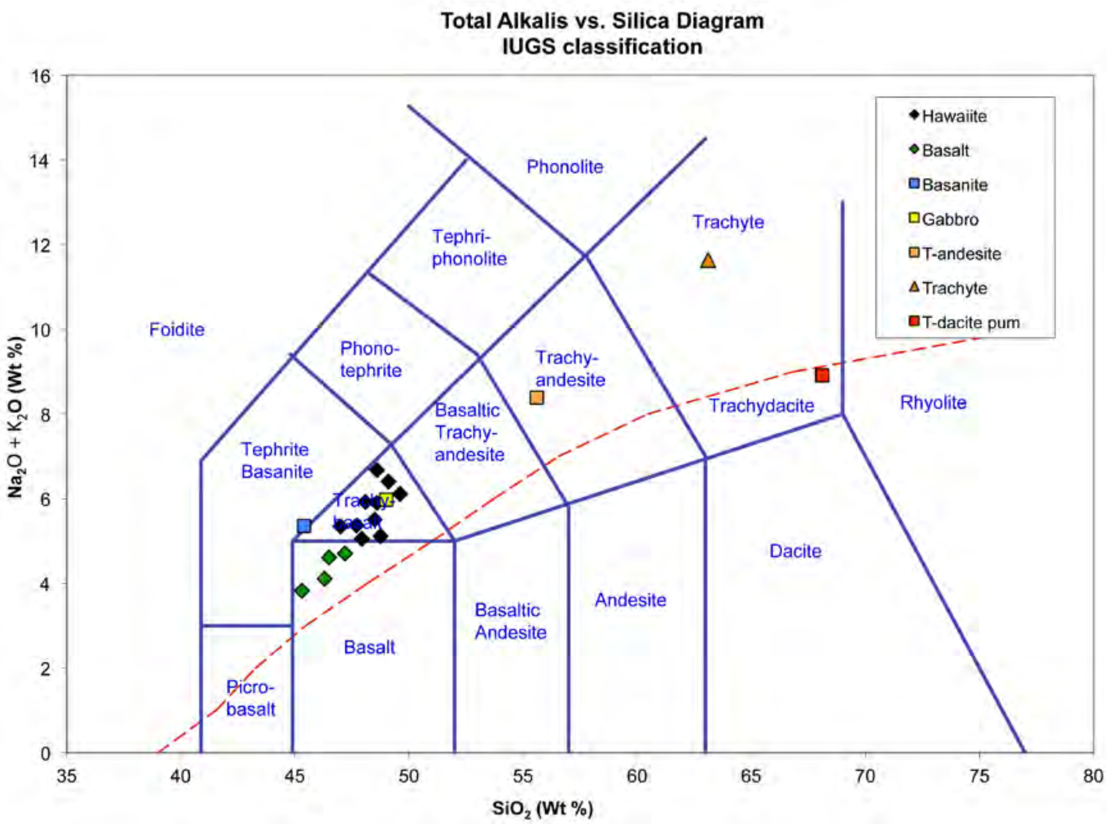

Figure 4. Total alkalis versus silica (after La Bas et al., 1986). Nearly all volcanic rocks on Laguna Cañoneros quadrangle are "basaltic." Red dashed line separates alkalic from calc-alkaline compositions.

We submitted 22 volcanic rock samples for chemical analysis at two different laboratories (Appendix 1). Most of the samples were analyzed for major and trace elements by ALS Laboratory Group, Reno, Nevada and Vancouver, Canada using their "complete characterization" package. For these analyses, all Fe is reported as Fe_2O_3. Details of sample preparation and analysis can be found in ALS Chemex (2011). Three of the above samples (F12-11, F12-24, and F12-32) were also analyzed at Washington State University, Pullman, Washington (see Rowe et al., 2007 for procedures) and all Fe is reported as FeO. In spite of the different data reduction schemes, the analyses of these three samples are more or less identical to the ALS samples. The plot of Fig. 4 shows that most of samples are basaltic and that most of the data plot on a fairly linear trend of alkalic compositions. One sample (F13-09) is actually a basanite (barely) – this is the quartz-bearing lava that forms the escarpment on the west side of Laguna Cañoneros (see cover photo). A sample of hornblende-bearing lava near the north edge of the quadrangle is chemically a trachybasalt; we initially mapped it as trachyandesite. Cerro Chivato is "garden variety" trachyte, as expected. The slightly porpyritic tuff (mentioned above) is compositonally a trachydacite, almost an alkali rhyolite. The oddest chemical result is from the extremely porphyritic lava flow exposed on the northwest flank of Cerro Aguila. Mapped at first as basalt, it is actually a porphyritic trachyandesite.

MAAR VOLCANOES AND DEPOSITS

One of the defining characteristics of Laguna Cañoneros quadrangle is the presence of numerous shallow volcanic depressions or “maars” (Table 1). Maar volcanoes are circular volcanic craters with encircling tephra ramparts possessing an interior vent cut into pre-existing country rock (Fisher and Schmincke, 1984, p. 258). Most maar eruptions are basaltic and create tuff rings in which wide, shallow craters are surrounded at ground level by a rim of hydromagmatic pyroclastic material. Small shallow lakes or *lagunas* (Note: Translations of Spanish words and names are from Pei and Ramondino, 1969) occupy many vents and/or interior depressions. The only maar on Laguna Cañoneros quadrangle currently possessing a real lake is Laguna Redondo; however, in this case, the lake is fed by a nearby well.

For the purposes of this map, unit Qlm consists primarily of poorly exposed, organic-rich, aeolian-derived clay and silt filling the circular vent; during wet periods the vent area may contain a shallow lake. We identified 23 maar vents of various sizes (see below); most are ≤1 km in diameter. Unit Qvm consists of poorly exposed hydromagmatic deposits that form around the vent area and are derived from explosive interaction of shallow groundwater with magma during eruption. Best exposures of Qvm occur in the modified drainage at the south end of Laguna Cañoneros maar where deposits consist primarily of plane-parallel base surge beds containing a mixture of quenched basaltic (hydroclastic) shards and fragments, sideromelane, yellow-brown palagonite, and lithic fragments. Other deposits of Qvm are primarily buried by colluvium and recognized by lag of poorly sorted and rounded gravel of foreign lithic fragments. Maximum observed thickness of Qvm is about 5 m.

Ages of various maar vents and deposits are generally unknown but most seem to be late Pliocene to early Pleistocene. The hydromagmatic deposits exposed in the south drainage of Laguna Cañoneros are too altered to date without considerable sample preparation. However, the age of the deposits (and thus the eruption) is constrained by an overlying flow of basanite (unit Thaqb, 2.58 Ma) and an underlying soil containing the trachydacite pumice (2.70 Ma; see Fig. 5 and appendices). We can provide a minimum age on some of the other maars

Table 1: Maar volcanoes with obvious vents on/adjacent to Laguna Cañoneros quadrangle.

Name	Translation	QTvm deposits
Laguna Chute	Long (narrow) lake	lag gravel beneath scoria cones
Laguna Blanca	White lake	none obvious
John Nelson Tank	{modified vent}	none obvious; present on east end (?)
Laguna Piedra	Stony pond	ring of boulders around vent
Unnamed vent	pond NE of L. Piedra	small ring of boulders around vent
Laguna Bonita	Pretty lake	none obvious
Laguna Cuate (west)	Twin lakes	none obvious; NE-SW migrating vent
Laguna Cuate (east)	Twin lakes	none obvious; NE-SW migrating vent
Laguna Fria	Cold pond	none obvious
Laguna Cruz	Cross lake	none obvious; present on south end (?)
Laguna Redonda	Round lake	lag gravel/boulders on SW shore (?)
Laguna Largo	Large lake	none obvious (just E of quad bdy.)
Unnamed vent	pond N of C. Colorado	none obvious; lag gravel on N shore
Laguna de Damacio	Damacio's lake	none obvious; buried around shoreline
Unnamed vent	pond S of Damacio	none obvious; buried on NE shore
Laguna (unnamed)	lake in southern quad	lag gravel/boulders on eastern shore
Laguna Telesfor	Telesfor (?) pond	none obvious
Laguna Blanquita	Little white pond	none obvious
Laguna Vieja	Ancient (stale) lake	none obvious
Laguna Cañoneros	Gunboat lake	double vent; deposits along S drain
Laguna Bandeja	Tray (platter) pond	lag gravel/boulders on margins
Laguna Reyes	Kings lake	lag gravel/boulders on margins
Laguna Encina	Oak lake	none obvious; NW shore (?)

from the age of lava flows that overlie the maar. For example, the age of the two Laguna Cuate maars is older than the basaltic flow that floods between them (>2.28 Ma, unit Qftb, Fig. 6). Using the same logic, Laguna Reyes is >2.14 Ma (age of overlying unit Qfatb), Laguna de Damacio is >2.26 Ma (age of overlying lava from Aguila), etc. The hydromagmatic deposits exposed beneath the east side of the scoria cone just east of Seboyeta Canyon (unit Tbas, subunit Tbash) formed 2.83 Ma.

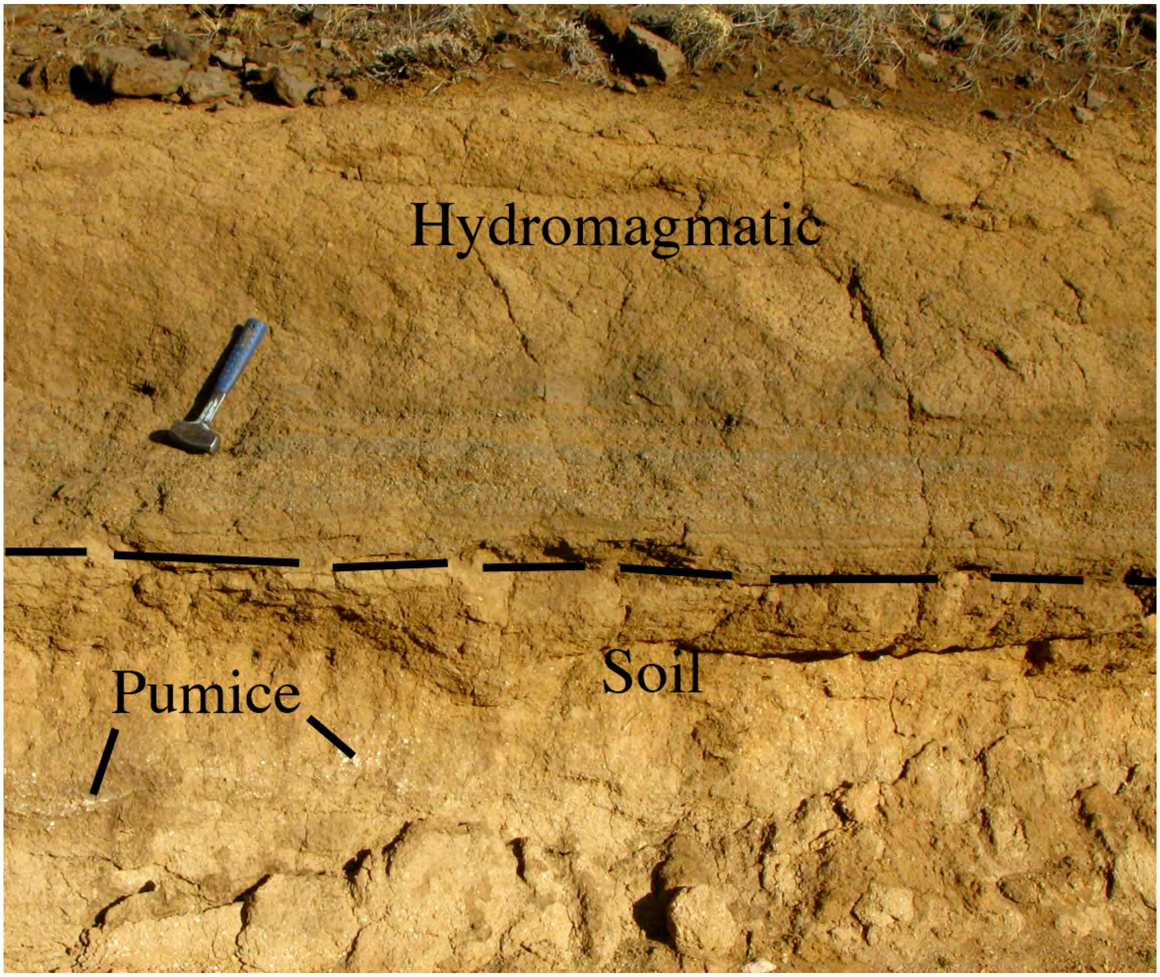

Figure 5. View looking east of drain wall on south end of Laguna Cañoneros showing plane parallel beds of basaltic hydromagmatic deposits overlying pumice-rich soil. Photo by J.R. Lawrence.

Figure 6. Panoramic view south across the two Laguna Cuates with overlying lava flow (2.28 Ma) that floods between them. Hill to left is Cerro Aguila (2.26 Ma); Mount Taylor is on skyline to right. Photo composite by J.R. Lawrence.

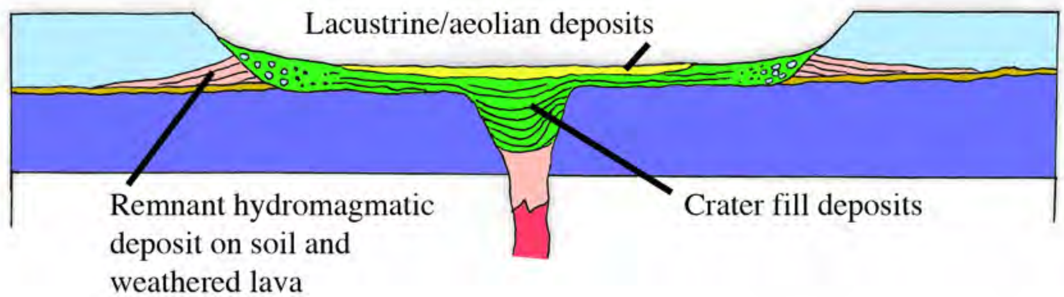

Figure 7. Idealized cross section of older maar crater such as Laguna Cañoneros (see front piece for a photo of this maar). The magma that formed the maar (red) erupted through Cretaceous rocks (white) and older lava flows (dark blue) that may be covered with soil (tan). The bedded tuff ring deposits (pink) associated with formation of the maar were flooded by younger lava flows (light blue). Erosion of the tuff ring caused backfilling of the pre-existing vent with crater fill deposits (green, unit QTvm) and young lacustrine and/or aeolian deposits (yellow, unit Qlm).

STRUCTURE

Practically all Cretaceous rocks are covered by Plio-Pleistocene volcanic and volcaniclastic rocks on Laguna Cañoneros quadrangle. A window into the Cretaceous occurs only in upper Seboyeta Canyon. Mount Taylor is on the southeastern margin of the Laramide-age San Juan Basin and is on the western flank of the northeast-striking McCarty syncline of Hunt (1938). An east-dipping monoclinal ridge in the northwestern part of the Lobo Springs quadrangle marks the western edge of the McCarty syncline (Goff et al., 2008; McCraw et al., 2009). The effect of this monoclinal ridge is to drop the Mesozoic rocks a thousand meters or more beneath Mount Taylor and quadrangles to the north. Several low amplitude folds that strike NW to NE in the Lobo Canyon area, southwest of Mesa Chivato, are superimposed on the large-scale synclinal structure. These folds, presumably Laramide in age, do not affect the overlying volcanic rocks.

Most faults in the Laguna Cañoneros quadrangle are normal faults having north to northeast trends, probably responding to NW-SE extension along the boundary between the Colorado Plateau and Rio Grande rift tectonic provinces (Baldridge et al., 1983; Aldrich and Laughlin, 1984). The best example of this structural trend is the belt of faults that define the northeast-trending Laguna Cuatas graben in the northwest part of the quadrangle. This graben is roughly 6 km long and about 2 to 3 km wide and extends into the El Dado Mesa quadrangle to the north. The southwestern end of the graben is completely covered by the scoria cone complex of Cerro Redondo. Geologic relations among offset lava flows indicate that this graben was forming by at least 3 Ma. Younger flows in this area ponded in a depression associated with the graben.

Quite a number of eroded scoria cones contain remnant dikes. Most dikes have an east to northeast trend apparently intruding into weak zones created by the regional tectonic fabric. A number of relatively young scoria cones in the northwest part of the quadrangle lie on a perfect northeast trend. Presumably, these cones are underlain by a dike system intruding a NE-trending fracture or fault system, which is part of the northeast-trending Jemez Lineament structural zone.

An ancient northeast-trending valley is filled with three lava flows and volcaniclastic sediments in upper Seboyeta Canyon (Fig. 8). The present canyon cuts across the older valley-fill lavas This ancient valley may have followed the trend of a pre-existing NE-trending fault but, if so, the fault can't be found in the alluvium, colluvium and landslide debris in the present canyon bottom. Each of the lava flows can be traced to nearby scoria cones because of distinctive phenocrysts and textures.

HYDROTHERMAL ALTERATION AND MINERAL DEPOSITS

We found no evidence for significant hydrothermal alteration, present or past hot spring activity, or subjacent deposition of epithermal ore deposits. Clearly, magmatism in the Laguna Cañoneros quadrangle produced insignificant thermal anomalies in the shallow crust. We found one old glory hole (mining prospect) in the summit of Cerro Chivato but our examination of the tailings showed no evidence for sulfides or any other important economic minerals. Throughout the rest of the quadrangle we found no deposits of sand and gravel, decorative stone (except red cinder), lode deposits, quartz or bonanza veins, or other mineralized structures. We conclude that Laguna Cañoneros quadrangle has no potential for mineral extraction and mining, other than bulk extraction of red cinder and scoria. We identified more than 35 scoria cones on the quadrangle.

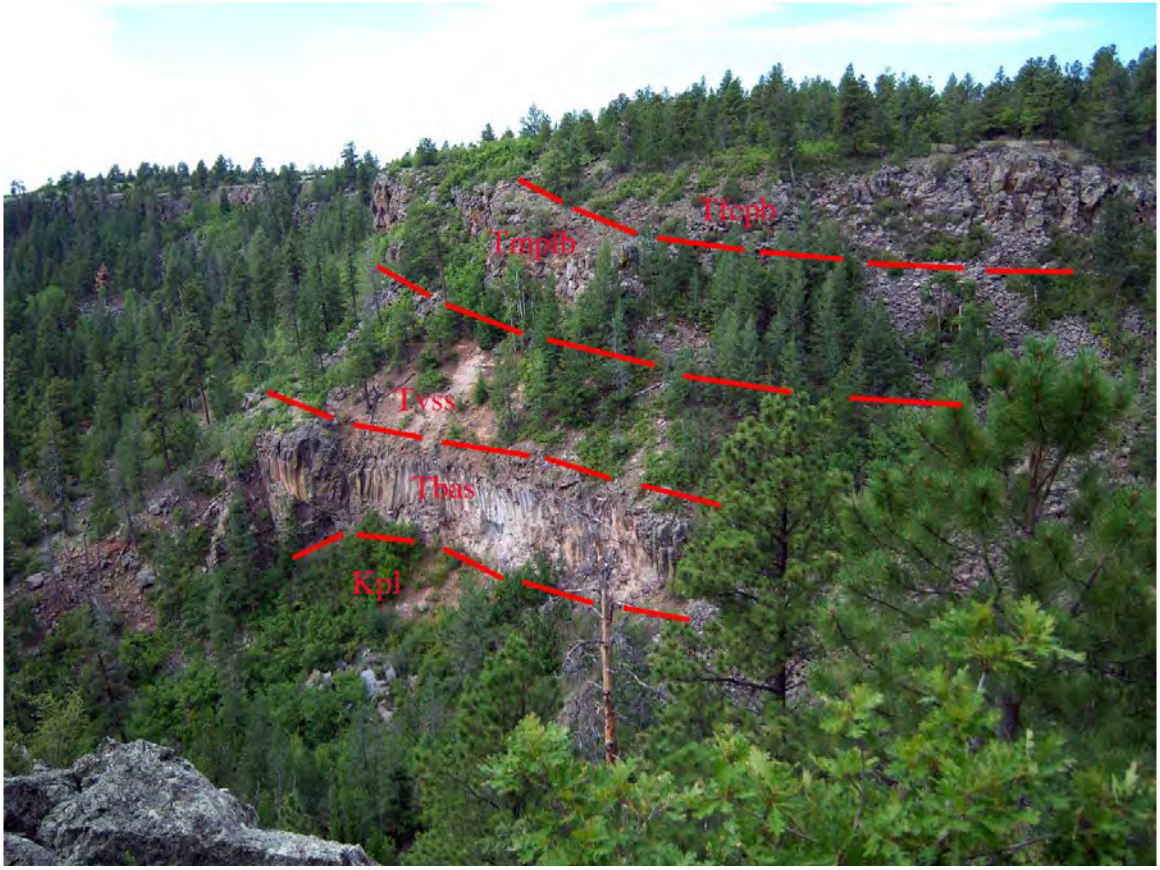

Figure 8. West wall of upper Seboyeta Canyon showing old valley filling volcanic sequence; Tfcpb = fine-grained cpx phyric trachybasalt; Tmplb = medium-grained plag phyric trachybasalt (2.70 Ma); Tvss = volcaniclastic sediments with interlayered silicic pumice fall deposits; Tbas = fine-grained aphyric trachybasalt (2.83 Ma); Kpl = Cretaceous Point Lookout Sandstone (Hasta Tongue; Skotnicki et al., 2012). Photo by F. Goff.

WATER RESOURCES

The Laguna Cañoneros quadrangle is relatively dry. We found a few springs and wet areas at the bottom of the volcanic sequence on top of Cretaceous rocks in upper Seboyeta Canyon. We also found a few small springs at the base of lava flows in the higher and slightly wetter areas and ravines of the southwestern quadrangle. None of the maar depressions, except for Laguna Redonda, held lakes or ponds during the times that we were mapping on the quadrangle (May through early November). Most available water comes from shallow wells (Figure 9) presumably drilled no deeper than the top of Cretaceous (≥60 to 200 m in most locations) and probably only a few tens of meters. We tasted the water at several wells; the water tasted dilute and non-mineralized suggesting a shallow source. The water is primarily used by stock and game.

Figure 9. Well northeast of Cerro Redondo and ESE of Laguna Cruz (UTM NAD 27 3910548, 0275234, about 8490 ft). This area of the quadrangle is lightly forested and contains several shallow wells with potable water. Photo by F. Goff.

ROCK DESCRIPTIONS

Note: Descriptions of map units are listed in approximate order of increasing age. Formal stratigraphic names of Cretaceous units are described by Sears et al. (1941), Lipman et al. (1979), Dillinger (1990), and Skotnicki et al. (2012). Field identification of volcanic rocks is based on hand specimens, petrography and chemical data published by Hunt (1938), Baker and Ridley (1970), Lipman and Moench (1972), Lipman and Mehnert (1979), Crumpler (1980a, 1980b, 1982), and Perry et al. (1990). The names of volcanic units are based on the above chemical data and the alkali-silica diagram of Le Bas et al. (1986). See Goff et al. (2008) for a contemporary description of the rocks and geology in the Mount Taylor area. Magnetic polarities are measured by Brunton compass (MPB) or with portable fluxgate magnetometer (MPF); correlations of polarities with age follow chart in Gee and Kent (2007).

Quaternary

Qal **Modern Alluvium (upper Pleistocene to Holocene)**—Deposits of sand, gravel and silt in main valley bottoms; generally very fine-grained eolian sand and minor pebble gravel at the top and angular poorly sorted boulders of lava at the base; locally includes stream terraces, alluvial fans, and canyon wall colluvium; valley floor alluvium is typically finer-grained, silt and sand dominated deposits with interbedded gravel beds, whereas low terrace deposits are predominantly sand and gravel. **Qal** is mostly Holocene in age; maximum thickness of various alluvium deposits is uncertain but may exceed 15 m.

Qc **Colluvium (upper Pleistocene to Holocene)**—Poorly sorted slope wash and mass wasting deposits from local sources; mapped only where extensive or where covering critical relations; thickness can locally exceed 15 m.

Qe **Eolian deposits (upper Pleistocene to Holocene)**—Windblown deposits of silt and fine sand 0.2 to greater than 1 m thick, and sheet wash composed of pebbly sand on various surfaces; mapped primarily in low relief locations.

Ql **Shallow lake deposits (upper Pleistocene to Holocene)**—Fine-grained, poorly exposed deposits of clay, silt and sand filling shallow, small diameter basins on lava flow surfaces and sag ponds along fault traces; thickness probably <5 m. Generally contain water only during rainy seasons.

Qay **Younger alluvium (upper Pleistocene to Holocene)**—Alluvium that lies above modern drainages, underlying surfaces adjacent to modern drainages that are located approximately 5 to 15 m above local base level. Generally pebble to boulder gravel, pebbly sand,

and silt capped by eolian sand. Maximum observed thickness about 15 m.

Qao **Older alluvium (middle Pleistocene to Holocene)—**Alluvium that lies above modern drainages and **Qay** deposits, forming higher surfaces between the volcanic vents. Generally pebble to boulder gravel capped by eolian sand. Maximum observed thickness about 15 m.

Qls **Landslides (middle Pleistocene to Holocene)—**Poorly sorted debris that has moved chaotically down steep slopes; slumps or block slides partially to completely intact, that have moved down slope; slumps and block slides usually display some rotation relative to their failure plane; thicknesses vary considerably depending on the size and nature of the landslide.

Qlm **Maar crater-fill deposits (middle Pleistocene to Holocene)—** Poorly exposed, organic-rich, aeolian-derived clay and silt filling the eroded tuff ring and circular vent; during wet periods the vent area may contain a shallow lake. Margins of deposits near surrounding lava flows may contain larger blocks of eroded basalt. Older deposits beneath the central portion of the crater are probably much older than Holocene. Probable thickness is ≤50 m.

Volcanic Rocks of Southwest Mesa Chivato (northeast and east of Mount Taylor)

Northwest Area

Qytb **Younger trachybasalt (Pleistocene?)—**Consists of black to dark gray lavas of relatively aphyric basalt with rare, very tiny phenocrysts of plagioclase ± olivine; a sequence of flows lies in NE corner of quadrangle that overlie **Qycopb** and apparently overlies **Qftb**. Various units are not dated and flows are ≤60 m thick.

Qantb **Gabbro-bearing olivine trachybasalt (lower Pleistocene?)—** Distinctive unit consisting of flows of dark gray, porphyritic olivine trachybasalt and red to black scoria deposits (**Qantc**) containing enclaves of gabbro, anorthosite and minor peridotite; phenocrysts consist of conspicuous olivine and scattered augite and plagioclase; overlies **Qmptb**; apparently underlies **Qytb**. Unit is not dated; MPB (1 site) = normal suggesting an age between 1.77 and 1.95 Ma (Gee and Kent, 2007); maximum exposed thickness about 45 m.

Qolpb **Olivine-rich plagioclase basalt (lower Pleistocene?)—**Dark gray to black flows and black to red scoria deposits (**Qolpc**) of olivine-rich, porphyritic basalt; contains scattered large phenocrysts of augite and plagioclase (Fig. 9, below); underlies **Qantb** but a small patch of **Qolpc** overlies southern flank of scoria cone **Qfptc**; apparently younger than scoria cone **Qatc** to the south. Flows and cone overlie deposits (**QTvm**) from Laguna Chute maar. Unit is not dated; maximum exposed thickness about 100 m.

Qfplb **Fine- to medium-grained, plagioclase-phyric trachybasalt (lower Pleistocene)—**Gray flows and red to black scoria deposits (**Qfplc**) of fine- to medium-grained trachybasalt with conspicuous trachytic texture caused by aligned plagioclase microphenocrysts; contains sparse small phenocrysts of plagioclase, augite and olivine; cone contains a thin, NE-trending, poorly exposed dike (**Qfpld**); flows lap into two maar volcanoes (Lagunas Blanca and Chute) along northwest boundary of quadrangle; underlain by unit *QTvm*; apparently overlies flows from cone **Qfptc**; $^{40}Ar/^{39}Ar$ age is 2.13 ± 0.01 Ma; MPB (1 site) = reverse (correlated); maximum exposed thickness about 75 m.

Qfptb **Fine-grained plagioclase phyric trachybasalt (lower Pleistocene?) —**Gray flows and red to black scoria deposits (**Qfptc**) of fine-grained trachybasalt with trachytic texture of small plagioclase microlites; contains rare small phenocrysts of augite and olivine; underlies **Qfplb** and **Qolpc**; eroded flows partially fill maar volcanoes John Nelson Tank, Laguna Piedra, and Laguna Blanca; unit is not dated; maximum observed thickness is about 65 m.

Qyob **Younger olivine trachybasalt (lower Pleistocene)—**Gray to black flows and red to black scoria deposits (**Qyoc**) of fine-grained basalt containing 2-4% resorbed olivine phenocrysts (≤5 mm) of uniquely translucent green color. The olivine is commonly iddingsitized. Felted groundmass contains abundant plagioclase and olivine microphenocrysts. There are three cones of this composition; cones contain several NNE-trending dikes (**Qyod**), some of which are faulted. Specimens on the cone are finer grained and also contain conspicuous resorbed plagioclase and clinopyroxene megacrysts. Overlies **Qftb** and **Qycopb**. Sample of flow from western cone in Cerro Pelon quadrangle has $^{40}Ar/^{39}Ar$ age of 2.18 ± 0.06 Ma; MPF (3 sites) are inconsistent but the age indicates the unit should be normal. Maximum observed thickness is about 70 m.

Qatb **Fine-grained aphyric trachybasalt of Cerro Cuate (lower Pleistocene)—**Gray to black flows and red to black cinder deposits (*Qatc*) of fine-grained, aphyric trachybasalt with no visible phenocrysts; scoria cone contains several dikes (**Qatd**); overlies

Figure 9. Fragment of basalt (unit **Qolpb**) showing abundant large crystals of olivine, lesser amounts of large, black clinopyroxene and smaller crystals of white plagioclase (see Appendices). Photo by F. Goff.

most adjacent units; $^{40}Ar/^{39}Ar$ age is 2.18 ± 0.02 Ma; maximum observed thickness is about 35 m.

Qfoqb **Fine-grained quartz-bearing olivine trachybasalt of Cerro Aguila (lower Pleistocene)** —Gray to black flows and red to black scoria deposits (**Qfoqc**) of fine-grained basalt having small phenocrysts of olivine and sparse small xenocrysts of quartz, some with green clinopyroxene reaction rims; scoria cone has several arcuate and linear dikes (**Qfoqd**); underlies several nearby units; overlies **Qmppb** and **Qpota**; $^{40}Ar/^{39}Ar$ age of lava SE of cone is 2.25 ± 0.01 Ma; $^{40}Ar/^{39}Ar$ age of dike in cone is 2.27 ± 0.01 Ma; maximum exposed thickness is about 85 m.

Qmptb **Medium-grained plagioclase phyric trachybasalt (lower Pleistocene?)**— Gray flows and small scoria cone of black to red cinders of medium-grained plagioclase phyric trachybasalt with microphenocrysts of augite and olivine; underlies **Qytb** and **Qantb** and overlies **Qycopb**; unit not dated; maximum observed thickness 40 m.

Qftb **Younger fine-grained plagioclase trachybasalt (lower Pleistocene) —** Light gray flows and red to black scoria deposits (**Qftc**) of aphyric, aphanitic trachybasalt containing a felted groundmass of very fine-grained plagioclase, clinopyroxene, and minor olivine. Flows originate from scoria cone (hill 8761) on west margin of quadrangle; scoria cone contains several dikes (**Qftd**); some flows may originate from cone **Qatc** along northern boundary between Cibola National Forest and Floyd Lee Ranch. Overlies **Qycopb**; underlies **Qyob** and **Qytb**. Flows are cut by or are adjacent to the following maars: Laguna Fria, Lagunas Cuatas, and Laguna Cruz. Sample of flow from adjacent Cerro Pelon quadrangle has $^{40}Ar/^{39}Ar$ age of 2.28 ± 0.07 Ma (Goff et al., 2010). Maximum observed thickness is about 50 m.

Qycopb **Younger porphyritic pyroxene olivine basalt (lower Pleistocene)—**Gray to black flows of very distinctive, speckled, medium to course-grained porphyritic basalt containing abundant phenocrysts (5-15%) of anhedral to resorbed black clinopyroxene (≤4 mm), green anhedral olivine (≤5 mm) and clear to white, zoned subhedral plagioclase (≤5 mm). Olivine is commonly iddingsitized and frequently rimmed or intergrown with clinopyroxene. Specimens generally contain a trace amount of xenocrystic quartz. Flows originate from scoria cone (**Tycopb**) near NW edge of quadrangle. Underlies **Qftb**; Sample of flow from adjacent Cerro Pelon quadrangle has $^{40}Ar/^{39}Ar$ age of 2.31 ± 0.06 Ma. Maximum observed thickness is about 30 m.

Qympb **Younger medium-grained plagioclase trachybasalt—**Gray to black flows and red to black cinder deposits **(Qympc)** of medium-grained basalt containing small, platy, interlocking microphenocrysts of plagioclase and tiny microphenocrysts of olivine and clinopyroxene; cinders contain rare fragments of Cretaceous sandstone; cone has young, conical shape; apparently underlies **Qftb**. Unit is not dated. Maximum observed thickness is about 60 m.

Qmppb **Medium-grained plagioclase phyric trachybasalt of Cerro Colorado (lower Pleistocene?)—**Gray to black flows and red to black scoria deposits (**Qmppc**) of medium-grained trachybasalt; fresh surfaces display shimmery reflection of aligned plagioclase microlites; contains rare phenocrysts of plagioclase ≤0.25 cm in length; overlies **Tfob**; underlies **Qfoqb**; flow surrounds a small, circular, unnamed maar (**Qlm**) north of scoria cone; unit is not dated; maximum observed thickness about 45 m.

Qpota **Porphyritic olivine trachyandesite (lower Pleistocene?)**—Gray, sugary flow of porphyritic trachyandesite containing large phenocrysts of plagioclase and smaller phenocrysts of augite and olivine; unit underlies quartz basalt of Cerro Aguila; unit is not dated; maximum observed thickness is about 20 m.

Southwest Area

Qfqtb **Fine-grained quartz-bearing olivine trachybasalt of Cerro Ortiz (lower to middle(?) Pleistocene)**—Flows of dark gray, fine-grained trachybasalt and red to black scoria deposits (**Qfqtc**) containing sparse, but easily recognizable, small xenocrysts of quartz, and small sparse phenocrysts of olivine and black augite in groundmass of tiny plagioclase, olivine, augite, opaque oxides, and glass; many of the xenocrysts have pale green clinopyroxene reaction rims with host lava; olivine shows minor high-temperature iddingsite alteration; flows originate from Cerro Ortiz that contains prominent NE-trending dikes (**Qfqtd**); relatively thin beds of hydromagmatic surge are exposed at base of flows on south side of Cerro Frio (**Qfqth**); flows overlie **QTvs**, **Qfob2**, and **Qmplb;** K-Ar date is 1.56 ± 0.17 Ma (whole rock; Lipman and Mehnert, 1979); MPB (1 site) = reverse (correlated); maximum observed thickness about 55 m.

Qmpcb **Medium-grained plagioclase and augite phyric trachybasalt (lower Pleistocene?)**—Gray flows and red to black scoria deposits (**Qmpcc**) of olivine and plagioclase phyric trachybasalt; cone contains an eroded dike (**Qmpcd**) trending about N40E; overlies **Qyxtb** and **QTvs**; unit is not dated; MPB (1 site) = normal suggesting an age between 1.77 and 1.85 Ma; maximum exposed thickness about 40 m.

Qyxtb **Young xenocrystal trachybasalt (lower Pleistocene)**—Flows consisting of black to gray, medium- to fine-grained hawaiite having very sparse phenocrysts of olivine, plagioclase, and augite and very rare xenoliths of mantle peridotite and extremely rare fragments of gabbro. Some specimens contain rare quartz xenocrysts. Flows originate from cone in adjacent Cerro Pelon quad (Goff et al., 2010) and have $^{40}Ar/^{39}Ar$ age of 1.85 ± 0.06 Ma; MPB (1 site) is reversed (lightning?); should be normal. Maximum thickness of flows is ≤60 m.

Qfob2 **Fine-grained porphyritic olivine basalt of Cerro Redondo (lower Pleistocene)**—Flows of dark gray to black, fine-grained basalt and red to black scoria deposits (**Qfoc2**) having small but abundant phenocrysts of olivine in groundmass of plagioclase, olivine, augite, opaque oxides and glass; contains rare small quartz xenocrysts; olivine displays minor high-temperature iddingsite alteration; upper (later) flows near vent are extremely porphyritic and contain xenocrysts of peridotite; flows primarily fill and follow a paleocanyon south of Cerro Redondo, which once extended into northern Seboyeta quadrangle (Skotnicki et al., 2011); flow surrounds an eroded, circular maar (Laguna Redonda, **Qvl**) that contains a lake fed by well water; east margin of cone is faulted and has small landslide; overlies **Qmplb** and **Qmab** but underlies **Qfqtb**; $^{40}Ar/^{39}Ar$ age is 1.90 ± 0.03 Ma on dike in summit area (**Qfob2d**); MPB (3 sites) = all normal (correlated); maximum observed thickness of flows is about 15 m.

Qmab **Medium-grained aphyric basalt (lower Pleistocene)**—Flows of light to dark gray trachybasalt and red to gray scoria deposits (**Qmac**) underlying east side of Cerro Redondo; flows have trachytic texture caused by aligned plagioclase microphenocrysts; groundmass also contains microphenocrysts of augite and olivine; underlies **Qfob2**; overlies **Toxtb**; unit is not dated; MPB (1 site) = reverse suggesting an age >1.95 Ma (Gee and Kent, 2007); maximum exposed thickness is about 60 m.

Qmpob **Medium-grained sparsely porphyritic olivine basalt (lower Pleistocene?)**—Gray to black flows and red to black scoria deposits (**Qmpoc)** of medium to fine-grained trachybasalt with small sparse phenocrysts of olivine and very sparse small phenocrysts of plagioclase and augite; cone contains NE-trending dike (**Qmpod**); overlies **Qfpob** and **Tfob**; unit not dated; maximum observed thickness about 35 m.

Qfpob **Fine-grained plagioclase and augite phyric olivine basalt (lower Pleistocene)**—Gray to black flows and red to black scoria deposits (**Qfpoc**) of basalt containing conspicuous phenocrysts of plagioclase, augite and olivine in fine-grained groundmass; cone contains several eroded dikes (**Qfpod**); apparently overlies *Qmab* and **Tfob**; underlies **Qmpob**; unit is not dated; MPB (1 site) = reverse suggesting an age >1.95 Ma (Gee and Kent, 2007); maximum exposed thickness is about 65 m.

Qyopb **Fine-grained to aphyric olivine plagioclase trachybasalt**—Gray to black flows and red to black scoria deposits **(Qyopc)** straddling west central margin of quadrangle; specimens are slightly porphyritic with relatively aphyric groundmass containing tiny phenocrysts of olivine ± clinopyroxene, and sparse small phenocrysts of plagioclase. Overlies **QTvs** and pre-dates **Qfob2**. Unit is not dated. Maximum observed thickness is about 60 m.

Qfcob **Fine-grained augite-bearing olivine basalt (lower Pleistocene)—** Gray to black flows and black to red scoria deposits (**Qfcoc**) of fine-grained olivine basalt containing sparse, large phenocrysts of augite; cone contains pond of basalt on western summit and eroded, NE-trending dikes (**Qfcod**) on east summit; underlies **Qfob2**; overlies **Tac** and **Tfob**; unit is not dated; MPB (1 site) = reverse suggesting an age >1.95 Ma (Gee and Kent, 2007); maximum observed thickness is about 80 m.

Qmplb **Medium-grained plagioclase-phyric olivine trachybasalt of Cerro Frio (lower Pleistocene)—**Gray, medium-grained, sparsely porphyritic trachybasalt flows and red to black scoria deposits (**Qmplc**) containing plagioclase phenocrysts ≤3 cm long in groundmass of plagioclase, olivine, augite, opaque oxides and glass; olivine shows very minor high-temperature iddingsite alteration; flows originate from Cerro Frio north of quad boundary; underlies **Qfob2** but overlies **Tfob**; sample of flow is dated at 2.44 ± 0.01 Ma (Skotnicki et al., 2011); MPB (2 sites) = both reverse (correlated); maximum observed thickness is about 35 m.

Qfab **Fine-grained aphyric trachybasalt (lower Pleistocene?)—**Black flows and red to black scoria deposits (**Qfac**) of very fine-grained aphyric trachybasalt containing visible microphenocrysts of plagioclase and olivine; cone contains a NE-trending dike (**Tfad**) and a sill-like body of basalt; overlies **Tfob**; unit is not dated; maximum observed thickness is about 35 m.

East-Central Area

Qfatb **Fine-grained aphyric trachybasalt (lower Pleistocene)—**Dark to light gray flows and red to black scoria deposits (**Qfatc**) of extremely fine-grained, aphyric trachybasalt containing no phenocrysts; prominent scoria cone (hill 8612) contains NE-trending dikes (**Qfatd**) and is cut by two NNE-trending faults forming small horst; flow surrounds maar deposits at Laguna Reyes; flows overlie or abut all adjacent units; $^{40}Ar/^{39}Ar$ plateau age is 2.10 ± 0.03 Ma; $^{40}Ar/^{39}Ar$ integrated age is 2.14 ± 0.02 Ma; MPB (1 site) = normal suggesting the later age is correct (Gee and Kent, 2007); maximum observed thickness is about 100 m.

Qafb **Fine-grained aphyric trachybasalt (lower Pleistocene)**—Gray to black flows and red to black scoria deposits (**Qafc**) of fine-grained aphyric trachybasalt with visible microlites of plagioclase; contains no phenocrysts; prominent scoria cone (hill 8413) contains two dikes (**Qafd**); scoria cone and flows are cut and incised by spectacular maar of Laguna Bandeja; overlies northeastern maar deposits of Laguna Cañoneros; overlies **QTmolb**; unit is not dated; MPB (1 site) = reverse suggesting unit is <2.58 Ma (Gee and Kent, 2007); maximum observed thickness is about 50 m.

Northeastern Area

Qtbf **Fine-grained trachybasalt (lower Pleistocene)**—Brown lava with 1 to 3% phenocrysts of olivine, pyroxene and plagioclase in an aphanitic matrix; contains rare quartz xenocrysts. Olivine phenocrysts are 3-5 mm in diameter and pyroxene and plagioclase are <2 mm. Overlies ***QTmolb***. Unit is 10 to 15 m thick.

Tertiary (Pliocene)

QTvs **Volcaniclastic sedimentary rocks (upper Pliocene-lower Pleistocene)**—Gray to tan to white debris flows, fluvial deposits and interbedded tuffs (**Ttdt**) shed from the Mount Taylor stratovolcano during growth. Debris flow component is most abundant near southwest margin of quadrangle and consists primarily of boulders and cobbles of angular to subangular trachydacite and trachyandesite in a volcanic sand matrix. Boulders form a lag deposit on surface of debris flows. Fluvial component contains rounded to subrounded cobbles. Tuffs consist mostly of thin beds and lenses of fall deposits with vesiculated pumice having phenocrysts of plagioclase, clinopyroxene ± hornblende ± biotite. Interlayered with some Quaternary mafic flows and cones (**Qyxtb** and **Qmpcb**); underlies a few older, often poorly exposed trachybasalts (**Tmotc** and **Tyopb**); flow from **Qfob2** occupies eroded ravine in **QTvs**; maximum exposed thickness is about 75 m.

QTvm **Hydromagmatic deposits from maar eruptions (upper Pliocene-lower Pleistocene)**—Consists of poorly exposed hydromagmatic deposits derived from explosive interaction of shallow groundwater with magma during eruption, which form around the vent area. Best exposures of **QTvm** occur in the modified drainage on south end of Laguna Cañoneros maar where deposits consist primarily of plane-parallel base surge beds containing a mixture of quenched basaltic (hydroclastic) shards and fragments, sideromelane, yellow-brown palagonite, and lithic fragments.

Other deposits of **QTvm** are primarily buried by colluvium and recognized by lag of poorly sorted and rounded gravel of foreign lithic fragments. **QTvm** immediately south of Laguna Cañoneros maar underlies unit **Thaqb** (2.58 Ma) but overlies layer of old volcaniclastic rocks (**Tvss** – too small to map) with trachydacite pumice dated elsewhere at 2.70 Ma (Skotnicki et al., 2012). Ages of other vents and deposits are not precisely known but most seem to be late Pliocene to early Pleistocene. Maximum observed thickness of **Qvm** is about 5 m.

QTmolb **Medium-grained olivine trachybasalt (upper Pliocene-lower Pleistocene)—**Gray to black flows of medium-grained trachybasalt with abundant small phenocrysts of olivine having iddingsite alteration; lava has a fine crystalline matrix and contains 1-2% phenocrysts of olivine phenocrysts that are 1-4 mm in diameter; groundmass is distinctly trachytic; surrounds the Laguna Vieja maar; overlies **Thaqb** and old cones (**Toatc** and **Toac**) near east margin of quadrangle; source of flows is from the north; unit is not dated; MPB (1 site) = reverse indicating an age <2.58 Ma (Gee and Kent, 2007); maximum observed thickness is about 15 m.

Ti **Mafic dikes—**Linear spines and fins identified only on air photos that cut mapped rocks of basaltic composition in northeast. Width of dikes ≤15 m.

Tmptb **Medium-grained porphyritic trachybasalt—**Gray to black flows and red to black cinder deposits (**Tmptc**) of medium-grained trachybasalt containing sparse but obvious phenocrysts of augite, olivine and plagioclase; also contains rare xenocrysts of quartz with pale green clinopyroxene reaction rims; underlies **Qfob2**; overlies **Taftb**; unit not dated; maximum observed thickness about 35 m.

Thaqb **Hackly aphyric quartz basanite—**Gray to black flows of aphyric basanite with distinctive hackly texture; contains abundant visible microlites of olivine and augite; some flows contain sparse xenocrysts of quartz, some with clinopyroxene reaction rims; quartz xenocryst size and abundance in some flows increase to NW toward source; east end of flow borders Laguna Cañoneros maar; overlain by **QTmolb**. Unit has $^{40}Ar/^{39}Ar$ age of 2.58 ± 0.01 Ma; MPB (1 site) = normal (correlated), exactly at a major magnetic polarity boundary (Gee and Kent, 2007); maximum observed thickness is about 15 m.

Tmopb **Medium-grained plagioclase phyric olivine basalt—**Gray flows and red to black scoria deposits (**Tmopc**) of plagioclase phyric trachybasalt with pronounced trachytic texture; contains minor small olivine phenocrysts; eroded scoria cone contains a complexly fingered dike (**Tmopd**); overlies **Tfpob** and abuts **Qmab**; underlies lava and scoria of Cerro Aguila **Qfoqb;** unit is not dated; MPB (1 site) = normal suggesting an age >2.58 Ma (Gee and Kent, 2007); maximum observed thickness is about 45 m.

Tfob **Fine-grained olivine basalt—** Dark gray to black, fine-grained basalt flows with rare megacrysts of 0.25 cm resorbed plagioclase and augite, and phenocrysts of olivine in groundmass of plagioclase, olivine, augite, opaque oxides and glass; megacrysts are less abundant with distance from source; some specimens contain small quartz xenocrysts; superficially resembles flows of unit **Qfob2** and **Qfoqb**; flows apparently originate from source buried by Cerro Pino cinder cone complex in north part of quadrangle; flows followed a paleocanyon south into Seboyeta quadrangle; two thin hydromagmatic beds (**Tfoh**) are found on lower south flank of Cerro Pino; underlies **Qfcob**, **Qmplb**, **Qfab** and **Qmppc**; overlies **Tac** and **Tfcpb**; unit is not dated; MPB (2 sites) = both normal suggesting an age >2.58 Ma (Gee and Kent, 2007); maximum observed thickness is about 35 m.

Taftb **Fine-grained aphyric trachybasalt—**Gray flows of very fine-grained trachybasalt containing no obvious phenocrysts; originates from faulted scoria cone just west of quadrangle boundary; underlies **Tmptb** and **Qfob2**; unit is not dated; maximum observed thickness is about 10 m.

Tmcpc **Medium-grained augite and plagioclase phyric trachybasalt scoria cone—**Nearly buried scoria cone containing bombs and cinders of red to black medium-grained vesicular trachybasalt with sparse but conspicuous phenocrysts of black augite and white plagioclase; underlies **Qfob2** and **Tmptb**; unit is not dated; maximum observed thickness is about 5m.

Tomtb **Older megacrystal trachybasalt—**Cone and flow complex on southwest boundary of the quadrangle that consist of gray to black flows and red to black cinder deposits (**Tomtc**) of fine-grained trachybasalt; contains 2-4% phenocrysts of euhedral olivine (≤6 mm), black anhedral clinopyroxene (≤5 mm), minor plagioclase (≤8 mm), and minor quartz xenocrysts (≤12 mm); eroded cone is cut by NE-trending dike and surrounded by younger **QTvs**. Unit is not dated. Maximum observed thickness is <55 m.

Toxtb **Older xenocrystal olivine trachybasalt—**Single knob of gray, fine-grained, olivine trachybasalt (hill 8495) and minor agglutinate that is probably an eroded vent; contains abundant small (≤0.25 cm) xenocrysts of peridotite consisting of olivine-hypersthene-chrome diopside-spinel; phenocrysts are mostly olivine with minor augite and plagioclase; underlies **Qmab**; unit is not dated; maximum observed thickness is about 25 m.

Toftb **Older plagioclase trachybasalt**—Gray flow consisting of aphyric, fine-grained hawaiite exposed along southwest edge of quadrangle; contains trace zoned euhedral plagioclase, tiny interlocking plates of plagioclase and microphenocrysts of olivine and clinopyroxene. Interbedded in **QTvs** and underlies **Qyxtb**. Unit is not dated; MPB (1 site) = normal suggesting an age >2.58 Ma; maximum observed thickness is ≤20 m.

Tfpob **Fine-grained augite and plagioclase phyric olivine trachybasalt**—Gray to black flows and red to black cinder deposits (**Tfpoc**) of fine-grained trachybasalt with conspicuous phenocrysts of augite, plagioclase and small olivine; scoria cone is highly eroded and contains great assortment of spindle bombs and agglutinate; underlies **Qmopb** and **Tfob**; unit is not dated; maximum observed thickness is about 20 m. Very similar looking thin flows of **Tfpob** overlie an extensive maar deposit (**Tfpoh**) in the SE corner of the quadrangle. The maar and associated flows overlie **Tfotb** but underlie **Tmpob**. Thickness of this sequence is about 20 m but is not dated.

Northeast Corner and Boundary Areas

Tcgp **Pyroclastic rocks of the Campo Grande volcanic center**—The Campo Grande volcanic center in the north-central part of the quadrangle is dominated by basaltic pyroclastic rocks (agglomerate, scoria, and spindle-shaped bombs). Pyroclastic rocks on the east side of the complex are generally <1 cm across; with a few larger fragments that are 9-12 cm in diameter. The pyroclastic material on the eastern ridge contains up to 5% altered to fresh ol-cpx-plag <7mm across. A NE-striking spine of agglomerate forms the eastern ridge; this wall of agglomerate is on line with a thin (<2 m) dike with a hackly weathering texture, an aphanitic matrix, and <1 mm ol-cpx phenocrysts. The sizes of spatter blocks, scoria, and volcanic bombs increases toward the west. Volcanic bombs on the knob southeast of the highest point of the complex (elevation 2755 m) are up to 2 m in length (Fig. 10, below), and bombs that are 1-2 m long are common on the ridge north of the highest point. The scoria, bombs, and blocks of lava are finer grained toward the west, with only trace amounts of ol-cpx-plag phenocrysts <1 mm in diameter. Unit is not dated; maximum observed thickness is about 120 m.

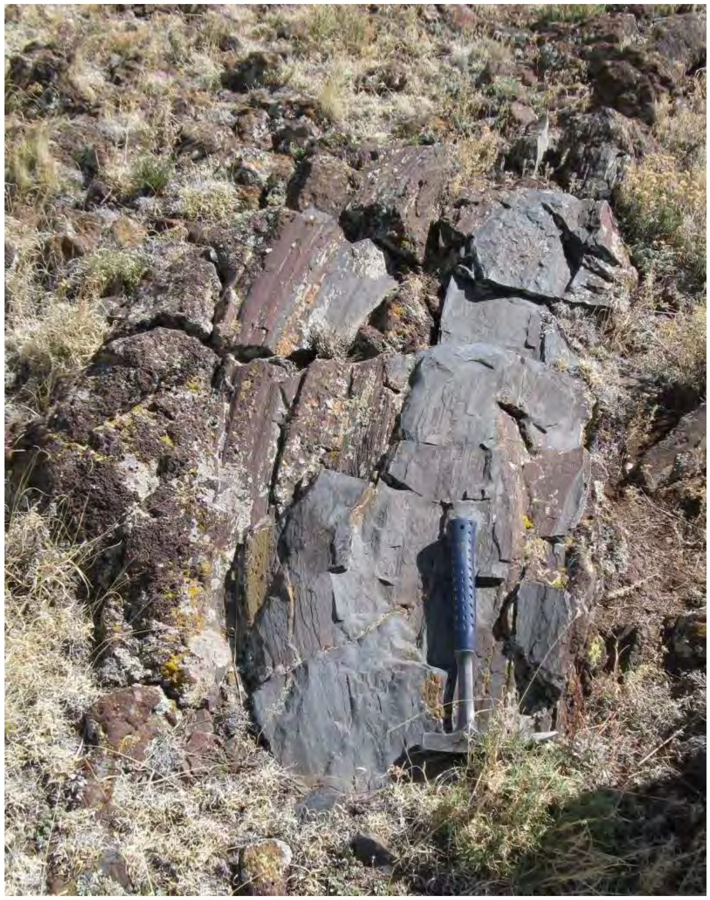

Figure 10. Photo of 2-m-diameter bomb on Campo Grande.

Tcgl **Basalt flows of the Campo Grande volcanic center—**The few lava flows exposed in the complex are discontinuously exposed and are varied in composition. A lava breccia on the north end of the olivine, pyroxene, and plagioclase set in a fine-grained matrix. A vesicular lava flow on the north side with a crystalline matrix of plagioclase is porphyritic with 3% elongate ol-cpx-plag phenocrysts; olivine is the dominant phenocryst – most are <2 mm but a few are 5-7 mm. Steeply dipping flows on the south side of the western satellite vent are from bottom to top: (1) lava with a fine-grained matrix of plagioclase laths < 2 mm long with phenocrysts of olivine and pyroxene <2 mm across; (2) lava with a matrix containing 1-2% plagioclase laths <2 mm long; and (3) an upper lava with a matrix of 1-2% plagioclase laths <2 mm long. A platy lava that is spotted on its weathered surface located on the south side of the eastern ridge has 1-2%oivine phenocrysts that are <1-2 mm and a few pyroxene phenocrysts; $^{40}Ar/^{39}Ar$ age is 2.52 ± 0.01 Ma; maximum observed thickness is about 35 m.

Tcpp **Pyroclastic rocks of the Cerro Pino volcanic center—**The Cerro Pino volcanic center located in the north-central part of the quadrangle is dominated by basaltic pyroclastic rocks (agglomerate, scoria, spindle-shaped bombs). At least six deposits were identified (**Tcpp1** [oldest] to **Tcpp6** [youngest]). In general, the pyroclastic blocks are <20 to 30 cm in diameter, although several 1-2 m long bombs were found on the northwest side of the complex (Figure 10). Olivine that is 3-6 mm across is the most common phenocryst (<1%). Some bombs also contained trace amounts of plagioclase (**Tcpp4)** and pyroxene phenocrysts (**Tcpp6**), quartz xenocrysts (**Tcpp6**), and pyroxene megacrysts <7 mm across (**Tcpp6**). Unit is not dated; maximum observed thickness is about 80 m.

Tcpl **Basalt flows of the Cerro Pino volcanic center—**The few lava flows exposed in the complex are discontinuously exposed and are characterized by 1-2 % olivine phenocrysts 3-4 mm in diameter set in an aphanitic matrix. The steeply dipping lava flows associated with Tccp5 are aphanitic, platy flows with trace of olivine-pyroxene phenocrysts that are <1 mm across. Apparently equivalent to unit **Tfob** described above but unit is not dated; maximum exposed thickness is about 15 m.

Tmb **Fine-grained megacrystal basalt and pyroclastic deposits—** Multiple flows and pyroclastic deposits (**Tmb1** [oldest] to **Tmb8** [youngest]) from vents in the northeastern part of the quadrangle just east of the Campo Grande center. Units **7**, **8**, and **9** are dominated by pyroclastic material and units **1** and **2** are primarily lava flows. The lava, agglomerate, scoria, and bombs contain 1-3% pyroxene megacrysts up to 2 cm across. The matrix is aphanitic to fine-grained and the lava is sparsely porphyritic with 1% plagioclase, pyroxene, and olivine phenocrysts <3-5 mm in diameter; xenocrysts of quartz 2-3 mm; rare "crustal" xenoliths are also present. Unit is not dated; maximum observed thickness is about 60 m.

Ttbf **Fine-grained trachybasalt—**A widespread unit composed of rather non-descript trachybasalt lava flows with a crystalline matrix of plagioclase laths and 1 mm pyroxene and olivine. Rare <<1% phenocrysts of olivine, plagioclase, and pyroxene 2-4 mm; olivine is the most common phenocryst. On the north side of Campo Grande, some flows in this succession have a spotted texture on weathered surfaces. Some flows southeast of Campo Grande have sparse quartz xenocrysts. Unit is not dated; maximum observed thickness is about 50 m.

Tspb **Medium-grained sparsely porphyritic olivine trachybasalt—** Multiple flows (**Tspb 1** [oldest] to **Tspb 7** [youngest]) of gray to black, medium-grained trachybasalt with abundant small microphenocrysts of plagioclase and visible microphenocrysts of olivine; flows apparently originate from a source north of the quadrangle. Various flows are differentiated by topographic breaks on air photos; no sediment was found between the flows; most specimens contain <1% plagioclase, pyroxene, and olivine phenocrysts that are 4-5 mm in diameter; cut by Laguna Blanquita maar; overlies old cone of **Toatc** and underlies **QTmolb;** unit is not dated; maximum observed thickness is about 8 m.

Tsmb **Sparsely megacrystal trachybasalt—**Lava in the northeastern corner of the quadrangle with <1% 5-7 mm megacrysts of pyroxene in a crystalline matrix composed of plagioclase laths. Light gray on weathered surfaces. Unit is 6-10 m thick.

Tpctb **Pyroxene-phyric porphyritic trachybasalt—**Distinctive pink lava with 15% clinopyroxene phenocrysts 2-4 mm in diameter and lesser amounts of plagioclase. Matrix is equigranular. Source of this unit is unknown; unit is not dated; maximum observed thickness is about 3 m.

Tttb **Trachybasalt—**Flow apparently originates from a source north of the quadrangle boundary. Crystalline matrix varies from aligned plagioclase laths to a more equigranular texture. Matrix minerals include olivine and pyroxene <2 mm. Similar to the **Tmspb** unit 3; unit is not dated; maximum observed thickness is about 10 m.

Tfvb **Fine-grained vesicular basalt—**Poorly exposed basalt that weathers gray and has sparse large vesicles on the weathered surface. Matrix is black, fine-grained <<1% ol-plag-cpx <2 mm. Unit is not dated; maximum observed thickness is <1 m.

Tspob **Sparsely porphyritic olivine basalt—**Lava flow containing <1% olivine and pyroxene < 4 mm set in an aphanitic matrix on the southwest flank of Campo Grande. Unit is 10-15 m thick.

Tolpyb **Porphyritic olivine, pyroxene basalt—**Lava with 1-3% phenocrysts of olivine, pyroxene, and plagioclase that are 3-7 mm in diameter. Matrix is aphanitic to crystalline. Younger flows in this succession have 1-2% pyroxene xenocrysts up to 1 cm across. Unit is 20 to 25 m thick.

Tpp **Porphyritic basalt with plagioclase phenocrysts—**Several lava flows from an unknown source; the basalt has an aphanitic matrix;

flows vary from 5-7% plagioclase laths <3 mm with trace amounts of <3 mm pyroxene and olivine phenocrysts to flows with 10-12% plagioclase laths <5 mm with trace <3 mm pyroxene and olivine phenocrysts. No sediment was observed between the flows. Various flows are not dated; unit is >30 m thick.

Tfvtb **Fine-grained vesicular trachybasalt—**Vesicular, aphyric to fine-grained basalt with <1% of <2-4 mm olivine and trace pyroxene and plagioclase <2 mm; source unknown; laps onto the **Tphta** flow described below; unit not dated; maximum observed thickness is <3 m.

Tatc **Old scoria cone by Arroyo Cañoneros—**Red to black scoria deposits exposed along west margin of arroyo near east boundary of quadrangle; consists of fine-grained nearly aphyric trachybasalt with very sparse small phenocrysts of olivine and plagioclase; contains nice assortment of bombs; overlain by **QTmolb;** unit is not dated; maximum exposed thickness is about 12 m.

Toac **Old scoria cone in Cañon de Pedro Padilla—**Red to black scoria deposits and black north-trending feeder dike (**Toad**) exposed in north canyon wall along east margin of quadrangle; consists of aphyric basalt with no phenocrysts; eroded scoria cone is overlain by **QTmolb** and **Taptb**; unit is not dated; maximum observed thickness is about 25 m.

Tphtb **Porphyritic hornblende trachybasalt—**Dark gray lava with 1 to 3% hornblende phenocrysts in a fine crystalline matrix of plagioclase, pyroxene and devitrified glass. Small olivine phenocrysts occur near the base of the flow. Phenocrysts are rounded near the base of the flow and are more euhedral near the top of the unit. The phenocrysts are black to greenish black and some are striated. Unit has $^{40}Ar/^{39}Ar$ age of 3.16 ± 0.01 Ma; maximum exposed thickness is about 20 m.

Ttr **Fine- to medium-grained trachyte of Cerro Chivato—**Light gray, highly foliated trachyte dome containing plagioclase in groundmass of plagioclase and clinopyroxene microlites; contains small sparse microlites of hornblende; intrusion breccia occurs on southern margin of dome; some specimens are spotted from deuteric alteration of groundmass; underlies all adjacent units; trachyte has $^{40}Ar/^{39}Ar$ age of 3.16 ± 0.02 Ma; maximum observed thickness is about 120 m.

Thba **Hackly basanite—**Lava with hackly and spotted textures on weathered surfaces. The lava is generally aphanitic with <<1%

olivine that is <1 mm, weathered and altered to iddingsite. Unit appears to underlie the hornblende trachybasalt described above (**Tphtb**); unit is 10 m thick.

Ttbfo **Older fine-grained trachybasalt—**Foliated lava with pyroxene and olivine phenocrysts that are 3 mm in diameter. This lava is probably interbedded with volcaniclastic sedimentary deposits; these deposits, which are covered with thick colluvium, are perhaps equivalent to **Tvss**. Unit is 5 m thick.

Southeast and Seboyeta Canyon areas

Tmpgb **Medium-grained, gabbro bearing, plagioclase phyric trachybasalt—**Gray flows and red to black scoria deposits **(Tmpgc)** of medium-grained trachybasalt with small scattered phenocrysts of plagioclase; contains conspicuous xenoliths of gabbro up to 5 cm in diameter that become more obvious close to the cone; cone contains two WNW-trending dikes (**Tmpgd**); underlies **Qfatb**; overlies **Tmpob, Tfotb,** and **Tmplb;** unit is not dated; MPF (1 site) = reverse suggesting an age ≤2.58 Ma; maximum observed thickness is about 25 m.

Tfcob **Fine-grained augite megacrystal olivine basalt—**Tiny flow remnant and red to black cinder deposits of fine-grained basalt containing abundant black augite megacrysts with resorbed margins up to 1 cm in diameter (Figure 11). Groundmass contains tiny olivine microphenocrysts with iddingsite alteration. Unit consists mostly of an eroded cone (**Tfcoc**) containing a NW-trending dike (**Tfcod**) and much bedded agglutinate; flow remnant is found on east flank of cone **Tmpoc;** underlies **Qfatb**; unit is not dated; maximum observed thickness is about 25 m.

Tfcpb **Fine-grained augite and plagioclase phyric trachybasalt—**Gray to black flows and red to black cinder deposits (**Tfcpc**) of fine-grained trachybasalt with sparse phenocrysts of augite and plagioclase and rare megacrysts of augite ≤1 cm in diameter; flow SW of scoria cone (hill 8487) has much agglutinate and seems to be part of NNE-trending fissure; overlain by **Qfatb**; unit is not dated; maximum observed thickness is about 80 m.

Figure 11. Agglutinate fragment in eroded scoria cone (unit **Tfcoc**) contains conspicuous megacryst of black clinopyroxene in fine-grained olivine basalt. Photo by F. Goff.

Taptb **Fine-grained aphyric trachybasalt—**Gray flows and red to black cinder deposits (**Taptc**) of fine-grained trachybasalt with rare small phenocrysts of olivine and many elongated microlites of plagioclase; scoria cone contains nice assortment of bombs and a north-trending dike (**Taptd**); overlies old scoria cone of **Toac** on east margin of quadrangle; apparently underlies **Tcpb;** unit is not dated; maximum observed thickness is about 65 m.

Tmpob **Medium-grained plagioclase phyric olivine trachybasalt—**Gray widespread flows and red to black cinder deposits (**Tmpoc**) of medium-grained trachybasalt with sparse phenocrysts of plagioclase and olivine in trachytic groundmass of plagioclase, augite and olivine; texture is occasionally sugary; eroded cone contains an arcuate dike (**Tmpod**); east flank of cone overlain by thin flow remnant from unit **Tfcob**; flows cut by maar volcanoes Laguna de Damacio and Laguna Telesfor; overlain by **Qfatb**, **Tmpgb,** and **Tfob**; overlies **Ttdt**; unit is not dated; MPB (2 sites) =

both normal suggesting an age ≥2.58 Ma; maximum observed thickness is about 30 m.

Tfpcb **Fine-grained augite and plagioclase phyric olivine trachybasalt—** Gray to black flow and red to black cinder deposits (**Tfpcc**) of fine-grained trachybasalt containing phenocrysts of augite, plagioclase and olivine; contains rare gabbroic xenoliths of orthopyroxene and plagioclase (Figure 12); contains rare quartz xenocrysts with clinopyroxene reaction rims; scoria cone contains dike or vertical rib of agglutinate trending N35W; underlies **Tmolb**; abuts **Ttr**; overlies **Ttdt**; unit not dated; maximum observed thickness is about 60 m.

Tvss **Volcaniclastic sandstone—**Gray to tan, fine- to course-grained fluvial sandstone containing small clasts and grains of quartz, plagioclase, olivine, augite, chert, pumice, and various types of basalt and intermediate composition volcanics; may contain thin beds of trachydacite or rhyolite tuffs too thin to map; exposed mostly in upper walls of Seboyeta Canyon where it occupies shallow channels cut into earliest lava flow surfaces in the region; a small exposure of **Tvss** occurs in trench along west side of Laguna maar in southern quadrangle; interbedded in **Tmplb**; overlies **Tbas**; maximum exposed thickness is about 35 m but usually is much less.

Figure 12. Weathered block of trachybasalt (unit **Tfpcb)** displays 3-cm-long gabbroic xenolith in fine-grained matrix (head of rock hammer for scale). Photo by C.J. Goff.

Ttdt **Porphyritic trachydacite tuffs—**White to light gray beds of pumice (Figure 13) and pumice-rich sediments interbedded in middle to lower parts of unit **QTvs** and **Tvss**; pumice is highly vesicular containing sparse, small phenocrysts of plagioclase, augite ± sanidine, biotite, hornblende and quartz; tuffs originate from sources within Mount Taylor; beds are up to 2 m thick; underlies Tfpcb east of Cerro Chivato; overlies **Tfcpb** in upper Seboyeta Canyon; $^{40}Ar/^{39}Ar$ dates on similar deposits to west and southwest range from 2.71 to 2.76 Ma (n=4; Goff et al., 2008, 2010). Date on pumice bed in tuff from Seboyeta quad is 2.700 ± 0.002 Ma (Skotnicki et al., 2011).

Figure 13. Poorly exposed beds of sparsely porphyritic trachydacite pumice wrap around slopes east of Cerro Chivato. Photo by C.J. Goff.

Tfcpob **Fine-grained, clinopyroxene porphyritic olivine basalt—** Distinctive flows of dark gray to black, fine-grained, porphyritic basalt with conspicuous black megacrysts of resorbed augite and small phenocrysts of plagioclase, olivine and magnetite in a groundmass of plagioclase, olivine, augite, opaque oxides and glass; olivine is extensively altered to high-temperature iddingsite; flows originate from scoria cone (**Tfcpoc**) containing NE-trending dike (**Tfcpod**); unit underlies **Tfob** and **Ttdt**; overlies *Tvss*. Unit is not dated; MPB (1site on dike) = normal suggesting an age >2.58 Ma; maximum exposed thickness is about 20 m.

Tmplb **Medium-grained plagioclase-phyric trachybasalt—**Flows and scoria deposits (**Tmplc**) of distinctive gray, medium-grained porphyritic trachybasalt with phenocrysts of plagioclase and very small phenocrysts of olivine and augite in groundmass of plagioclase, olivine, augite, opaque oxides and glass; the scoria cone contains a NNW-trending dike (**Tmpld**); underlies **Tmgpb** and **Tfcpb**, interlayered in **Tvss**, and overlies Cretaceous rocks along northern edge of Seboyeta Canyon. Unit has $^{40}Ar/^{39}Ar$ age of

2.70 ± 0.02 Ma; MPB (2 sites) = both normal (correlated); maximum exposed thickness about 15 m.

Tfac **Fine-grained, aphyric trachybasalt scoria cone—**Exhumed scoria cone in bottom of unnamed ravine on west margin of quadrangle; consists of red to black cinder deposits surrounding an eroded, arcuate dike (**Tfad**); trachybasalt is fine-grained and aphyric with a few tiny but visible microlites of olivine and plagioclase; underlies all adjacent units; unit is not dated; maximum observed thickness is about 8 m.

Tac **Aphyric trachybasalt scoria cones—**Two isolated cones of red to black scoria deposits consisting of aphyric, vesiculated trachybasalt; the northwest cone contains a well-exposed NW-trending dike (**Tad**) and has a small exposure of lava to east (**Tab**); surrounded by units **Qmab**, **Qfob2,** and **Qfcob**; the southeast cone contains a beautiful assortment of bombs, is partially surrounded by **Tfob**, and is cut by the Laguna maar (**Qlm**); cones are not dated; maximum exposed thickness is about 50 m.

Tgab **Medium-grained olivine gabbro—**Tabular body of gray medium-grained, equigranular gabbro consisting of plagioclase, olivine, and augite: exposed along low ridge between parallel unnamed ravines; overlain and surrounded by **Qmab**; may be associated with eroded scoria cone (**Tac**); unit is not dated; maximum observed thickness is about 15 m.

Tbas **Aphyric olivine trachybasalt—**Dark gray, fine-grained, nearly aphyric trachybasalt flows with rare tiny phenocrysts of plagioclase and olivine in a groundmass of plagioclase, abundant olivine, opaque oxides and glass; olivine shows intense, high-temperature iddingsite alteration; vugs, vesicles and cracks are commonly filled with opal/chalcedony, calcite and Fe-oxides; weathered surfaces are distinctly to vaguely spotted in outcrop, resembling some basanite flows elsewhere around Mount Taylor region; unit is massive to rubbly; source is scoria cone with NE-trending dike (**Tbasc** and **Tbasd)** just east of Seboyeta Canyon; east side of cone also contains a thin layer of hydromagmatic deposits (**Tbash**); flow fills paleo-valley developed on top of Cretaceous rocks; underlies **Tvss** and **Tmplb**; $^{40}Ar/^{39}Ar$ age is 2.83 ± 0.02 Ma; MPB (1 site from outcrop in bottom of canyon) = normal (correlated); maximum exposed thickness is about 40 m.

Tfotb **Fine-grained olivine trachybasalt—**Dark gray, fine-grained trachybasalt flows with sparse phenocrysts of olivine, plagioclase and augite in groundmass of plagioclase, olivine, augite, opaque oxides and glass; flows originate from eroded hills of cinders and scoria (**Tfotc**) on southeast tip of Mesa Chivato (Red Mesa) in adjacent Seboyeta quadrangle. Flows overlie Cretaceous rocks but underlie maar deposit and associated flows of **Tfpob** and **Tfpoh** mentioned above; unit is not dated; MPF (1 site) = reverse suggesting an age >3.04 Ma; maximum exposed thickness of flows is about15 m.

Totb **Older basalt and trachybasalt (shown only in cross section)—** Gray to black flows of older basaltic lavas that underlie most other volcanic units and overlie Cretaceous rocks in map area; equivalent to **Totb** in San Mateo and Cerro Pelon quadrangles (McCraw et al., 2009; Goff et al., 2012). Ages of dated flows to west are around 3.1 to 3.3 Ma; thickness ≤45 m.

Cretaceous

(adapted from Goff et al., 2012 and Skotnicki et al., 2012)

Mesa Verde Group

Kmf **Menefee Formation (shown in cross section only)—**Interbedded golden to yellow orange, medium to thin bedded sandstone, black to gray to brown shale and siltstone with carbonized wood fragments, and minor coal. The sandstones are composed of well to moderately sorted, very fine- to fine-grained angular to subrounded quartz and lithic grains. The sandstone beds are cross-bedded to tabular-bedded to massive. Cross beds commonly dip east to northeast. Sandstones are weakly cemented to well cemented. Petrified wood fragments are common. Maximum exposed thickness in other quadrangles ≥45 m.

Kpl **Point Lookout Sandstone, Hasta tongue—**Fine-grained quartz sandstone with rare darker lithic grains. Uppermost 5 m shows planar cross-bedding in sets up to 1 m. Below about 5 m bedding is mostly horizontal with low-angle cross beds, especially in the lowermost 2-3 m. Forms prominent light gray cliffs; maximum exposed thickness is about 45 m.

Crevasse Canyon Formation

Kcg **Gibson Coal Member—**Interbedded light orange very fine-grained quartz sandstone in massive to thinly bedded layers up to 4 m thick and dark shale. The shale commonly contains dark brown to black lignite coal in seams up to 2 m thick. Locally contains light gray fragments of fossilized wood; maximum exposed thickness <50 m.

Kcda **Dalton Sandstone Member (shown only in cross section)—** Consists of two prominent sandstone layers, a lower yellowish-orange layer and an upper white layer with an intervening shale bed. The basal sandstone near the contact with the underlying Mulatto Tongue of the Mancos Shale often has thin beds containing abundant pelecypods casts and molds. The upper and lower contacts are gradational with the overlying Gibson Coal Member of the Crevasse Canyon Formation and the underlying Mulatto Tongue of the Mancos Shale. Maximum exposed thickness to southwest in Lobo Springs quadrangle is ≤25 m (Goff et al., 2008).

Kcs **Stray Sandstone Member (shown only in cross section)—**Consists of two prominent reddish-orange sandstone layers with an intervening shale bed. The top of the Stray Sandstone is a thin (<1 m) conglomerate with pebbles to cobbles of quartzite, chert, and quartz. The upper and lower contacts are gradational with the overlying Mulatto Tongue of the Mancos Shale and the underlying Dilco Coal Member of the Crevasse Canyon Formation. The Stray pinches out under the southeastern part of the quadrangle. Maximum exposed thickness to southwest in Lobo Springs quadrangle is ≤40 m. (Goff et al., 2008).

Kcdi **Dilco Coal Member (shown only in cross section)—**Interbedded black to brown siltstone, thin to medium bedded tan, brown, and olive-green sandstone, and black coal. The sandstones are cross-bedded to ripple laminated. The coal beds are < 0.5 m thick and are usually in the lower part of the unit. The upper and lower contacts are gradational with the overlying Stray Sandstone of the Crevasse Canyon Formation and the underlying main body of the Gallup Sandstone. Maximum exposed thickness to southwest in Lobo Springs quadrangle is ≤150 m (Goff et al., 2008).

Gallup Sandstone

Kgm **Main body (shown only in cross section)—**Yellowish gray, white, or golden yellow, medium to thick-bedded, cross-bedded sandstone. Carbonaceous shale is intercalated with the sandstone. Locally contains fossiliferous (*Innocermid*) beds near the top. Beds are primarily planar-tabular or laminated. The lower contact is gradational with Mancos Shale and the upper contact is gradational with the Dilco Coal Member of the Crevasse Canyon Formation. Maximum exposed thickness to southwest in Lobo Springs quadrangle is ≤25 m (Goff et al., 2008).

Kgu **Upper tongue (combined with *Km* in cross section)—**White medium-bedded, cross-bedded to tabular sandstone that is locally capped by well-cemented, fractured, brown-weathering, planar cross-bedded sandstone. The brown sandstone is carbonate cemented; the weakly cemented white sandstone does not react to hydrochloric acid. The upper and lower contacts are gradational with Mancos Shale. Maximum exposed thickness to southwest in Lobo Springs quadrangle is ≤30 m (Goff et al., 2008).

Kgl **Lower tongue (combined with *Km* in cross section)—**White medium-bedded, cross-bedded to tabular sandstone that is locally capped by well-cemented, fractured, brown-weathering, planar cross-bedded sandstone. Brown sandstone is carbonate cemented; the weakly cemented white sandstone does not react to hydrochloric acid. The top of unit is locally conglomeratic with sandstone clasts and sharks teeth. The upper and lower contacts are gradational with Mancos Shale. Maximum exposed thickness to southwest in Lobo Springs quadrangle is ≤15 m (Goff et al., 2008).

Mancos Shale

Kmsa **Satan Tongue—**Interbedded dark shale and less abundant very fine-grained quartz sandstone exposed in Seboyeta Canyon in SE part of the map. Maximum observed thickness is about 65 meters. Pinches out and interlayers with the Point Lookout sandstone going to the northwest (Sears et al., 1941).

Kmm **Mulatto Tongue—**Golden yellow, thin-bedded, tabular to ripple-laminated sandstone and black shale. Burrows and scattered pelecypod molds are common in the sandstone beds. Coarse to very coarse sandstone beds near the basal contact with the Stray Sandstone and lenses of conglomerate with well-rounded pebbles of black and white chert and black quartzite are locally present. Upper and lower contacts are gradational with the Dalton and Stray Sandstone members of the Crevasse Canyon Formation. Maximum exposed thickness to southwest in Lobo Springs quadrangle is ≤50 m (Goff et al., 2008).

Km **Main body—**Black to dark brown shale and silty shale intercalated with finely laminated to cross-bedded thinly bedded sandstone. The sandstones are well-sorted, fine-grained quartz arenites. Upper and lower contacts are gradational. Small tongues of Main Mancos are interbedded within the Gallup Sandstone units. Maximum exposed thickness of Main Mancos beneath Gallup Sandstone is ≤50 m. Maximum drilled thickness including Bridge Creek Limestone (described below) is roughly 145 to 180 m (Goff et al., 2008, Table 2; Skotnicki et al., 2012).

Kmb **Bridge Creek Limestone (combined with *Km* in cross section)—** Finely laminated, fossiliferous, light gray limestone interbedded with thin black shale below the Main body of the Mancos Shale. Unit is correlative with the Greenhorn Limestone. Contains abundant invertebrate fossils including *Pycnodonte* aff. *P. kellumi*, *Exogyra levis*, *Plicatula* cf. *P. hydrotheca*, cf. *Caryocorbula* and *Turritella* sp. (Barry Kues, University of New Mexico, personal communication). Maximum exposed thickness to southwest in Lobo Springs quadrangle is ≤25 m (Goff et al., 2008).

Dakota Formation

Kd **Dakota Formation, undivided (shown only in cross section)—** Alternating sandstones and shales of Dakota Formation and Mancos Shale; Dakota unit identified in uranium well logs to west near San Mateo (Reise, 1977, 1980) is inferred to be the lower Oak Canyon Sandstone Member (about 25 m thick). Aggregate thickness of Dakota is about 100 m in northwestern map area (Owen and Owen, 2003; see also cross sections in Goff et al., 2008 and McCraw et al., 2009).

Jurassic

Morrison Formation

Jbb + Jwc **Brushy Basin and Westwater Canyon Members (shown only in cross section)—**Alternating sandstones and shales identified only in drill holes to the west and southwest (see Reise, 1977; Lucas and Zeigler, 2003). Goff et al., 2012); as defined here probably includes Jackpile Member on top of Brushy Basin beneath east side of quadrangle; may include Salt Wash Member; thickness probably around 80 ± 20 m depending on location.

Jrc **Recapture Member (shown only on cross section A-A′)—**Consists of grayish-red sandy claystone and clayey sandstone with limy nodules, and white, clean, fine- to medium-grained sandstone in beds 1.5 to 15 m thick (Freeman and Hilpert, 1957). May contain imbricated gypsum-rich beds Basal conglomeratic sandstone rests on channeled surface of underlying Bluff Sandstone. At other localities the Recapture rests conformably on, or at other localities, is interlayered with Bluff. In the Laguna Pueblo area, the unit varies tremendously in thickness 20 to 170 ft thick; thickens to north from pueblo area. Thickness in cross section is quite speculative.

CROSS SECTIONS

We constructed two east-west cross sections across Laguna Cañoneros quadrangle as part of the mapping project (see map sheet). As mentioned above, the only window into the Mesozoic section occurs in upper Seboyeta Canyon in the southeastern part of the quadrangle. Fortunately, this canyon is rather deep (≤800 ft or ≤245 m) and exposes three Cretaceous units (discussed below). The canyon widens to the south into Seboyeta quadrangle where Skotnicki et al. (2012) produced over 20 measured sections in upper Cretaceous rocks. Good subsurface control is also provided east of Laguna Cañoneros quadrangle by driving the access roads along the southeastern side of Mesa Chivato through Lobo Ranch and up into the Red Mesa Wind Farm. Finally, good subsurface control is obtained from examination of well logs west of our project area on the Cerro Pelon quadrangle. The west ends of our two cross sections join the east ends of the cross sections constructed for the Cerro Pelon quadrangle.

The Cretaceous stratigraphy in this region shows two important trends resulting from ancient changes in sea level (see also Sears et al., 1941, p. 110 and their fig. 22). The first trend is the pinch out to the east of the Stray Sandstone in the Crevasse Canyon Formation. The Stray forms two prominent, extensive sandstone ledges roughly 25 to 40 m in total thickness that are clearly visible above the Dilco Coal Member in Rinconada and Water Canyons, several miles southwest of Laguna Cañoneros quadrangle (Goff et al., 2008; Osburn et al., 2010) and in the San Mateo area to the west (McCraw et al., 2009). However, the Stray is missing in the Cretaceous section mapped throughout the Seboyeta quadrangle (Skotnicki et al., 2012). We show the Stray throughout our cross section A-A′ but show it pinching out in section B-B′ beneath the southern part of our map area.

The second important trend is the pinch out to the west of the Satan Tongue of the Mancos Shale. The Satan is interbedded within the Point Lookout Sandstone and supposedly thickens to the northeast of Mesa Chivato (Sears et al., 1941). The Satan is the uppermost Cretaceous unit in upper Seboyeta Canyon, appears at the top of several stratigraphic sections prepared by Skotnicki et al. (2012), and can be seen in the canyons east of Red Mesa Wind Farm. In contrast, no Satan is found in the Cretaceous sections exposed west of Laguna Cañoneros quadrangle (Goff et al., 2008; McCraw et al., 2009; Osburn et al., 2010). We show the Satan as a west-tapering wedge within the Point Lookout Sandstone in both our cross sections, although the exact position of the pinch out is speculative.

Both cross sections traverse several noteworthy volcanic features. Section A-A′ intersects (west to east) the double maar at Lagunas Cuates (Fig. 6), the trachyte dome of Cerro Chivato, and the spectacular maar of Laguna Cañoneros (both shown in the cover photo). Section B-B′ crosses (west to east) the old scoria cone of hill 8282 (unit **Tac**), the large scoria cone with several dikes (hill 8356, unit **Tfcpc**), and adjacent scoria cones now partially covered with windmills at Red Mesa Wind Farm (units **Tbasc** and **Tmplc**; Figure 14).

Figure 14. View south from Floyd Lee Ranch of three windmills standing on eroded scoria cone (unit **Tmplc**, 2.70 Ma) in Red Mesa Wind Farm, southeast Laguna Cañoneros quadrangle (photo by F. Goff).

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Appendix 1: Normalized chemical analyses of selected volcanic rocks from the Laguna Cañoneros quadrangle. Samples with suffix W were analyzed at Washington State
All other samples were analyzed by ALS Chemex, Reno, NV. Locations given are UTM NAD 27 if measured.

Sample	F12-11W	F12-11	F12-12	F12-15W	F12-24W	F12-24	F12-32W	F12-32	C13-01	C13-10	F13-01
Map unit	Tbas	Tbas	Tmplb	Qmplb	Qantb	Qantb	Tgab	Tgab	Ttdt	Qfob 2	Qfplb
Field name	Trachybasalt	Trachybasalt	Trachybasalt	Trachybasalt	Xeno tbasalt	Xeno tbasalt	Oliv gabbro	Oliv gabbro	Tdacite pum	Oliv basalt dike	Trachybasalt
Location	60m below F12-12	60m below F12-12	Seboyeta Can	East of Sec 16 tank	NW quad	NW quad	West central quad	West central quad	East of Cerro Chivato	Cerro Redondo	Northwest quad edge
Northing			3904688	3904865	3916914	3916914	3907712	3907712	3912514	3909544	3917285
Easting			279920	274595	274892	274892	276048	276048	280866	274062	279307
SiO_2	48.09	47.8	48.5	47.7	48.8	48.7	49.1	48.9	68.1	46.5	47.0
TiO_2	3.074	3.00	2.74	3.331	2.417	2.44	3.122	3.11	0.30	2.42	3.14
Al_2O_3	16.08	15.10	16.04	16.93	15.78	15.42	17.67	17.12	15.67	14.86	16.82
Fe_2O_3		13.06	12.88			12.20		12.88	4.26	12.78	14.25
FeO	12.44			13.02	11.36		12.05				
MnO	0.19	0.18	0.18	0.18	0.174	0.18	0.176	0.18	0.11	0.17	0.18
MgO	5.73	6.49	5.48	5.09	7.32	6.92	4.39	4.31	0.65	8.60	5.29
CaO	8.50	8.52	7.89	7.75	8.38	8.31	6.77	6.74	1.88	9.45	7.34
Na_2O	3.66	3.70	3.99	3.94	3.63	3.74	4.18	4.30	3.60	3.30	3.90
K_2O	1.43	1.32	1.51	1.43	1.43	1.42	1.77	1.69	5.31	1.31	1.45
P_2O_5	0.806	0.79	0.77	0.625	0.697	0.69	0.779	0.76	0.12	0.64	0.57
Total	100.00	99.96	99.98	100.00	99.99	100.02	100.01	99.99	100.00	100.00	99.94
LOI		0.39	(-0.12)			0.18		0.24	6.79	(-0.19)	(-0.10)
Tot alkalis	5.09	5.02	5.50	5.37	5.06	5.16	5.95	5.99	8.91	4.61	5.35
C		0.06	0.09			0.05		0.03	0.32	0.03	0.06
S	0.02	0.02	0.04	0.01	0.01	0.02	0.00	0.02	0.02	<0.01	<0.01
Cl	0.01			0.01	0.01		0.01				

Appendix 1. Continued

Sample	F13-02	F13-09	F13-20	F13-31	F13-33	F13-34	F13-37	F13-39	F13-55	JKL-H8761	JKL-Weird
Map unit	Qolpb	Tbaqb	Qfatc	Ttr	Tphtb	Qfpod	Toxtb	Qfoqb	Qfoqd	Qftb	Qpota
Field name	Oliv basalt	Qtz basanite	Trachybasalt	Trachyte	Hbd tbasalt	Ol basalt dike	Xeno basalt	Ol tbasalt	Tbasalt dike	Trachybasalt	Porph tandesite
Location	NW quad	West edge of L. Cannoneros	Quad center	Cerro Chivato	North of Cerro Chivato	W center quad	SE of F13-55	N of F13-34	Cerro Aguila	NW quad	NW C Aguila
Northing	3916784	3911913	3909674	3912200	3913925	3908618	3910257	3910106	3912113	3912000	3912169
Easting	275327	282349	279457	280143	280482	276352	276059	277057	276772	274920	276314
SiO_2	45.3	45.4	49.1	63.1	48.6	47.2	46.3	49.6	48.6	48.1	55.6
TiO_2	2.48	3.27	2.72	0.33	3.05	2.81	2.84	2.25	2.50	3.12	1.38
Al_2O_3	12.19	15.82	17.17	17.34	17.43	16.35	14.44	16.20	16.37	16.67	17.51
Fe_2O_3	13.43	14.15	12.66	5.83	13.53	12.70	14.28	11.90	12.32	14.08	8.78
FeO											
MnO	0.17	0.18	0.18	0.18	0.21	0.15	0.17	0.18	0.18	0.18	0.20
MgO	13.53	6.98	3.89	0.21	3.63	6.86	8.80	5.30	5.30	4.50	2.51
CaO	8.66	8.11	6.97	0.97	5.92	8.60	9.05	7.65	7.98	6.78	4.98
Na_2O	2.79	3.66	4.61	6.73	4.24	3.46	3.11	4.30	4.12	4.36	5.37
K_2O	1.03	1.70	1.80	4.91	2.44	1.25	1.00	1.81	1.78	1.56	3.02
P_2O_5	0.45	0.74	0.87	0.42	0.96	0.62	0.51	0.83	0.86	0.71	0.67
Total	100.03	100.01	99.97	100.02	100.01	100.00	100.05	100.00	100.01	100.06	100.02
LOI	(-0.31)	0.54	1.08	0.72	1.92	0.69	(-0.07)	(-0.10)	0.12	(-0.06)	0.11
Tot alkalis	3.82	5.36	6.41	11.64	6.68	4.71	4.11	6.11	5.90	5.92	8.39
C	0.03	0.06	0.07	0.07	0.08	0.19	0.11	0.02	0.08	0.04	0.06
S	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	<0.01	<0.01	<0.01
Cl											

Appendix 2
THIN SECTION DESCRIPTIONS
(by F. Goff)

General Comments: Locations use US Geological Survey, Laguna Cañoneros 7.5 minute topographic quadrangle, UTM NAD 27 (1982) unless otherwise noted. Textures, petrology and rock names generally follow the examples in Williams et al. (1954). Rock names use classification schemes of Le Bas et al. (1986) for volcanic rocks. Magnetic polarities were determined by waving a horizontal Brunton compass at a vertical outcrop face; normal polarity = needle repels, reverse polarity = needle attracts.

Abbreviations: Kspar = generic potassium feldspar (variety noted if possible); plag = plagioclase, qtz = quartz, bio = biotite, hbd = hornblende, opx = orthopyroxene, cpx = clinopyroxene, ol = olivine; io = generic iron ore, mt = magnetite, ilm = ilmenite, gl = glass; HT-idds = high-temperature iddingsite (mainly reddish orange hematite and maghemite); ser = sericite, chl = chlorite, cc = calcite, ep = epidote, Fe-oxide = generic low-temperature secondary iron oxide(s), sl = slightly, MP = magnetic polarity.

F12-11: Fine-grained olivine basanite (unit Tbas)
Location: Near top of flow, 60 m below F12-12 (described below) in NE wall, Seboyeta Canyon
Color & Texture: Dark gray to black, fine-grained to aphyric, vesicular, glassy, intersertal
Phenocrysts: Abundant small ol w/ HT-idds and lesser small plag, some partially resorbed
Groundmass: Plag, ol w/ HT-idds, tiny cpx, io, gl
Secondary: Relatively fresh, some vesicles contain cc and zeolite
Comments: Chemical analysis (Table 2) = trachybasalt (not basanite); MP = normal
Petrographic Name: Fine-grained olivine trachybasalt

F12-12: Medium-grained plagioclase-phyric trachybasalt (unit Tmplb)
Location: 3904688/279920, NE rim of Seboyeta Canyon
Color & Texture: Gray, medium-grained, sl vesicular, sl porphyritic, sl trachytic
Phenocrysts: Two generations of plag, some resorbed, ol w/minor HT-idds, minor cpx and io
Groundmass: Plag, ol, minor cpx, io, very little gl
Secondary: Fresh
Comments: Chemistry (Table 2) = trachybasalt; MP = normal
Petrographic Name: Plagioclase-porphyritic trachybasalt

F12-24: Fine-grained, xenolith-bearing trachybasalt (unit Tantb)
Location: 3916914/274892, in scoria cone cluster, NW portion of quadrangle

Color & Texture: Dark gray, fine-grained, sl vesicular, porphyritic, intersertal, sl trachytic
Phenocrysts: Plag, ol w/ HT-idds, cpx
Groundmass: Plag, ol, cpx, io, gl
Xenocrysts: Three types; plag-ol-opx-cpx, cpx-ol-minor plag, mt-apatite
Secondary: Some Fe-oxide
Comments: Chemistry (Table 2) = trachybasalt; MP = normal
Petrographic Name: Xenolith-bearing, fine-grained, porphyritic trachybasalt

F12-32: Medium-grained olivine gabbro (unit Tgab)
Location: 3907712/276048, west-central quadrangle
Color & Texture: Gray, medium-grained, equigranular, holocrystalline
Mineralogy: Plag, ol w/ minor HT-idds, cpx, io, no gl
Secondary: Fresh
Comments: Chemistry (Table 2) equivalent to trachybasalt
Petrographic Name: Medium-grained olivine gabbro

C13-01: Trachydacite pumice (unit Ttdt)
Location: 3912514/280866, east of Cerro Chivato
Color & Texture: White, pumiceous, sl porphyritic, stretched vesicles
Phenocrysts: Small plag, sanidine, bio, minor cpx; some sanidine in clots
Groundmass: Gl and vesicles
Secondary: Minor ser in glass, minor clay filling vesicles
Comments: Chemistry (Table 2) = trachydacite
Petrographic Name: Biotite trachydacite pumice

C13-10: Olivine basalt (unit Qfob2)
Location: 3909544/274062, summit of Cerro Redondo
Color & Texture: Black, fine- to medium-grained, porphyritic, sl vesicular, intersertal
Phenocrysts: Ol w/ minor HT-idds, cpx, mt, some ol and cpx are skeletal
Groundmass: Plag, ol, cpx, io, gl
Xenoliths: Melted chunks of another basalt; melted fragments of cpx-plag and ol-cpx
Secondary: Fresh
Comments: Chemistry (Table 2) = basalt; MP = normal
Petrographic Name: Xenolith-bearing, porphyritic olivine basalt

F13-01: Medium-grained, plagioclase-phyric trachybasalt (unit Qfplb)
Location: 3917285/279307, north edge of quadrangle east of Laguna Blanca
Color & Texture: Gray, medium-grained, holocrystalline, sl trachytic
Phenocrysts: A few small plag and ol w/ minor HT-idds
Groundmass: Plag, ol, titanaugite (purple-brown pleochroism), io, no gl
Secondary: Fresh
Comments: Chemistry (Table 2) = trachybasalt; MP = reverse

Petrographic Name: Medium-grained, plagioclase-phyric trachybasalt

<u>F13-02: Fine-grained, porphyritic olivine basalt</u> (unit Qolpb)
Location: 3916784/275327, in cluster of cones near NW corner of quadrangle
Color & Texture: Black, fine-grained, porphyritic, sl vesicular, intersertal
Phenocrysts: Mostly ol, some cpx and plag, larger crystals have resorbed edges
Groundmass: Plag, ol, cpx, io, gl
Secondary: Fresh
Comments: Chemistry (Table 2) = basalt
Petrographic Name: Porphyritic olivine basalt

<u>F13-07: Medium-grained olivine trachybasalt</u> (unit QTmolb)
Location: 3912307/283144, east part of quadrangle, north of Laguna Bandeja
Color & Texture: Gray, medium-grained, sl porphyritic, sl vesicular, intersertal
Phenocrysts: Ol w/ major HT-idds, a few small plag and cpx
Groundmass: Plag, ol, cpx, io, gl
Secondary: Fresh
Comments: MP = reverse
Petrographic Name: Medium-grained olivine trachybasalt

<u>F13-08: Aphyric basalt in scoria cone</u> (unit Qatc)
Location: 3911593/283162, cone just south of Laguna Bandeja
Color & Texture: Black, very fine-grained to aphyric, glassy, vesicular, sl trachytic
Phenocrysts: Small ol and plag
Groundmass: Plag, ol w/ minor HT-idds, cpx, io, gl
Secondary: Fresh
Comments: Cone is cut by Laguna Bandeja maar
Petrographic Name: Aphyric trachybasalt

<u>F13-09: Hackly aphyric quartz basalt</u> (unit Thaqb)
Location: 3911913/282349, west edge of Laguna Cañoneros
Color & Texture: Gray, fine-grained, sl vesicular, intersertal
Phenocrysts: Tiny sparse ol w/ very minor HT-idds, and a few small plag
Xenocrysts: A few sparse quartz xenocrysts, some with cpx reaction rims
Groundmass: Plag, ol, cpx, io, gl
Secondary: Fresh
Comments: Chemistry (Table 2) = basanite (barely); MP = normal
Petrographic Name: Quartz-bearing olivine basanite

<u>F13-16: Medium-grained, plagioclase-phyric trachybasalt</u> (unit Tmgtb)
Location: 3906404/280922, south-central quadrangle east of Laguna de Frances
Color & Texture: Gray, medium-grained, holocrystalline, intersertal to trachytic, sl vesicular

Phenocrysts: Sparse small plag and io
Groundmass: Plag, ol w/ HT-idds, cpx, io, very minor gl
Xenoliths: Coarse-grained gabbro (plag-cpx-minor ol)
Secondary: Fresh
Comments: Gabbro xenoliths fairly abundant toward scoria cone source
Petrographic Name: Gabbro-bearing trachybasalt

F13-19: Aphyric trachybasalt dike in scoria cone (unit Tfatd)
Location: 3909552/280042, along power line road in scoria cone, central part of quadrangle
Color & Texture: Gray, sl vesicular, holocrystalline, trachytic
Phenocrysts: Very sparse small plag
Groundmass: Plag, ol w/ minor HT-idds, titanaugite, io, no gl
Secondary: Fresh – beautiful thin section
Comments: Chemistry of similar sample (F13-20, Table 2) = trachybasalt; MP = normal
Petrographic Name: Aphyric trachybasalt

F13-26: Maar sediment (basaltic sandstone) (unit QTvm)
Location: 3911421/ 282076, drainage at south end of Laguna Cañoneros
Color & Texture: Pale yellow brown, clastic, medium-grained, well-sorted, mixture of sub-angular to sub-rounded sand-sized fragments
Mineralogy: Several types of basaltic fragments (mostly fresh to altered plag-ol-cpx-io) in matrix of palagonite clay and opal
Secondary: Palagonite, opal, Fe-oxide
Comments: Not dateable, underlies, Thaqb
Petrographic Name: Basaltic hydromagmatic sandstone

F13-27: Pumiceous volcanic sandstone (unit QTvs – too small to show on map)
Location: Same as above; underlies hydromagmatic deposit described above
Color & Texture: Pale pinkish white, clastic, medium- to coarse-grained, mixture of pumice, crystals, felsic and mafic volcanic fragments
Mineralogy: The pumice contains biotite and feldspar, very little cpx
Secondary: Opal and clay in vesicles of pumice
Comments: Not dateable; pumice resembles C13-01 above and pumice dated at 2.70 Ma to south
Petrographic Name: Pumiceous volcanic sandstone

F13-31: Fine-grained trachyte (unit Ttr)
Location: 3912200/280143, summit of Cerro Chivato
Color & Texture: White to pale gray, fine-grained, trachytic, sl vesicular
Phenocrysts: Multitude of tiny plag, some io
Groundmass: Plag, io, tiny cpx, minor gl
Secondary: Minor Fe-oxide staining

Comments: Chemistry (Table 2) = trachyte
Petrographic Name: Fine-grained trachyte

F13-33: Hornblende trachybasalt (unit Tphtb)
Location: 3913925/280482
Color & Texture: Dark gray to black, vesicular, porphyritic, glassy, intersertal
Phenocrysts: Abundant zoned lamprobilite (basaltic hornblende) with resorbed and oxidized margins
Groundmass: Plag, ol w/ HT-idds, cpx, io, gl
Secondary: Minor Fe-oxide and clay in vesicles
Comments: Chemistry (Table 2) = trachybasalt
Petrographic Name: Porphyritic hornblende trachybasalt

F13-34: Porphyritic olivine basalt dike (unit Qfpod)
Location: 3908618/276352, in scoria cone east of Cerro Redondo
Color & Texture: Spotted black, porphyritic, vesicular, intersertal, glassy
Phenocrysts: Abundant resorbed, almost round plag, ol, cpx; some plag-cpx and ol-cpx clots, some sieve-textured plag
Groundmass: Plag, ol w/ HT-idds, cpx, io, gl
Secondary: Fresh
Comments: Chemistry (Table 2) = basalt; MP = reverse
Petrographic Name: Porphyritic, pyroxene-phyric olivine basalt

F13-39: Fine-grained olivine basalt (unit Tfqob)
Location: 3910106/277057, west of Laguna de Damacio by "Panama Canal"
Color & Texture: Dark gray, fine-grained, sl porphyritic, sl vesicular, sl trachytic
Phenocrysts: A few ol w/ minor HT-idds, and a few plag
Groundmass: Plag, ol, cpx, io, gl and a few small cpx clots
Secondary: Fresh
Comments: Chemistry (Table 2) = trachybasalt
Petrographic Name: Fine-grained olivine trachybasalt

JRL-H8761: Fine-grained, plagioclase-phyric trachybasalt (unit Qftb)
Location: 3912000/274920, flow W of scoria cone, hill 8767, in NW quad
Color & Texture: Gray, fine-grained, vesicular, holocrystalline, intersertal
Phenocrysts: A few small plag and sparse ol w/HT-idds
Groundmass: Plag, ol, cpx, io, very little gl
Secondary: Fresh
Comments: Chemistry (Table 2) = trachybasalt
Petrographic Name: Fine-grained, plagioclase-phyric trachybasalt

JRL-H8645: Porphyritic olivine basalt (unit Qyod)
Location: 3913050/273873, dike in NE-trending cone cluster west of Laguna Cuates

Color & Texture: Dark gray, medium-grained, porphyritic, glassy, intersertal
Phenocrysts: Abundant ol and a few cpx
Groundmass: Plag, ol, cpx, io, gl
Secondary: Fresh
Comments: None
Petrographic Name: Porphyritic olivine basalt

JRL-Weird: Porphyritic basalt (?) (unit Qpota)
Location: 3912169/276314, NW flank of Cerro Aguila
Color & Texture: Gray splotchy white, very porphyritic, holocrystalline, sl vesicular
Phenocrysts: Abundant large resorbed and sieved plag, a few smaller cpx, sparse ol w/HT-idds, and mt
Groundmass: Plag, cpx, a little ol, io, apatite, no gl
Secondary: Fresh
Comments: Chemistry (Table 2) = trachyandesite; mapped initially as basalt
Petrographic Name: Porphyritic trachyandesite

JRL-CAguila: Olivine trachybasalt dike (unit Qfoqd)
Location: 3912113/276772, north of summit of Cerro Aguila
Color & Texture: Dark gray, medium-grained, sl porphyritic, vesicular, intersertal, glassy
Phenocrysts: Abundant small plag, ol, and a few cpx
Groundmass: Plag, ol, cpx, io, gl
Secondary: Fresh
Comments: Chemistry (Table 2) = trachybasalt; hand sample has qtz xenocrysts
Petrographic Name: Olivine trachybasalt

13LC16: Fine-grained olivine basalt (unit Tcgl)
Location: Part of Campo Grande lava flows near northern edge of quad
Color & Texture: Dark gray to black, fine-grained, intersertal, glassy
Phenocrysts: Abundant small ol w/ minor HT-idds, a few large mt
Groundmass: Plag, ol, cpx, io, gl
Secondary: Fresh
Comments: None
Petrographic Name: Fine-grained olivine trachybasalt