Geology of the Guadalupe Mountain 7.5-minute Quadrangle, Taos County, New Mexico

by Keith I. Kelson, Ren A. Thompson, and Paul W. Bauer

March, 2015

New Mexico Bureau of Geology and Mineral Resources
Open-file Geologic Map OF-GM 168

Scale 1:24,000

This quadrangle map has been open-filed in order to make it available. The map has not been reviewed according to New Mexico Bureau of Geology and Mineral Resources standards, and due to the ongoing nature of work in the area, revision of this map is likely. As such, dates of revision will be listed in the upper right corner of the map and on the accompanying report. The contents of the report and map should not be considered final and complete until it is published by the New Mexico Bureau of Geology & Mineral Resources.

Mapping of this quadrangle was funded by a matching-funds grant from the STATEMAP program of the U.S. Geological Survey National Cooperative Geologic Mapping Program and the New Mexico Bureau of Geology and Mineral Resources.

Description of Map Units

CENOZOIC

pattern **Artificial fill** (modern-historic) − Areas of artificially deposited fill and debris; delineated where areally extensive; consists predominantly of mill tailings and dams, plus related land disturbances, west of Questa that were derived from mining activities east of Questa

Qal **Alluvium** (Holocene) − Poorly to moderately sorted sand, pebbles, and boulders in stream channels, valley floors, and active floodplains; clasts of granitic, metamorphic, volcanic, and sandstone rock types; clasts along Red River, Rio Grande, and tributaries draining the Sangre de Cristo Mountains are dominated by granitic rock types, quartzite, and basalt; clasts along tributaries draining the western side of the Rio Grande are dominated by volcanic rock types; weak or no soil development; up to 7 m estimated thickness

Qsw **Sheetwash alluvium** (late Pleistocene to Holocene?) − Alluvial aprons composed mostly of pebbly to silty sand that accumulates on gentle slopes, such as those on Servilleta Basalt (Tsb); some of the silt- to fine sand-size fraction in these deposits may be of eolian origin (Shroba and Thompson, 1998); deposits of unit Qsw along the shores of intermittent ponds or small lakes on Servilleta Basalt (Tsb); low-lying areas of unit Qsw are susceptible to sheet flooding due to unconfined overland flow, and locally to stream flooding and gullying; recently disturbed surface of unit Qsw may be susceptible to minor wind erosion; estimated thickness is 1 to 5 m, but possibly as much as 10 m.

Qc **Colluvium** (middle Pleistocene to Holocene) − Mostly locally derived, poorly to moderately sorted, angular to well-rounded sand, pebbles, and boulders; mapped on hillslopes and valley margins only where it obscures underlying relations; mantles slopes in Red River gorge and northeastern side of Red River fault zone in eastern part of quadrangle; estimated at generally less than 5 m thick

Qe **Eolian deposits** (Pleistocene to Holocene) − Well-sorted, fine to medium sand with silt; rare gravel lag; poorly exposed except in local road cuts; located predominantly on western side of the Rio Grande; weak to moderate soil development

Qls **Landslides** (late Pleistocene to Holocene) − Poorly sorted sand to boulders; includes large rotational slide blocks within the Rio Grande gorge, which include large, rotated and detached beds of Servilleta Basalt (Tsb); may also include areas underlain by Holocene colluvium in Rio Grande and Red River gorges

Qfy Qty **Young alluvial-fan and stream terrace deposits** (latest Pleistocene to Holocene) − Poorly sorted silt, sand, pebbles, cobbles, and boulders; clasts primarily of quartzite, schist, granite, and volcanic rock types; associated soils have stage I calcium carbonate development

Qfyv **Young alluvial-fan deposits from volcanic terrane** (latest Pleistocene to Holocene) − Poorly sorted silt, sand, pebbles, cobbles, and boulders; clasts primarily of volcanic rock types; associated soils have stage I calcium carbonate development; source areas primarily volcanic terrane on west side of Rio Grande and drainages on Guadalupe Mountain

Qt7rr **Stream terrace deposits of the Red River** (early to middle Holocene) − Poorly sorted silt, sand, pebbles, cobbles, and boulders; clasts primarily of quartzite, schist, granite, and volcanic rock types; associated soils have stage I calcium carbonate development; typically present as thin (< 5 m) alluvial deposit on strath surface cut on volcanic bedrock deposit; equivalent to Qt7 of Pazzaglia (1989) and Kelson (1986)

Qt5rr **Stream terrace deposits of the Red River** (late Pleistocene) − Poorly sorted silt, sand, pebbles, cobbles, and boulders; clasts primarily of quartzite, schist, granite, and volcanic rock types; associated soils have stage II to III calcium carbonate development; typically present as thin (< 5 m) alluvial deposit on strath surface cut on volcanic bedrock or nit QTl (Lama Formation); equivalent to Qt5 of Pazzaglia (1989) and Kelson (1986)

Qfo **Undifferentiated alluvial fan deposits** (middle to late Pleistocene) − Probably correlative with alluvial units Qt2 through Qt6; poorly sorted silt, sand, pebbles, and cobbles; not correlated to other fan units because of lack of well-defined age control, clear stratigraphic position, and distinct lithologic characteristics; in Guadalupe Mountain quadrangle, composed primarily of intermediate and basaltic volcanic clasts

Qt3rr **Stream terrace deposits of the Red River** (middle? Pleistocene) − Poorly sorted silt, sand, pebbles, cobbles, and boulders; clasts primarily of quartzite, schist, granite, and volcanic rock types; associated soils have stage III calcium carbonate development; typically present as thin (< 5 m) alluvial deposit on strath surface cut on volcanic bedrock or unit QTl (Lama Formation); equivalent to Qt3 of Pazzaglia (1989) and Kelson (1986)

Qao3 **Older alluvium** (middle? Pleistocene) – Poorly sorted silt, sand, and pebbles; clasts primarily of granitic, metamorphic, basaltic, and intermediate volcanic rocks; distinctly smaller clast sizes than units Qt2rr, Qt1rr, and Qt0rr; upper soil horizons locally affected by surface erosion; may be mantled locally by unit Qe; typically present as thin (< 5 m) alluvial deposit on strath surface cut on volcanic bedrock near rim of Rio Grande gorge; located only upstream of the Red River fault zone; correlative with unit Qao3 in Sunshine quadrangle (Ruleman et al., 2007)

Qt2 **Stream terrace deposits** (middle Pleistocene) – Poorly sorted silt, sand, pebbles, cobbles, and boulders; clasts primarily of quartzite, schist, granite, and volcanic rock types; associated soils have stage III to IV calcium carbonate development; associated soils have stage III to IV calcium carbonate development, thick argillic Bt soil horizons, and 7.5YR to 10YR hues in soil Bt horizons; upper soil horizons locally affected by surface erosion

Qf1 **Alluvial-fan deposits** (middle Pleistocene) – Poorly sorted silt, sand, and rare pebbles; clasts primarily of granitic, intermediate volcanic, basaltic, and metamorphic rock types; stage III and IV calcium carbonate development where preserved, although soil horizons are commonly affected by surface erosion; correlative with unit Q1p of Kelson (1986); differentiated from unit QTl by larger clast size, less oxidation, poor sorting, absence of abundant manganese oxide staining, and clasts that are less weathered

Qt1rr **Stream terrace deposits of the Red River** (middle Pleistocene) – Poorly sorted silt, sand, pebbles, and boulders; clasts of basalt, quartzite, metamorphic rock types, volcanic rock types; soil development not documented but upper soil horizons probably affected by surface erosion; present only locally along rim of the Red River gorge; inset into Qt0rr gravel deposits and Tertiary volcanic rocks along the Red River gorge

Qt0rr **Old stream terrace deposits flanking the Red River** (early? to middle? Pleistocene) – Poorly sorted sand, pebbles, and cobbles; clasts of basalt, quartzite, and many volcanic and metamorphic rock types; upper part commonly affected by surface erosion; present upstream and downstream of Red River Fish Hatchery and in the confluence area between the Rio Grande and Red River; merges with unit Qt0rg in southernmost part of quadrangle and in Arroyo Hondo quadrangle

QT0rg **Stream gravel deposited by ancestral Rio Grande** (late Tertiary? to middle? Pleistocene) – Poorly sorted sand, pebbles, and cobbles; clasts of basalt, quartzite, slate, schist, other metamorphic rock types, and volcanic rock types; very rare Amalia Tuff clasts; associated with broad, highest terrace west of Rio Grande; upper soil horizons commonly affected by surface erosion; locally mantled by eolian sand

QTl **Lama Formation** (late Tertiary to middle Pleistocene) – Poorly sorted sand, pebbles, and cobbles; clasts of basalt, quartzite, metamorphic rock types, and volcanic rock types; locally high percentage of angular to subangular quartzite pebbles and cobbles; commonly cross-bedded, and stained with black manganese oxide and yellowish-orange iron oxide coatings; oxidized; clasts are typically weathered or grussified; contains distinct discontinuous sandy interbeds; commonly crudely imbricated; imbrication suggests westerly flow direction in area north of Taos Municipal Airport; present along piedmont between Sangre de Cristo Mountains range front and Red River and Rio Grande gorges; underlies Garrapata Ridge and probably much of Cebolla Mesa in southeastern part of quadrangle; fills a paleo-valley on northeastern side of Red River fault zone at elevation of present-day Red River; correlative with unit previously called "Blueberry Hill formation" to the south near Taos and with "Basin Fill deposit" of Kelson (1986); a tephra in the uppermost strata yielded a $^{40}Ar/^{39}Ar$ date of 1.6 Ma (elevation ca. 7660 ft, M. Machette, USGS, personal comm., 2008); also contains a reworked tephra in road cut near Red River Fish Hatchery (elevation ca. 7160 ft) that was probably derived from nearby ca. 5 Ma volcanic units (R. Thompson, personal comm., 2015); thickness unknown

Tsbu **Servilleta Basalt, upper** (Pliocene) − Flows of dark-gray tholeiitic basalt characterized by small olivine and tabular plagioclase phenocrysts, diktytaxitic texture, and local vesicle pipes and segregation veins; forms thin, fluid, widespread pahoehoe basalt flows of the Taos Plateau volcanic field erupted principally from five large shield volcanoes in the central part of the Taos Plateau (Lipman and Mehnert, 1979) but also from several small shields and vents to the northwest of the map area near the Colorado border (Thompson and Machette, 1989; K. Turner, personal comm., 2014); flows commonly form columnar-jointed cliffs where exposed with a maximum thickness of approximately 50 m in the Rio Grande gorge south of the map area approximately 16 km northwest of Taos, NM; regionally correlative with upper Servilleta of Dungan et al., 1984 and Peterson, 1985; separated by sedimentary intervals as much as 70 m thick in the southern part of quadrangle (Leininger, 1982); $^{40}Ar/^{39}Ar$ ages from basalts exposed in the Rio Grande gorge (Cosca et al., 2014) range in age from 4.78 +/- 0.03 Ma for the lowest basalt near the Gorge Bridge, to 3.59 +/- 0.08 Ma for the highest basalt flow at the Gorge Bridge broadly consistent with previous results by Appelt, (1998); in the map area, the base of the upper Servilleta Basalt lava flow section at La Junta Point yielded an $^{40}Ar/^{39}Ar$ age of 3.78 +/- 0.08 Ma (sample 10RG05 - M. Cosca, personal comm., 2014), whereas a lava flow at the base of section south of Cerro Chiflo yielded an $^{40}Ar/^{39}Ar$ age of 3.78 +/- 0.08 Ma (sample RT08GM02 - M. Cosca, personal comm., 2014)

Tc **Chamita Formation, Santa Fe Group** (Pliocene) − In cross sections only. Sedimentary intervals between Servilleta Basalt flow members (Leininger, 1982), as much as 70 m thick in southern part of quadrangle, as exposed in the Rio Grande gorge; typically rounded to subrounded pebble- to cobble-size clasts in a sand to silt matrix; thick sections in the southern part of the map area reflect Proterozoic clast provenance and are dominated by schist, quartzite, and amphibolite with lesser volcanic clasts derived from the Latir volcanic field (Lipman and Reed, 1989); locally, thin interbeds are typically dominated by pebble-size clasts in a fine sand to silt matrix and commonly includes the rock types above in addition to subangular and subrounded volcanic clasts derived locally from adjacent volcanic highlands of the Taos Plateau volcanic field

Tdm **Dacite of Unnamed Cerrito East of Montoso (UCEM)** (Pliocene) − Dark gray, sparsely phyric, low-silica, calc-alkaline dacite (64 wt% $Si0_2$, 6 wt% Na_20+K_20) lava flows erupted from two vent areas east of Cerro Montoso; contains rare skeletal pyroxene phenocrysts and resorbed, subhedral olivine and quartz xenocrysts in a microcrystalline to glassy groundmass; locally includes small volume, aerially restricted andesite flows (McMillan and Dungan, 1988); $^{40}Ar/^{39}Ar$ age determinations of 4.08 +/- 0.04 Ma (sample 11RG42) and 4.6 +/- 0.02 Ma (sample 11RG27) from north and south UCEM areas respectively (M. Cosca, personal comm., 2014); Appelt (1998) reported a similar $^{40}Ar/^{39}Ar$ age determinations of 4.11 +/- 0.13 Ma from the northern part of mapped UCEM deposits; caps west rim of Rio Grande gorge, forming thin veneer, rarely more than single flow thickness on underlying flows of Servilleta Basalt (unit Tsbu) and local interbedded sedimentary deposits (Leininger, 1982; Peterson, 1981); neither relations are shown at the scale of this map due to extensive distribution of landslide deposits (unit Qls) in the southern part of the Rio Grande gorge in map area; scoria and spatter agglutinate common near poorly defined vent areas

Tvr **Volcanic deposits of Red River volcano** (Pliocene) − Dacite lava flow and near vent pyroclastic deposits of moderate relief on the south side of Guadalupe Mountain and in canyon exposures in the middle and upper reaches of the Red River where ; dacite lava flows cap the gorge sequence on both sides of the drainage; ; lava flow exposed on both side of the Red River were fed locally by dikes exposed on both sides of the canyon; McMillan and Dungan (1986) reported chemical compositions for the underlying basaltic andesite (unit Tvhc) to dacite suite ranging from 52-61 wt% SiO_2 and 4.2-7.4 wt% Na_2O+K_2O; medium grey dacite lavas are porphyritic, containing 5-15% phenocrysts of augite and bronzite with common olivine xenocrysts in a fine-grained to glassy groundmass of plagioclase, glass, pyroxenes, and tantanomagnetite (McMillan and Dungan, 1986); dacite lavas are typically thick, up to tens of meters locally, and are characteristically discontinuous and aerially restricted; deposits of the Red River volcano overlie andesitic lava flows of the Hatchery volcano (unit Tvh) and locally deposits of south Guadalupe Mountain (unit Tags); $^{40}Ar/^{39}Ar$ age determination of 4.67 +/- 0.06 Ma (sample RT08GM12 - M. Cosca, personal comm., 2014) was obtained from a sample collected near the northeastern limit of exposed deposits

Tvhc **Volcanic deposits of Hatchery volcano, near vent** (Pliocene) − Near-vent deposits associated with lava flows of map unit Tvh, predominantly cinder, spatter and agglutinate exposed in the Red River drainage approximately 1.25 kilometers northwest of the New Mexico State Fish Hatchery; near-vent spatter, agglutinate, and volcanic bombs are common near hill 7590’ on the south side of the Red River

Tvh **Volcanic deposits of Hatchery volcano** (Pliocene) − Includes a sequence of lava flow, intercalated volcanic breccia, and near vent pyroclastic deposits in canyon exposures in the middle and upper reaches of the Red River drainage and as low relief hills adjacent to the Red River; lava flows include a series of predominantly basaltic andesite and andesite lava flows; McMillan and Dungan (1986) reported chemical compositions for the basaltic andesite to overlying dacite (unit Tvr) ranging from 52-61 wt% SiO_2 and 4.2-7.4 wt% Na_2O+K_2O; dark gray basaltic andesite and andesite lava flows typically contain 5-10% phenocrysts of olivine and plagioclase; olivine phenocrysts can be large (up to 6mm) exhibiting well-developed skeletal overgrowths (McMillan and Dungan, 1986); andesite lava flows with aa flow tops and well exposed basal flow breccias tend to be thin, a few meters to 10 m thick, and are laterally continuous based on exposures in the Red River canyon; deposits of the Hatchery volcano overlie dacite lava flows of Guadalupe Mountain, and locally overly two lava flows of Servilleta Basalt at the base of the Red River gorge near the New Mexico State Fish Hatchery (not differentiated at the map scale); $^{40}Ar/^{39}Ar$ age determination of 4.82 +/- 0.07 Ma (sample 11RG42 - M. Cosca, personal comm., 2014) was obtained from a sample at the base of the section approximately 0.6 km southwest of the New Mexico State Fish Hatchery

Tagn **Dacite of Guadalupe Mountain, north** (Pliocene) − Predominantly trachydacite lava flows (62 wt% SiO_2, 6.3 wt% Na_20+K_20) and associated near-vent pyroclastic deposits; contains sparse, small phenocrysts of plagioclase, hypersthene, and augite in a pilotaxitic glassy groundmass; proximal lava flows, lava dome remnants, and near-vent pyroclastic deposits consisting mostly of spatter and agglutinate of the geographic north peaks of Guadalupe Mountain; spatter and cinder deposits are found locally in association with flank lavas and may represent remobilized central vent deposits or mark the location of satellite vents on the flanks of north Guadalupe Mountain; distinguished from lava flows of south Guadalupe Mountain on the basis of reversed magnetic polarity based on paleomagnetic and aeromagnetic determinations (M. Hudson and V.J.S. Grauch respectively, personal comm., 2014); $^{40}Ar/^{39}Ar$ age determination of 5.04 +/- 0.04 Ma (sample 10RG06 - M. Cosca, personal comm., 2014)

Tags — **Dacite of Guadalupe Mountain, south** (Pliocene) − Predominantly trachydacite lava flows (62 wt% SiO_2, 6.3 wt% $Na_{2}0+K_{2}0$) and associated near-vent pyroclastic deposits; contains sparse, small phenocrysts of plagioclase, hypersthene, and augite in a pilotaxitic glassy groundmass; proximal lava flows, lava dome remnants and near-vent pyroclastic deposits consisting mostly of spatter and agglutinate of the geographic south peaks of Guadalupe Mountain; distinguished from lava flows of north Guadalupe Mountain on the basis of reversed magnetic polarity based on paleomagnetic and aeromagnetic determinations (M. Hudson and V.J.S. Grauch respectively, personal comm., 2014); $^{40}Ar/^{39}Ar$ age determination of 5.00 +/- 0.04 Ma (sample 10RG07 - M. Cosca, personal comm., 2014); stratigraphic position relative to unit Tagn is based on geophysical modeling of aeromagnetic data (B. Drenth, V.J.S. Grauch, personal comm., 2014) and age constraints relative to geomagnetic time scale; Appelt (1998) reported $^{40}Ar/^{39}Ar$ ages of 5.11±0.08 and 5.34±0.06 Ma for groundmass separates from the south side of Guadalupe Mountain

Tag — **Dacite of Guadalupe Mountain, undifferentiated** (Pliocene) − Predominantly trachydacite lava flows (62 wt% SiO_2, 6.3 wt% $Na_{2}0+K_{2}0$); contains sparse, small phenocrysts of plagioclase, hypersthene, and augite in a pilotaxitic glassy groundmass; distal lava flows exposed in the Rio Grande gorge and the Red River gorge (not shown at this map scale) are highly elongate and individual flows are laterally restricted, typically forming overlapping finger-like lobes characterized by radial cooling fractures and concentric brecciated carapaces where exposed in cross section; flows exposed in the Rio Grande gorge range considerably in thickness from a few meters to several tens of meters; lava flow directions exposed in the Rio Grande gorge appear to be predominantly from east to west, suggesting a primary source area at Guadalupe Mountain; dacite lava flows overlie both Cerro Chiflo dome deposits and lower Servilleta Basalt lava flows in the Rio Grande gorge; $^{40}Ar/^{39}Ar$ age determination of 5.27 +/- 0.05 Ma (sample 11RG08 - M. Cosca, personal comm., 2014)

Tao — **Andesite of Cerro de la Olla** (Pliocene) − Dark gray to black, porphyritic olivine andesite (58.5 wt% SiO_2, 6.9 wt% $Na_{2}0+K_{2}0$) lava flows erupted from vents near summit of Cerro de la Olla, one of the largest, petrologically uniform, shield volcanoes of the Taos Plateau volcanic field (Lipman and Mehnert, 1979); contains 2-3% phenocrysts of olivine in a microcrystalline groundmass of plagioclase, olivine, augite, Fe-Ti oxides; the lower slopes of Cerro de la Olla in the northwestern part of the map area are commonly mantled in colluvium and rarely preserve well-developed flow morphology; instead outcrops typically exhibit blocky flow tops and remnants of numerous discontinuous and aerially restricted flow lobes; Appelt (1998) reported $^{40}Ar/^{39}Ar$ ages of 4.97±0.06 Ma for a groundmass separate from the west side of Cerro de la Olla

Tsbl — **Servilleta Basalt, lower** (Pliocene) − Flows of dark-gray tholeiitic basalt characterized by small olivine and tabular plagioclase phenocrysts, diktytaxitic texture, and local vesicle pipes and segregation veins; forms thin, fluid, widespread pahoehoe basalt flows of the Taos Plateau volcanic field erupted principally from five large shield volcanoes in the central part of the Taos Plateau (Lipman and Mehnert, 1979) but also from several small shields and vents to the northwest of the map area near the Colorado border

(Thompson and Machette, 1989; K. Turner, personal comm., 2014); flows commonly form columnar-jointed cliffs where exposed with a maximum thickness of approximately 50 m in the Rio Grande gorge south of the map area approximately 16 km northwest of Taos, NM; regionally correlative with upper Servilleta of Dungan et al., 1984 and Peterson, 1985; separated by sedimentary intervals as much as 70 m thick in the southern part of quadrangle (Leininger, 1982); $^{40}Ar/^{39}Ar$ ages from basalts exposed in the Rio Grande gorge (Cosca et al., 2014) range in age from 4.78 +/- 0.03 Ma for the lowest basalt near the Gorge Bridge, to 3.59 +/- 0.08 Ma for the highest basalt flow at the Gorge Bridge broadly consistent with previous results by Appelt, (1998); in the map area, the base of the lower Servilleta Basalt lava flow section at La Junta Point yielded an $^{40}Ar/^{39}Ar$ age of 5.22 +/- 0.11 Ma (sample RT08GM07 - M. Cosca, personal comm., 2014), 440,000 years older than previously reported ages for the base of the Servilleta Basalt

Tam **Andesite of Cerro Montoso** (Pliocene) − Dark gray to black, porphyritic olivine andesite (57.6 wt% SiO_2, 8 wt% Na_20+K_20) lava flows erupted from vents on Cerro Montoso, one of the largest, petrologically uniform, shield volcanoes of the Taos Plateau volcanic field (Lipman and Mehnert, 1979); contains 2-3% phenocrysts of olivine in a microcrystalline groundmass of plagioclase, olivine, augite, Fe-Ti oxides; the lower slopes of Cerro Montoso in the western side of the map area are often mantled in colluvium and rarely preserve well-developed flow morphology; instead outcrops typically exhibit blocky flow tops and remnants of numerous discontinuous and aerially restricted flow lobes; Appelt (1998) reported an $^{40}Ar/^{39}Ar$ age of 5.88±0.18 Ma for a groundmass separate from the west side of Cerro Montoso

Tvc **Trachyandesite of Cerro Chiflo** (Miocene) − Eroded remnants of large lava dome of porphyritic trachyandesite (63 wt% SiO_2, 7.7 wt% Na_2O+K_2O; rock designation based on IUGS classification (Le Bas and others, 1986); formerly described by Lipman and Mehnert (1979) as quartz latite; forms prominent cliff outcrops along Rio Grande gorge in northern part of map area; light brown to gray, weakly to strongly flow laminated, with phenocrysts of plagioclase, hornblende, and sparse biotite in a devitrified groundmass; xenoliths of Proterozoic schist, gneiss, and granite are common; flow breccias preserved around margins of dome and ramp structures common throughout the exposed interior; Appelt (1998) reported $^{40}Ar/^{39}Ar$ ages of 5.31±0.31 and 5.32±0.08 Ma for groundmass separates from the west and east sides of the dome, respectively; more recent , preliminary $^{40}Ar/^{39}Ar$ total fusion age determinations of 10.65 Ma and 9.86 Ma on biotite and hornblende separates respectively (sample 11RG43 - M. Cosca, personal comm., 2014) are more consistent with previously determined Miocene potassium-argon ages reported by Lipman and Mehnert (1979)

Tsf **Santa Fe Group, undivided** (Miocene) − In cross section only. Basin-fill clay, silt, sand, pebbles, cobbles, and boulders of the Rio Grande rift; principally of the Tesuque Formation; thickness unknown

Tvb **Volcanic deposits of Brushy Mountain** (Oligocene) − Volcanic rocks and deposits consisting primarily of andesite to dacite lava flows and flow breccias and rhyolite block-and-ash flows and ash-flow tuff with volumetrically minor air-fall deposits (Thompson et al., 1986; Thompson and Schilling, 1988). Light tan, poorly welded, lithic-rich, rhyolite ash-flow tuff forms base of section near low saddle of Brushy Mountain; lower rhyolite contains phenocrysts of plagioclase and altered biotite, light brown altered pumice and angular to subangular vitrophyric inclusions (<0.5 cm to several cm) containing plagioclase phenocrysts and reddish-brown dacite inclusions (2 cm to several cm); locally overlain by thin outflow deposits of Amalia Tuff (unit Tat); post-Amalia Tuff deposits include light-grey to white rhyolite dome deposits including locally, block-and-ash flows, ash-flow tuffs, and air-fall deposits; all deposits are mineralogically similar containing sanidine, quartz, and minor biotite phenocrysts in a devitrified glass matrix; exposed in quarry on south side of Brushy Mountain and north side of Cerro Montoso; thin (< 2-3 m) andesite lava flows locally overlie rhyolite dome deposits and consist of medium- to dark-brown, porphyritic flows and flow remnants containing olivine, clinopyroxene, and plagioclase phenocrysts, plagioclase glomerocrysts, and minor orthopyroxene microphenocrysts in a fine- to medium-grained trachytic groundmass composed predominantly of plagioclase, clinopyroxene, and Fe-Ti oxides; the upper part of the section consists of light- to dark-gray, aphyric to porphyritic, dacite lava flows and flow breccias containing variable amounts of hornblende, plagioclase, clinopyroxene, Fe-Ti oxides, and minor orthopyroxene, sanidine, sphene and zircon in a fine-grained to microcrystalline groundmass; lava flows are locally variable in thickness, discontinuous and commonly delineated on the basis of blocky rubble deposits and float; in the Rio Grande gorge, deposits are dominantly andesite to dacite breccias and reworked pyroclastic deposits overlying biotite and horblende bearing dacite lava flows; Zimmerer and McIntosh (2012) reported $^{40}Ar/^{39}Ar$ age determination on sanidine from a basal rhyolite of the Brushy Mountain section of 25.17 +/- 0.04 Ma and 22.69 +/- 0.08 from groundmass concentrates from an andesite lava flow in the upper part of the section

Tvt **Volcanic deposits of Timber Mountain** (Oligocene) − Volcanic rocks and deposits consisting primarily of andesite to dacite lava flows and flow breccias and lesser rhyolite flows and ash-flow tuff (Thompson et al., 1986; Thompson and Schilling, 1988); light-brown, lithic-poor, densely welded, rhyolite ash-flow tuff forms base of section and contains moderately to highly flattened pumices, phenocrysts of plagioclase, sanidine, quartz, and biotite with subordinate amounts of Fe-Ti oxides, clinopyroxene, and orthopyroxene in a glassy to partially devitrified matrix; rhyolite ash-flow tuff is overlain by a lower sequence of moderately porphyritic lava flows and pyroclastic deposits containing variable amounts of plagioclase, clinopyroxene, Fe-Ti oxides, hornblende plus or minus biotite, and sanidine xenocrysts; locally contains abundant micropillows of basaltic lava and dacite xenoliths as much as 10 cm in diameter; lower dacite sequence is separated from an upper dacite sequence locally by medium- to dark-brown, porphyritic lava flow remnants containing olivine, clinopyroxene, and plagioclase phenocrysts, plagioclase glomerocryts, and minor orthopyroxene microphenocrysts in a fine- to medium-grained trachytic groundmass composed of plagioclase, clinopyroxene, and Fe-Ti oxides; upper dacite sequence contains medium- to light-gray porphyritic, glassy lava flows and lava dome remnants containing phenocrysts of hornblende, biotite, plagioclase, clinopyroxene, and Fe-Ti oxides in variable proportion; a whole rock $^{40}Ar/^{39}Ar$ age of 24.22 +/- 0.12 Ma (M. Cosca, personal comm., 2014) was obtained from a basal dacite vitrophyre southwest of the map area

Tat **Amalia Tuff** (Oligocene) − Light gray to light brown moderately welded porphyritic, peralkaline, rhyolite ash-flow tuff erupted from the Questa caldera approximately 15 km to the east (Lipman and Reed, 1989); consists primarily of quartz and sanidine phenocrysts in a devitrified matrix; Fe-Ti oxides, titanite, and alkali amphibole phenocrysts are minor; forms low erosional hills of outflow in the northwest part of the map area; Zimmerer and McIntosh (2012) reported a mean age of 25.39 +/- 0.04 Ma based on thirteen $^{40}Ar/^{39}Ar$ laser fusion analyses for Amalia Tuff

References:

Appelt, R.M., 1998, $^{40}Ar/^{39}Ar$ Geochronology and volcanic evolution of the Taos Plateau volcanic field, northern New Mexico and southern Colorado: MS thesis, New Mexico Institute of Mining and Technology, Socorro, NM, 58 p.

Cosca, M., Thompson, R., and Turner, K., 2014, High precision $^{40}Ar/^{39}Ar$ geochronology of Servilleta Basalts of the Rio Grande gorge, New Mexico: Abstract V51A-4728 presented at 2014 Fall Meeting, AGU, San Francisco, Calif., 15-19 Dec.

Dungan, M.A., Muehlberger, W.R., Leininger, L., Peterson, C., McMillan, N.J., Gunn, G., Lindstrum, M., and Haskin, L., 1984, Volcanic and sedimentary stratigraphy of the Rio Grande gorge and the late Cenozoic geologic evolution of the San Luis Valley: New Mexico Geological Society, 35th Field Conference, Guidebook, p. 157-170.

Kelson, K.I., 1986, Long-term tributary adjustments to base-level lowering in northern Rio Grande rift, New Mexico [M.S. thesis]: Albuquerque, University of New Mexico, 210 p.

Lambert, P.W., 1966, Notes on the late Cenozoic geology of the Taos-Questa area, New Mexico: New Mexico Geological Society, 17th Field Conference, Guidebook, p. 43-50.

Le Bas, M.J., Le Maitre, R.W., Streckeisen, A., and Zanettin, B., 1986, A chemical classification of volcanic rocks based on the total alkali-silica diagram: Journal of Petrology, v. 27, p. 745-750

Leininger, R.L., 1982, Cenozoic evolution of the southernmost Taos Plateau, New Mexico: M.S. thesis, University of Texas at Austin, Austin, Texas, 110 p.

Lipman, P.W., and Mehnert, H.H., 1979, The Taos Plateau volcanic field, northern Rio Grande rift, New Mexico, in Riecker, R.E., ed., Rio Grande rift – Tectonics and magmatism: Washington, D.C., American Geophysical Union, p. 289-311.

Lipman, P.W., Mehnert, H.H., and Naeser, C.W., 1986, Evolution of the Latir volcanic field, northern New Mexico, and its relation to the Rio Grande rift, as indicated by potassium-argon and fission track dating: Journal of Geophysical Research, v. 91, p. 6329-6345.

Lipman, P.W., and Reed, J.C., Jr., 1989, Geologic map of the Latir volcanic field and adjacent areas, northern New Mexico: U.S. Geological Survey Miscellaneous Investigations Series Map I-1907, Scale 1:48000.

McMillan, N.J., and Dungan, M.A., 1986, Magma mixing as a petrogenetic process in the development of the Taos Plateau volcanic field, northern New Mexico: Journal of Geophysical Research, B, Solid Earth and Planets, v. 91, no. 6, p. 6029-6045.

Miggins, D.P., Thompson, R.A., Pillmore, C.L., Snee, L.W., and Stern, C.R., 2002, Extension and uplift of the northern Rio Grande rift: evidence from $^{40}Ar/^{39}Ar$ geochronology from the Sangre de Cristo mountains, south-central Colorado and northern New Mexico: Geological Society of America Special Paper 362, p. 47-64.

Pazzaglia, F.J., 1989, Tectonic and climatic infl uences on the evolution of Quaternary depositional landforms along a segmented range-front fault, Sangre de Cristo Mountains, north-central New Mexico [M.S. thesis]: Albuquerque, University of New Mexico, 246 p.

Pazzaglia, F.J., and Wells, S.G., 1990, Quaternary stratigraphy and geomorphology of the northern Rio Grande Rift, in Bauer, P.W., Lucas, S.G., Mawer, C.K., and McIntosh, W.C., eds., Southern Sangre de Cristo Mountains: New Mexico Geological Society Guidebook, 41st Field Conference, p. 423–430.

Peterson, C.M., 1981, Late Cenozoic stratigraphy and structure of the Taos Plateau, northern New Mexico: M.S. thesis, University of Texas at Austin, Austin, Texas, 57 p.

Ruleman, C., Shroba, R., and Thompson, R., 2007, Chapter C – Field trip day 3; Quaternary Geology of Sunshine Valley and Associated Neotectonics along the Latir Peaks Section of the Sangre de Cristo fault zone: in Machette, M.N., Coates, M.M. andJohnson, J.L. (eds.) 2007 Rocky Mountain Section Friends of the Pleistocene Field Trip—Quaternary Geology of the San Luis Basin of Colorado and New Mexico, September 7-9, 2007, 24 p.

Thompson, R.A., Dungan, M.A., and Lipman, P.W., 1986, Multiple differentiation processes in early-rift calc-alkaline volcanics, northern Rio Grande rift, New Mexico: Journal of Geophysical Research, v. 91, p. 6046-6058.

Thompson, R.A., and Schilling, S.P., 1988, Generalized geologic maps of the Brushy Mountain and Timber Mountain areas, Taos County, New Mexico: U.S. Geological Survey Open-file report 88-561, 1 plate.

Thompson, R.A., and Machette, M.N., 1989, Geologic map of the San Luis Hills area, Conejos and Costilla counties, Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I-1906, scale 1:50,000.

Zimmerer, M.J., and McIntosh, W.C., 2012, The geochronology of volcanic and plutonic rocks at the Questa caldera: Constraints on the origin of caldera-related silicic magmas: Geological Society of America Bulletin, v. 124, no. 7/8, p. 1394-1408.