GEOLOGY OF THE QUESTA 7.5-MINUTE QUADRANGLE, TAOS COUNTY, NEW MEXICO

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New Mexico Bureau of Geology and Mineral Resources
Open-file Geologic Map OF-GM 247

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.

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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

af — **Artificial fill and disturbed land** (modern-historic) − Excavations and areas of artificially deposited fill and debris; delineated where aerially extensive; consists predominantly of mine waste-rock piles at the molybdenum mine located east of Questa

ds — **Mine waste rock and related features** (modern-historic) − Angular blocks and finer deposits, mainly from Tertiary plutonic rocks; predominantly located in and adjacent to the inactive, open pit molybdenum mine located 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; weak to no soil development; up to 7 m estimated thickness

Qt — **Talus** (Holocene) − Angular rock fragments as much as 1 m in diameter forming talus cones, talus aprons and scree slopes; locally well sorted; grades into colluvium as sand and silt content increases (Lipman and Read, 1989)

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; prevalent along bases of mountain-front facets

Qls **Landslides** (Pleistocene to Holocene) − Lobate accumulations of poorly sorted soil and rock debris on slopes marked by hummocky topography and downslope-facing scarps. Derived from bedrock and glacial deposits, and includes small earth flow, block-slump, and block-slide deposits (Lipman and Read, 1989)

Qfy **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; includes unit Qt8 of Kelson (1986)

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

Qt8rr **Stream terrace deposits of the Red River** (middle to late Holocene) − Poorly sorted silt, sand, pebbles, cobbles, and boulders; clasts primarily of quartzite, schist, granite, and volcanic rock types; deposits have negligible soil development; typically present as thin (< 5 m) alluvial deposit beneath high-stage floodplain or adjacent to active alluvial channels; equivalent to Qt8 of Pazzaglia (1989) and Kelson (1986)

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; equivalent to Qt7 of Pazzaglia (1989) and Kelson (1986)

Qt6rr **Stream terrace deposits of the Red River** (latest Pleistocene) − Poorly sorted silt, sand, pebbles, cobbles, and boulders; clasts primarily of quartzite, schist, granite, and volcanic rock types; associated soils have stage I to II calcium carbonate development; typically present as thin (< 5 m) alluvial deposit on strath surface cut on volcanic bedrock or unit QTl (Lama Formation); associated with the Q6 surface of Kelson (1986)

Qmt **Moraine and till** (Pleistocene) − Terminal and lateral moraines, and thick valley-bottom till; poorly sorted and generally unstratified clay, silt, and sand containing erratic boulders; characterized by hummocky or ridged topography; some till is mapped with colluvium (Lipman and Read, 1989)

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 unit QTl (Lama Formation); associated with the Q5 surface of Kelson (1986)

Qt4rr **Stream terrace deposits of the Red River** (middle to late 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, argillic Bt soil horizons and 10YR to 7.5YR hues in Bt horizons; typically present as thin (< 5 m) alluvial deposit on strath surface cut on volcanic bedrock or unit QTl (Lama Formation); associated with the Q4 surface of Kelson (1986)

Qtu **Stream terrace deposits, undivided** (middle to late Pleistocene) − Poorly sorted silt, sand, pebbles, 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 unit QTl (Lama Formation)

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)

Qt2rr **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 to IV 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 Qt2 of Pazzaglia (1989) and Kelson (1986)

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

Qfo **Alluvial fan deposits, undivided** (middle to late Pleistocene) − Probably correlative with alluvial units Qt2 through Qt5; 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

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

Qf1 **Alluvial fan deposits** (middle Pleistocene) − Poorly sorted silt, sand, and rare pebbles; clasts primarily of granitic, intermediate volcanic, basalt, 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); ash probably within Qf1 deposits at locality on Ranchos de Taos quadrangle near Stakeout Road dated at 1.27+/-10.02 Ma (^{40}Ar-^{39}Ar method, W. McIntosh, personal commun., 1996); deposit is more than 5 m thick in northeastern part of quadrangle, and is thinner from northeast to southwest; differentiated from unit QTl (Lama Formation) by larger clast size (Kelson, 1986), less oxidation, poor sorting, absence of abundant manganese oxide staining, and clasts that are less weathered

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; underlies mesa between villages of Questa and Cerro; correlative with unit previously informally 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) − In cross section only. 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); west of 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); 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

Tu **Tertiary rocks along the Sangre de Cristo fault, undivided** (Miocene and Oligocene) − Rocks related to the Questa magmatic system that are unmapped along the Sangre de

Cristo fault zone; these units were mapped as Quaternary deposits by Lipman and Read (1989), but are herein mapped as unknown bedrock that is generally covered by surficial deposits that are too thin to delineate as map units

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_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 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) − In map area, deposits are depicted only in cross section; inferred to be correlative with mapped deposits in the Guadalupe Mountain quadrangle immediately west of map area; predominantly trachydacite lava flows (62 wt% SiO_2, 6.3 wt% Na_20+K_20); 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 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)

Tsbl **Servilleta Basalt, lower** (Pliocene) − In cross section only. 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); west of 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

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

Tgy **Lucero Peak Pluton** (Miocene) − White to pale pink, medium to coarse grained equigranular granite to quartz monzonite (Lipman and Read, 1989)

Tqi **Latite and quartz latite** (Miocene and Oligocene) − Light tan to gray latite and quartz latite, often stained rust brown, with 15-30% phenocrysts of sanidine, pyroxene and/or hornblende, sparse quartz, and altered cubes of pyrite; plagioclase phenocrysts to several centimeters in length are present; occurs as dikes up to 20 m wide and elongate intrusive masses north of the D.H. Lawrence Ranch (Lipman and Read, 1989)

Trp **Porphyritic rhyolite** (Miocene and Oligocene) − White to light tan to light gray porphyritic rhyolite typically containing 5-20% phenocrysts of quartz, sanidine, and sparse plagioclase and biotite; occurs as dikes 1-10 m wide and local irregular and shallow intrusions (Lipman and Read, 1989); generally only observed as float

Tri **Aphanitic rhyolite** (Miocene and Oligocene) − Aphanitic to sparsely porphyritic rhyolite, otherwise similar to Trp (Lipman and Read, 1989)

Trpp **Peralkaline rhyolite** (Miocene and Oligocene) − Dikes and irregular intrusions of alkali rhyolite and granite porphyry (76-77% SiO_2) chemically similar to the Amalia Tuff (Tat) and associated caldera-related rhyolitic lava flows; contains 1-25% phenocrysts of quartz and sodic alkali feldspar; locally contains small phenocrysts of arfvedsonite and acmite, especially in the caldera-margin ring dike along Jaracito Canyon and in the Virgin Canyon-Virsylvia Peak area, where the peralkaline rhyolite forms marginal facies of metaluminous biotite-bearing intrusions of granite porphyry within the caldera; dated by K-Ar and F-T methods at about 26 Ma (Lipman and Read, 1989)

Tapi **Porphyritic andesite and dacite** (Miocene and Oligocene) − Fine-grained, dark gray, aphanitic and porphyritic andesite and minor basalt; where present, phenocrysts include hornblende, plagioclase, biotite, and little or no quartz or sanidine (Lipman and Read, 1989)

Tqk **Potassium feldspar quartz latite** (Miocene and Oligocene) − Coarsely porphyritic, light-gray quartz latite containing potassium feldspar phenocrysts as long as 5 cm (Lipman and Read, 1989)

Tvs **Volcanic sedimentary rocks** (Oligocene) − Relatively well-bedded and well-sorted volcanic sedimentary rocks of andesitic to rhyolitic composition at many levels in the volcanic sequence; dominantly fluviatile and deltaic deposits; the volcanic sedimentary rocks are locally tuffaceous and interfinger and intergrade in places with the tuff of Tetilla Peak (Tt); also included are local air-fall and reworked silicic tuff underlying the Amalia Tuff (Trt); exposed thickness nowhere more than about 50 m (Lipman and Read, 1989)

Tg **Biotite granite** (Oligocene) − Granitic roof phase of the Rio Hondo pluton emplaced in the Questa caldera at about 26 Ma, during volcanism and caldera formation; medium-grained and equigranular, with sparse aplite and no hornblende (Lipman and Read, 1989)

Tgp **Granite porphyry** (Oligocene) − Fine-grained porphyritic biotite granite and aplite, texturally transitional between mapped bodies of granite (Tg) and intrusive porphyritic rhyolite (Trp) or rhyolite (Tri), especially in the Rito del Medio and Canada Pinabete areas (Lipman and Read, 1989)

Tgd **Rio Hondo Pluton** (Oligocene) − White to pale, grayish-orange, medium- to fine-grained, massive to locally foliated granodiorite; white to pale orange, aphanitic-porphyritic border facies has quartz phenocrysts and local breccia; has potassium feldspar phenocrysts up to 4 cm in size; generally forms rounded outcrops with abundant grus (Lipman and Read, 1989)

Tat **Amalia Tuff** (Oligocene) − Light gray to light brown, moderately welded, porphyritic, peralkaline, rhyolite ash-flow tuff; consists primarily of quartz and sanidine phenocrysts in a devitrified matrix; Fe-Ti oxides, sphene, and alkali amphibole phenocrysts are minor;

Miggins et al. (2002) reported a $^{40}Ar/^{39}Ar$ sanidine age of approximately 25.1 Ma; erupted from the Questa caldera (Lipman and Reed, 1989)

Tatl **Lithic-rich lower facies of Amalia Tuff** (Oligocene) − Nonwelded to partly welded tuff up to 30 m thick, containing as much as 5% fragments of andesitic volcanic rocks; sparse fragments of Proterozoic rocks present locally; generally grades upward into main unit; locally difficult to distinguish from older tuff of Tetilla Peak (Tt) (Lipman and Reed, 1989)

Ta **Andesitic lava flows** (Oligocene) − Purplish-gray to gray, aphanitic to porphyritic andesite lava flows and flow breccias, with minor interbedded volcaniclastic sediments; phenocrysts include plagioclase and hornblende (Lipman and Read, 1989)

Tq **Lava flows and domes** (Oligocene) − Massive quartz latite, locally flow layered; commonly gray to greenish gray, especially where propylitically altered in interiors of thick flows; tops of less altered flows are light red-brown or light gray; intrusive quartz latite (Tqi) locally is difficult to distinguish from flow rocks; maximum thickness is at Latir Mesa, where sections through seemingly single flows or domes exceed 500 m (Lipman and Read, 1989)

Tt **Tuff of Tetilla Peak** (Oligocene) − Quartz-rich, light-colored, weakly welded, rhyolitic ash-flow tuff containing abundant small volcanic fragments; contains 10-30% phenocrysts of quartz, sanidine, plagioclase and sparse chloritized biotite; lithic fragments mostly andesite and quartz-bearing rhyolite (Lipman and Read, 1989)

Trc **Rhyolite of Cordova Creek** (Oligocene) − Light-tan to light-gray rhyolitic lava flows and domes (74-77% SiO_2) containing about 5% phenocrysts of quartz, alkali feldspar, plagioclase, and biotite; commonly massive and devitrified; locally flow laminated; large domes centered at Cordova Creek, Van Diest Peak, and Italian Creek also appear to be sources for main accumulations of tuff of Tetilla Peak; as thick as 250 m at head of Cordova Creek (Lipman and Read, 1989)

Tps **Prevolcanic sedimentary rocks** (Lower Oligocene or Eocene) − Discontinuous lenses of weakly indurated shale, sandstone, and conglomerate derived from Proterozoic sources; commonly expressed mainly by reddish-brown silty soil; cobbles of green quartzite are locally distinctive; outcrops rare, except where baked near granitic intrusion along the Red River; indurated Tertiary sedimentary rocks, which have been correlated with Permian and Pennsylvanian Sangre de Cristo Formation (McKinlay, 1956; Clark and Read, 1972), occur only within areas of Tertiary thermal metamorphism and lack limestone interbeds characteristic of the Sangre de Cristo in adjacent areas; probably correlative with the Vallejo Formation of Upson (1941) in the Sangre de Cristo Mountains in southern Colorado, and with the Blanco Basin Formation and Telluride Conglomerate in the San Juan Mountains; thickness 0-100 m (Lipman and Read, 1989)

PROTEROZOIC

Zd **Diabase dikes** (Neoroterozoic? or early Paleozoic?) − Nonfoliated, dark gray-green, medium- to fine-grained rocks with well preserved ophitic texture; 10-20 cm thick with chilled margins (Lipman and Read, 1989)

Xq **Quartzite** (Paleoproterozoic) − White to gray, massive, vitreous quartzite with crossbeds defined by heavy mineral concentrations; pervasively fractured into decimeter-scale, angular lozenges by joints, irregular fractures, and bedding (Lipman and Read, 1989)

Xms **Biotite muscovite schist and gneiss** (Paleoproterozoic) − Medium- to coarse-grained, thinly layered to massive, lustrous, quartz-mica schist and gneiss; commonly contains sillimanite; locally contains garnet, andalusite, and cordierite (Lipman and Read, 1989)

Xfg **Felsic gneiss** (Paleoproterozoic) − Pale gray to orange-brown, micaceous, weakly to moderately foliated, quartzofeldspathic gneiss locally grading to micaceous quartzite; commonly interlayered with amphibolite and amphibole gneiss (Lipman and Read, 1989)

Xcg **Metaconglomerate** (Paleoproterozoic) − Composed of closely packed 0.5-4-cm angular to subrounded white, blue-gray, and red-brown quartz pebbles in a fine-grained arkosic matrix; interlayered with muscovitic felsic gneiss south of Lama Canyon (Lipman and Read, 1989)

Xqc **Quartz monzonite of Columbine Creek** (Paleoproterozoic) − White to gray to pale tan, moderately to strongly foliated quartz monzonite; recrystallized to sugary textured, non-foliated rock near Tertiary plutons; age is 1730 Ma (Lipman and Reed, 1989)

Xa **Amphibolite** (Paleoproterozoic) − Thinly layered to massive, fine- to coarse-grained, medium green to dark green to black amphibolite and amphibole gneiss; locally contains calc-silicate gneiss, biotite-hornblende gneiss, felsic gneiss, and muscovite biotite schist (Lipman and Read, 1989)

Xmi **Mafic and ultramafic rocks** (Paleoproterozoic) − Medium- to coarse-grained dark-green to greenish-gray weakly foliated gabbro and serpentinized ultramafic rocks; gabbro consists of equant clots of hornblende in a matrix of calcic plagioclase, epidote, and sparse quartz; in smaller bodies the gabbro is medium to fine grained, distinctly foliated, and displays chilled margins; original ophitic or intergranular textures are locally preserved and a few bodies display relict cumulus layering; ultramafic rocks are similar to gabbro, except that quartz is absent and plagioclase sparse; mapped only where intrusive into supracrustal rocks; similar rocks are widespread as inclusions in plutonic rocks where they are mapped as amphibolite (Xa); age of most bodies undetermined, but zircon from gabbro sill west of Gold Hill yielded an upper-intercept concordia date of 1741 Ma, interpreted as the emplacement age (Lipman and Read, 1989)

Xvf **Felsic metavolcanic rocks** (Paleoproterozoic) − Fine-grained, light gray, greenish-gray, or pink, massive to strongly foliated, felsic, blastoporphyritic gneiss containing conspicuous 2-5-mm ovoid grains of bluish-gray quartz and 1- to 5-mm laths of white feldspar; groundmass consists of a microcrystalline mosaic of quartz, plagioclase, K-feldspar, epidote, and scattered flakes of biotite; feldspar porphyroblasts include both plagioclase (oligoclase) and grid-twinned microcline with irregular blotches of albite; composition is similar to rhyolite or rhyodacite; widespread layering and local graded bedding show that a large part of the unit is derived from tuffs or volcaniclastic rocks; zircon from volcaniclastic rock northeast of Gold Hill yielded an upper-intercept concordia age of 1,765 Ma (Lipman and Read, 1989)

Xu **Proterozoic, undivided** (Paleoproterozoic) − Undivided Proterozoic crystalline rocks shown in cross section only

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