APPENDIX 1

Geologic unit descriptions for Plates 1 and 2

Description of Map Units for Geologic Map and Cross Sections (Plates 1 & 2) of the Southern Taos Valley Study Area

by Paul W. Bauer, Keith I. Kelson, and Scott B. Aby

January, 2016

Cenozoic Deposits and Rocks

af — **Artificial fill and disturbed land** (modern-historic) – Excavations and areas of human-deposited fill and debris; shown only where aerially extensive

Qal — **Alluvium** (latest Pleistocene and Holocene) – Generally brownish and/or reddish, poorly to moderately sorted, angular to rounded, thinly to thickly bedded, loose silt and silty sand with subordinate coarse lenses and thin to medium beds of mostly locally derived clasts; mapped in active channels, floodplains, low (young) alluvial terraces, tributary-mouth fans, and some valley-slope colluvial deposits; weak to no soil development; piece of charcoal from within Qal yielded conventional ^{14}C ages ranging from about 3275 to 1800 yrs before present; up to 7 m estimated thickness

Qe — **Eolian deposits** (late Pleistocene to Holocene) – Light-colored, well-sorted, fine to medium sand and silt deposits that are recognized as laterally extensive, low-relief, sparsely vegetated, mostly inactive, sand dunes and sand sheets that overlie Servilleta Basalt on the Taos Plateau; rare gravel lag; weak to moderate soil development; northeast-trending longitudinal dune-crest orientations; predominant wind direction from southwest; up to several meters thick

Qc — **Colluvium** (middle Pleistocene to Holocene) – Mostly locally derived, light- to dark-brown, orange, and rarely reddish, poorly to moderately sorted, angular to well-rounded, silty to sandy conglomerate/breccia with clasts locally to >1m; mapped on hill slopes and valley margins only where it obscures underlying relations; estimated at generally less than 5 m thick

Qls — **Landslides in Rio Grande gorge and tributaries** (late Pleistocene to Holocene) – Poorly sorted rock debris and sand to boulder debris transported downslope; occurs on slopes marked by hummocky topography and downslope-facing scarps; includes small earth flow, block-slump, and block-slide deposits; includes large rotational Toreva slide blocks within the Rio Grande and Rio Pueblo de Taos gorges, which include large, rotated and detached blocks of intact Servilleta Basalt; south of the Rio Grande, landslide deposits do not form well-defined lobes, as they do to the north, and may be partly colluvial; the southern deposits are poorly exposed except in road cuts along the highway just north of Rinconada where the deposits are arranged in thick, apparently tabular bodies with a range of compositions

Qac/Tp — **Alluvial and colluvial deposits** (Holocene to Pleistocene) – Poorly exposed gravel and sand composed of Tertiary volcanic clasts and/or granitic clasts and gruss; overlies Tpl and Tpt-Ttc in complexly faulted area in Miranda Canyon; approximately 5-10(?) m thick

Qfy Qty — **Young alluvial-fan and stream terrace deposits** (latest Pleistocene to Holocene) – Poorly sorted deposits of silt, sand, pebbles, cobbles and boulders; deposits are typically clast-supported and poorly bedded; pebble and cobble clasts are typically imbricated; terrace deposits unconformably overlie the local bedrock; clasts are primarily sedimentary rocks, quartzite, slate, schist, metavolcanic, granitic rocks, and Tertiary granitic and volcanic rocks; uppermost sediments are commonly silty sand, probably overbank deposits; weak to moderate pedogenic development, including A, Bw, Bwk and Bk soil horizons and stage I to II calcium carbonate development; map unit Qty is typically on valley floors of large to medium drainages, whereas Qfy exists as young mountain-front fans and valley fills in small tributaries; thickness up to 5 m

Qt6rp **Stream terrace deposits of the Rio Pueblo de Taos and tributaries** (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; associated with the Q6 surface of Kelson (1986)

Qf4 Qt4rp **Alluvial-fan and stream terrace deposits of the Rio Pueblo de Taos and tributaries** (middle? to late Pleistocene) – Poorly sorted silt, sand, pebbles, and boulders; associated soils have stage III calcium carbonate development, argillic Bt soil horizons and 10YR to 7.5YR hues in Bt horizons; clasts primarily of granitic and metamorphic rocks north of Rio Pueblo de Taos, and granitic, metamorphic, and sedimentary rock types south of Rio Pueblo de Taos; clasts also include basaltic rock types along Arroyo Seco and along Rio Pueblo de Taos downstream of Los Cordovas; modified from Kelson (1986)

Qf3 Qt3rp **Alluvial-fan and stream terrace deposits of the Rio Pueblo de Taos and tributaries** (middle to late Pleistocene) – Poorly sorted silt, sand, pebbles, and boulders; stage II to III calcium carbonate development; clasts primarily of quartzite, slate, and schist; granitic clasts also exist east of Arroyo del Alamo

Qf2 Qt2rp **Alluvial-fan and stream terrace deposits of the Rio Pueblo de Taos and tributaries** (middle? Pleistocene) – Poorly sorted silt, sand, pebbles, and boulders; clasts primarily of granitic and metamorphic rocks north of Rio Pueblo de Taos, and granitic, metamorphic and sedimentary rocks south of Rio Pueblo de Taos; 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 may be affected by surface erosion; modified from Kelson (1986); finer grained to the north, away from the Picuris Mountains range front; grouped into unit Qfo northeast of the Rio Grande del Rancho

Qt2rg **Stream terrace deposits of the Rio Grande** (middle? Pleistocene) – Poorly sorted silt, sand, pebbles, and boulders; clasts primarily of granitic, metamorphic, intermediate volcanic, basalt, and sedimentary rocks; locally may contain clasts of Tertiary Amalia Tuff; 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 may be affected by surface erosion; may be mantled locally by unit Qe; modified from Kelson (1986); estimated thickness 1 to 10 m

Qf1 Qt1rp **Alluvial-fan and stream terrace deposits of the Rio Pueblo de Taos and tributaries** (middle Pleistocene) – Poorly sorted silt, sand, pebbles, and boulders; clasts primarily of quartzite, slate, and schist; granitic clasts also present east of Arroyo del Alamo; finer grained to the north, away from the Picuris Mountains range front; stage III to IV calcium carbonate development, although soil horizons are commonly affected by surface erosion; Qf1 is differentiated from QT_L by larger clast size (Kelson, 1986), less oxidation, poor sorting, absence of abundant manganese oxide staining, and clasts that are less weathered; ash probably within Qf1 deposits at locality near Stakeout Road dated at 1.27 ± 0.02 Ma (^{40}Ar-^{39}Ar method, W. McIntosh, personal communication, 1996); where exposed to the south, thickness is up to 12 m

Qfu **Alluvial fan deposits, undivided** (middle to late Pleistocene) – Poorly sorted silt, sand, pebbles, and cobbles; mapped along majority of Sangre de Cristo range front, but not correlated to other fan units because of lack of well-defined age control, clear stratigraphic position, or distinct lithologic characteristics; probably correlative with alluvial fan deposits Qf1 through Qf6; shown on map as Qfu/ QT_L where a thin layer of Qfu overlies QT_L

Qfo Qto **Alluvial fan and terrace deposits, undivided** (middle to late Pleistocene) – Poorly sorted deposits of silt, sand, and pebbles; deposits are typically matrix-supported and poorly bedded; clasts are primarily Paleozoic sedimentary rocks and Proterozoic granitic and metamorphic rock types; on Pilar Mesa, deposit is dominated by slate pebbles and cobbles; between Arroyo del Alamo and Arroyo Hondo, deposit commonly is gravel remnants preserved on interfluves; moderate pedogenic development, including A, Bt, Btk and Bk soil horizons and stage III and IV calcium carbonate development; upper soil horizons are commonly affected by surface erosion; map unit Qto typically occurs as isolated remnants on ridge crests, and is probably correlative with units Qt1 through Qt4, whereas Qfo exists as mountain-front fans and probably overlaps with units Qf2 through Qf4, but not assigned to other fan units because of lack of well-defined age control, clear stratigraphic position, and distinct lithologic characteristics; thickness up to 3 m

Tsb **Servilleta Basalt** (Pliocene) – Tsb can locally be subdivided into lower Servilleta Basalt (Tsbl), middle Servilleta Basalt (Tsbm), and upper Servilleta Basalt (Tsbu) (Dungan et al., 1984); 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 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 communication, 2014); additional buried vents west of the Rio Grande are likely; flows typically form columnar-jointed cliffs where exposed, with a maximum thickness of approximately 50 m in the Rio Grande gorge approximately 16 km northwest of Taos; separated by sedimentary intervals as much as 70 m thick in the southern part of the map area (Leininger, 1982); 40Ar/39Ar 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); the base of the upper Servilleta Basalt lava flow section at La Junta Point yielded an 40Ar/39Ar age of 3.78 +/- 0.08 Ma (sample 10RG05 - M. Cosca, personal communication, 2014), whereas a lava flow at the base of the section south of Cerro Chiflo yielded an 40Ar/39Ar age of 3.78 +/- 0.08 Ma (sample RT08GM02 - M. Cosca, personal communication, 2014)

QT_L **Lama formation** (Pliocene to early? Pleistocene) – Poorly sorted sand, pebbles, and cobbles; clasts of basalt, quartzite, other metamorphic rock types, and other 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, and southerly flow direction in areas north and west of Rio Pueblo de Taos, with northwesterly flow direction in area southeast of Rio Pueblo de Taos; well drillers records in the Questa area show clay layers in the shallow subsurface that are interpreted as lacustrine deposits; the unit is present between the Sangre de Cristo Mountains range front and the Rio Grande gorge over most of the map area; correlative with Lambert's (1966) two informal facies of the "Servilleta Formation" (the "sandy gravel facies" found south of the Rio Hondo, and the "gravelly silt facies" found between the Rio Hondo and the Red River); correlative with Kelson's

(1986) informal “Basin Fill deposit;” correlative with the unit previously informally called “Blueberry Hill formation” in the Taos area; also correlative with Pazzaglia’s (1989) late Neogene-Quaternary rift fill sequence (unit Q1) which he informally named the Lama formation; herein, for this study area, the Lama formation is defined as the uppermost, pre-incision, sedimentary rift fill, and where extant represents the uppermost member of the Santa Fe Group; the unit therefore includes all of the basin fill between the oldest Servilleta Basalt (5.55 +/- 0.37 Ma near Cerro Azul, D. Koning, personal communication, 2015) and the oldest Rio Grande (and tributary) terrace gravels (e.g., Qt0rg, Qt0rr); the Lama formation and the underlying Chamita Formation are texturally and compositionally similar and may be indistinguishable in boreholes, although Koning et al. (2015) noted a coarsening of sediment (southwest of the map area) that roughly coincides with the Chamita/Lama contact in the map area; the top of the Lama formation is typically marked by a sharp unconformity and color/textural contrasts with overlying gravels; the unit contains several laterally variable components of sedimentary fill that are associated with various provenance areas related to east- or west-flowing tributary watersheds that have been fairly persistent in the late Cenozoic; locally contains tephra layers; reworked tephra in a road cut near the Red River Fish Hatchery (elevation ca. 7160 ft) was probably derived from nearby ca. 5 Ma volcanic units (R. Thompson, personal communication, 2015); a tephra in the uppermost Lama formation yielded a date of ~1.6 Ma based on a chemical correlation with the 1.61 Ma Guaje Pumice eruption in the Jemez Mountains (elevation ca. 7660 ft, M. Machette, USGS, personal communication, 2008); thickness ranges from zero to an exposed thickness of about 25 m at the southwestern end of Blueberry Hill, but may be considerably thicker in other parts of the map area

Tlc **Clay, Lama formation** (Pliocene) – In cross sections only. Light gray, sedimentary clay layer that is poorly exposed in the walls of the Rio Grande gorge; small (20 to 50 microns) crystals in clay matrix are composed of quartz and feldspar (both plutonic and volcanic); relatively uniform grain size; lies within the clastic units of the Lama formation; where exposed, spatially related to small springs and seeps that are exposed on the nearby canyon walls at elevations of approximately 6200 ft; locally exposed to the southwest near the Village of Pilar where springs emerge along the top of the layer at elevations of about 6300 ft; could be an eolian layer, but more likely a lacustrine clay that accumulated behind a basalt-dammed ancestral Rio Grande; thickness is estimated at 1 to 3 m

Tc **Chamita Formation, undivided, Santa Fe Group** (Miocene? and Pliocene) – In cross sections only. Sedimentary deposits between the lowest Servilleta Basalt and the Tesuque Formation; typically rounded to subrounded pebble- to cobble-size clasts in a sand to silt matrix; thick sections to the south reflect Proterozoic clast provenance and are dominated by schist, quartzite, and amphibolite with lesser volcanic clasts derived from the Latir volcanic field; 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; the top of Tc is herein defined as the sediments below the youngest Servilleta Basalt flows

Tto **Ojo Caliente Sandstone of Tesuque Formation, Santa Fe Group** (Miocene) – Very pale brown (10 YR7/4), well- to moderately well-sorted, subrounded to rounded, loose to moderately well indurated sandstone; this unit is a distinctive eolian sand dune deposit sourced from the southwest (Galusha and Blick, 1971); dominant grain size is fine sand; abundant 1.3-5.0 cm thick, brown, $CaCO_3$ concretions; QFL proportions near Dixon average 62% quartz, 28% feldspar, 10% lithics and LvLsLm ratio averages 82% Lv, 8% Ls, and 10% Lm (Steinpress, 1980); thin reddish-brown, finely laminated siltstone horizons exist locally; tabular crossbeds are common, with sets over 4 m in height; the best exposures are in roadcuts along NM-68, northeast of Pilar; in the map area, these sediments underlie the Pilar Mesa member of the Chamita Formation below an interfingering(?) contact, and some of the sand in the Pilar Mesa member is probably reworked Ojo Caliente Sandstone and/or sand derived from the same source during Pilar Mesa member time; age range of 13.5-10.9 Ma is based on regional relationships (Koning et al., 2005); approximately 250 m thick

Ttc **Chama-El Rito Member of Tesuque Formation, Santa Fe Group** (Miocene) – Buff, whitish, pink, red and brownish, moderately to very poorly sorted, subangular to subrounded, tabular to lensoidal(?), thinly to very thickly bedded, massive, plane-bedded, or crossbedded, loose to carbonate-cemented muddy siltstone to silty, very fine to very coarse sandstone interbedded with moderately to poorly sorted, mostly subrounded, medium- to very thick-bedded tabular beds and broad lenses of silty/sandy and sandy pebble conglomerate; clasts composed mostly of Tertiary volcanic rocks and quartzite with lesser amounts of Paleozoic sandstone, granitic rocks, Pilar Formation slate, schist, and rare amphibolite; ranges in age regionally from possibly >22 Ma to ~13 Ma (Aby, 2008); thickness unknown, but is expected to range considerably in the subsurface

Tpt-Ttc **Tuffaceous member of Picuris Formation and/or Chama-El Rito Member of Tesuque Formation, undivided** (Miocene) – Interbedded and/or complexly faulted, poorly exposed, sparse outcrops of tuffaceous and pumiceous silty sandstones and volcaniclastic sandstone and conglomerate; stratigraphic/temporal relations between the tuffaceous members of the Picuris Formation and the Chama-El Rito Member are discernible (and clearly 'layer cake') in the southern Picuris Mountains, however, locally the Tuffaceous member is either absent or not exposed along most of the range front; along the northeastern edge of the map area are poorly exposed, and possibly complexly faulted, outcrops of both tuffaceous and volcaniclastic rocks that indicate possible interfingering of the two units; elsewhere, these rocks were referred to as the middle tuffaceous member of the Picuris Formation (Aby et al., 2004); age is less than ~25 Ma based on abundant clasts of 25 Ma Amalia Tuff, but minimum age is unknown; thickness in the map area is unknown

Tp **Picuris Formation, undivided** (Oligocene to Miocene)- In cross section only. In the Picuris Mountains area (Aby et al., 2004) consists of an upper member of tuffaceous and pumiceous silty sandstones and volcaniclastic sandstone and conglomerate; a member of buff to white and/or pinkish, silty sandstone to fine cobble conglomerate and nonfriable to strong, very fine lower to very coarse upper, very poorly to moderately sorted, rounded to subangular, thinly to thickly bedded, silica-cemented silty to pebbly sandstone which locally contains a basal portion of poorly sorted pebbly/gravelly sandstone and/or cobble/boulder conglomerate composed exclusively of Proterozoic clasts; a member of light buff, yellowish, and locally white, ash-rich, quartzose, silty, fine sand to pebbly, pumiceous sandstone; a lower member of red, greenish, and yellowish, moderately to very poorly sorted, subangular to subrounded, pebbly/silty sandstone and mudstone containing very thick(?) to thin beds and/or lenses and/or isolated clasts of subangular to rounded Proterozoic quartzite (up to 3 m across) and massive quartzite conglomerate; paleoflow measurements indicate source to the north (Rehder, 1986); age range is from at least 35.6 Ma to less than 25 Ma; thickness unknown, but at least 450 m in the Picuris Mountains area

Tplq **Llano Quemado Breccia member of Picuris Formation** (Oligocene) – Light gray to red, monolithologic volcanic breccia of distinctive extremely angular, poorly sorted, light-gray, recrystallized rhyolite clasts in a generally reddish matrix; rhyolite clasts contain phenocrysts of biotite, sanidine, and quartz; highly lithified, due to partial welding of the matrix rather than silica or carbonate cement; ridge-former; unit shows both clast and matrix support; beds are generally 1-8 m thick; clasts are up to 15 cm in diameter, and overall clast size decreases southward; less than 1% of clasts are Proterozoic slate and weathered Tertiary volcanic rocks; the breccia is interpreted as a series of flows from a now-buried, nearby rhyolite vent (Rehder, 1986); $^{40}Ar/^{39}Ar$ date on sanidine from a rhyolite clast collected 1 km southwest of Ponce de Leon spring is 28.35 ± 0.11 Ma; apparent thicknesses of 5-45 m, although subsurface extent is unknown

Tpa **Andesitic porphyry** (Oligocene) − Poorly exposed, reddish-gray, andesitic porphyry that is exposed only in a single small exposure in northern Miranda Canyon where it appears to underlie Tplq; age unknown, although it may be related to the volcanic component of Tplq

Tpl **Lower member of Picuris Formation** (Oligocene) − Mostly poorly exposed, red, greenish, and yellowish, moderately to very poorly sorted, subangular to subrounded, pebbly/silty sandstone and mudstone containing very thick(?) to thin beds and/or lenses and/or isolated clasts of subangular to rounded Proterozoic quartzite (up to 3 m across) and massive quartzite conglomerate; commonly highly weathered with fractured clasts; most available exposures consist of very well-carbonate-cemented quartzite pebble and cobble conglomerate intervals exposed near mapped faults; the lower contact is placed at the first accumulation of diverse Proterozoic clasts (quartzite, Pilar Formation slate, +/ − schist); the upper 10 m in Agua Caliente Canyon is a well-exposed bed of well-sorted, quartzite-cobble conglomerate (figure 7 of Aby et al., 2004); the orientation of 95 well-imbricated clasts in this interval suggest derivation from the northeast (average paleotransport direction =143 degrees), at odds with a previous interpretation that this unit was derived from the Picuris Mountains to the southeast (Leininger, 1982); this unit was informally named the Bradley Conglomerate member of the Tesuque Formation (Leininger, 1982), but that name has been abandoned; this unit has also been referred to as the Lower Conglomerate member of the Picuris Formation (Aby et al., 2004) but, locally, much of the unit is fine grained; near the top(?) of the section in Agua Caliente Canyon is an ash layer dated at 34.5 ± 1.2 Ma by $^{40}Ar/^{39}Ar$ (Aby et al., 2004); regionally, this unit contains variable amounts of intermediate composition volcanic rocks (dated by $^{40}Ar/^{39}Ar$ at 32.4 to 28.8 Ma; Aby et al., 2007), and fluvially reworked Llano Quemado breccia (28.35 Ma); the oldest ashes are dated at 35.5 Ma and 35.6 Ma (Aby et al., 2004), but maximum age of unit is unknown; at least 250 m thick where not faulted

Tbo **Older basaltic rocks** (Oligocene) − In cross section only. Volcanic rocks that predate the Tesuque Formation and may exist within the Picuris Formation; may include the Hinsdale Formation and/or similar units; thickness unknown, but probably less than 30 m

Paleozoic Rocks

breccia **Mixed fault breccia** (late Proterozoic? to Tertiary?)-Fault breccia composed of a mixture of Paleoproterozoic Hondo Group, Vadito Group, and granitic rock along the Picuris-Pecos fault; ridge former where the breccia is strongly silicified

/P,/Pu **Sedimentary rocks of the Taos Trough, undivided** (Pennsylvanian) − Poorly exposed; greenish, reddish, yellowish, buff, tan, black, and brown; very friable-to-firm; sandy to clayey; thinly to thickly bedded; poorly to moderately well-cemented(?), sandy to clayey siltstone, mudstone, and shale interbedded with mostly greenish and brownish, firm to very strong, poorly to moderately well-sorted, poorly to moderately well rounded, thin- to very thickly bedded, moderately to very well-cemented, quartzose, feldspathic, and arkosic, silty to pebbly sandstone and sandy conglomerate and less common thin- to thick-bedded, grayish and blackish limestone of the Alamitos and Flechado Formations; contains a rich assortment of fossils; sandstones commonly contain plant fragments that have been altered to limonite(?); contacts between beds are generally sharp, rarely with minor scour (less than ~20 cm); the lower contact is sharp, planar(?), and disconformable(?) where it overlies Mississippian rocks; lower contact is mapped at the top of the Del Padre Sandstone or highest Mississippian carbonate, or at the base of the lowest sedimentary bed where Mississippian rocks are absent; conglomeratic layers in the lower part of the unit locally contain rare, sometimes banded, chert pebbles; equivalent to the Sandia, Madera, and La Posado Formations to the south; colluvial deposits have not been mapped on the Tres Ritos quadrangle, but most of the Pennsylvanian rocks are covered by brown to nearly black, loose, very poorly sorted, rounded to angular, massive- to very crudely bedded, sandy-silty conglomerate and pebbly silty sand; this material is clearly colluvial based on its landscape position and the random orientation of larger clasts within a matrix of usually dark, organic-rich fines; windthrow (movement of soil by toppling of trees) is thought to be an active process in the map area, and is probably responsible for the pervasive colluvial mantle; fusilinids collected in the Taos quadrangle are Desmoinesian in age (Bruce Allen, personal communication, 2000); Miller et al. (1963) measured an incomplete section of 1756 m along the Rio Pueblo near the Comales Campground, and an aggregate thickness of Pennsylvanian strata in the map area of >1830 m

Mu **Sedimentary rocks of the Arroyo Penasco Group** (Mississippian) – Includes the Del Padre Sandstone member of Espiritu Santa Formation, the Espiritu Santa Formation carbonate sedimentary rocks, and the Tererro Formation carbonate sedimentary rocks

PROTEROZOIC ROCKS OF THE PICURIS MOUNTAINS

Ytpl **Piedra Lumbre Formation, Trampas Group** (Mesoproterozoic) – Includes several distinctive rock types: 1) quartz-muscovite-biotite-garnet-staurolite phyllitic schist with characteristic sheen on crenulated cleavage surfaces; euhedral garnets are 1 mm, biotite books are 2 mm, and scattered anhedral staurolites are up to 5 mm in diameter; 2) finely laminated light gray phyllitic quartz-muscovite-biotite-garnet schist and darker bluish gray fine-grained biotite quartzite to metasiltstone; quartzite layers range in thickness from 1 cm to 1 m; and 3) light-gray to gray garnet schist with lenses of quartzite to metasiltstone; calc-silicate layers exist locally; original sedimentary structures including graded bedding are preserved; well-developed cleavage parallel to both layering and axial surfaces of small intrafolial isoclinal folds; dominant layering in much of this unit is transpositional; in the core of the Hondo syncline, unit is thicker, contains a greater variety of rock types, and is gradational with the Pilar Formation; U-Pb analyses of detrital zircons from a quartzite in the upper part of the section (unit Ytplq?) were interpreted to constrain the unit to be less than about 1470 Ma in depositional age (Daniel et al., 2013); apparent thickness is 200-400 m

Ytp **Pilar Formation, Trampas Group** (Mesoproterozoic) – Dark gray to black, carbonaceous phyllitic slate; extremely fine-grained homogeneous rock except for rare 1- to 2-cm-thick light-colored bands of quartz and muscovite that may represent original sedimentary bedding; in thin section, fine-grained matrix consists of quartz (50-70%), muscovite (15-30%), and prominent streaky areas of graphitic material; lenticular porphyroblasts (0.1 to 0.5 mm) are altered to yellow-brown limonite; pervasive slaty cleavage is locally crenulated; small isoclinal folds locally; basal 1.5-m-thick, black to blue-black, medium-grained, garnet quartzite is distinctive; garnets are anhedral, oxidized, and red-weathered; gradational with Ytpl; Daniel et al. (2013) calculated a mean 207Pb/206Pb zircon age of 1488 ± 6 Ma for a 1-2-m-thick, white, schistose layer that was interpreted as a metamorphosed tuff, and therefore represents the depositional age of the sedimentary protolith; thickness unknown due to extreme ductile deformation

Xpeg **Pegmatite** (Mesoproterozoic) – Includes both simple (quartz-K-feldspar-plagioclase-muscovite) pegmatites and complex zoned pegmatites containing rare minerals in the Trampas quadrangle; simple pegmatites are by far the most abundant in the map area; pegmatite bodies typically are dikes or lenses, locally aligned parallel to country rock foliation; thicknesses range from 2 cm to 15 m; no apparent spatial relationship exists between pegmatite bodies and plutonic bodies, and no evidence exists to suggest that pegmatites are connected to plutons at depth; more than one generation of pegmatite formation is represented, and at least one generation is younger than the youngest granite at 1450 Ma (Long, 1976)

Xh **Hondo Group, undivided** (Paleoproterozoic) – In cross section only. Schist and quartzite units of the Ortega and Rinconada Formations

Xhr **Rinconada Formation, undivided** (Paleoproterozoic)-Undivided schists and quartzites near the Pilar-Vadito fault in the Carson quadrangle that are pervasively fractured and faulted; U-Pb analyses of detrital zircons from two quartzite units was interpreted to constrain the unit to be less than about 1700 Ma in depositional age (Daniel et al., 2013)

Xhr6 **R6 schist member, Rinconada Formation** (Paleoproterozoic)-Tan, gray, silver quartz-muscovite-biotite-staurolite-garnet schistose phyllite interlayered with fine-grained, garnet-bearing, muscovite quartzite; euhedral staurolites (<5 cm) abundant in some layers; small euhedral garnets (<2 mm) throughout; strong parting along well-developed foliation; sharp contact with Ytp might represent a large unconformity; thickness is approximately 90 m

Xhr5 **R5 quartzite member, Rinconada Formation** (Paleoproterozoic)-Variety of white to blue medium-grained quartzites interlayered with fine-grained schistose quartzites and quartzose schists; measured section by Hall (1988) from top to bottom: 1) tan to white, friable, thinly layered, crossbedded micaceous quartzite; 2) blue, medium-grained, thickly layered, resistant saccharoidal quartzite; locally crossbedded; 3) white to tan, friable schistose quartzite layered with blue, medium-grained saccharoidal quartzite; thin layers of fine-grained quartz-muscovite-biotite schist; basal 1.5 m massive blue medium-grained quartzite; 4) tan, thinly layered, micaceous quartzite layered with quartz-rich muscovite schist; abundant crossbedding; 5) blue and white streaked, thickly bedded, medium-grained quartzite with abundant crossbedding; and 6) tan, thinly layered, micaceous quartzite interlayered with quartz-rich quartz-muscovite schist; abundant crossbedding; gradational contact with Xhr6; thickness is approximately 75 m

Xhr3 **R3 quartzite member, Rinconada Formation** (Paleoproterozoic) – Interlayered crossbedded quartzites and pelitic schists; distinctive marker layer near center of unit is 25-m-thick, white, thinly bedded, ridge-forming quartzite; sharp contact with Xhr4; thickness is approximately 75 m

Xhr1/2 **R1/R2 schist member, Rinconada Formation** (Paleoproterozoic) – Lower unit of fine- to medium-grained, tan to silver, quartz-muscovite-biotite schist with small euhedral garnets (<2mm) and scattered euhedral staurolite twins (<1.5cm); near base are black biotite books (<2cm) and on the upright limb of the Hondo syncline in Section 7 are spectacular, andalusite porphyroblasts up to 8 cm across; upper unit of gray to tan, red-weathering, coarse-grained quartz-muscovite-biotite-staurolite-albite-garnet schist containing interlayers of 1-10 cm, red-, gray-, or tan-weathering, fine-grained, muscovite-garnet quartzite; abundant staurolites are twinned, euhedral, up to 3 cm; abundant garnets are euhedral and small (<2mm); strong parting along foliation plane; sharp to gradational contact with Xhr3; lower and upper unit have previously been subdivided into R1 and R2 members, respectively, based on mineralogy (Nielsen, 1972); thickness is approximately 265 m

Xho **Ortega Formation, Hondo Group, undivided** (Paleoproterozoic) – Gray to grayish-white, medium- to coarse-grained quartzite; generally massive and highly resistant to weathering; locally well-cross-bedded, with kyanite- or sillimanite-concentrated in thin, schistose, muscovite-rich horizons; crossbeds are defined by concentrations of black iron-oxide minerals; common accessory minerals are ilmenite, hematite, tourmaline, epidote, muscovite, and zircon; gradational contact with Rinconada Formation; U-Pb analyses of detrital zircons from two quartzite layers was interpreted to constrain the unit to be less than about 1700 Ma in depositional age (Daniel et al., 2013); thickness is 800-1200 m

Xmg **Miranda granite** (Paleoproterozoic?) – East of the Picuris-Pecos fault; typically consists of pink to white, medium-grained, mica-rich, granitic rock with euhedral megacrysts of feldspar; these granitic rocks are everywhere weathered looking, fairly equigranular, and commonly crumbly; appears to intrude the Rio Pueblo schist along its southern contact; pegmatites are locally voluminous; contains at least one tectonic foliation; three closely spaced, orthogonal joint sets cause this rock to weather into small, angular blocks; age unknown, but similar in occurrence and texture to the ca. 1.6 Ga Tres Piedras Granite of the east-central Tusas Mountains

Xvg **Glenwoody Formation** (Paleoproterozoic) – Feldspathic quartz-muscovite schist and quartzose schist exposed in isolated exposures along the northern flank of the Picuris Mountains and in the Pilar cliffs; white, light gray, pink, or green; commonly contains megacrysts of feldspar and rounded and flattened quartz in a fine-grained matrix of quartz, muscovite and feldspar; contact with overlying Ortega Formation is a south-dipping ductile shear zone; pervasive extension lineation in schist plunges south; upper 40 m of schist is pinkish, and contains anomalous manganese and rare earth elements, and unusual minerals such as piemontite, thulite, and Mn-andalusite (viridine); L.T. Silver reported a preliminary U-Pb zircon age of ca. 1700 Ma (Bauer and Pollock, 1993); may be equivalent to the Rio Pueblo schist and the ca. 1700 Ma Burned Mountain Formation of the Tusas Mountains; base unexposed; minimum thickness is about 200 m

Xv **Vadito Group, undivided** (Paleoproterozoic)-Metavolcanic, metavolcaniclastic, and metasedimentary rocks; U-Pb analyses of detrital zircons from a a schist and a conglomerate layer was interpreted to constrain the unit to be less than about 1700 Ma in depositional age (Daniel et al., 2013)

XYu **Proterozoic rocks, undivided** (Paleoproterozoic and Mesoproterozoic) – In cross section only. Supracrustal metamorphic rocks, metaplutonic rocks, and plutonic rocks

References Cited

Aby, S.B., 2008, Geologic Map of the Servilleta Plaza quadrangle, Taos County, New Mexico: New Mexico Bureau of Geology and Mineral Resources Open-File Geologic Map OF-GM 182, scale 1:24,000.

Aby, S.B., Hallet, B., and Bauer, P.W., 2007, Geologic map of the Tres Ritos quadrangle, Taos County, New Mexico: New Mexico Bureau of Geology and Mineral Resources Open-File Geologic Map OF-GM 145, scale 1:24,000.

Aby. S.B., Bauer, P.W., and Kelson, K.I., 2004, The Picuris Formation: A late Eocene to Miocene sedimentary sequence in northern New Mexico, *in* Brister, B.S, Bauer, P.W., Read, A.S., and Lueth, V.W., eds., Geology of the Taos Region: New Mexico Geological Society, 55th Annual Field Conference, p. 335-350.

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

Bauer, P.W., and Pollock, T.R., 1993, Compilation of Precambrian Isotopic Ages in New Mexico: New Mexico Bureau of Geology and Mineral Resources Open-File Report 389, 130 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, California, 15-19 December.

Daniel, C.G., Pfeifer, L.S., Jones III, J.V., and McFarlane, C.M., 2013, Detrital zircon evidence for non-Laurentian provenance, Mesoproterozoic (ca. 1490-1450) deposition and orogenesis in a reconstructed orogenic belt, northern New Mexico, USA: Defining the Picuris orogeny: Geological Society of America Bulletin, v. 125, no. 9/10, p. 1423-1441.

Dungan, M.A., Muehlberger, W.R., Leininger, L., Peterson, C., McMillan, N.J., Gunn, G., Lindstrom, M., and Haskin, L., 1984, Volcanic and sedimentary stratigraphy of the Rio Grande Gorge and the Late Cenozoic geologic evolution of the southern San Luis Valley: *in* Baldridge, W.S., Dickerson, P.W., Riecker, R.E., and Zidek, J., Rio Grande Rift (Northern New Mexico): New Mexico Geological Society, 35th Annual Field Conference, Guidebook, p. 157–170.

Galusha, T., and Blick, J.C., 1971, Stratigraphy of the Santa Fe Group, New Mexico: American Museum of Natural History Bulletin 144, 127 p.

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: *in* Northrop, S.A., and Read, C.B., eds., Taos-Raton-Spanish Peaks Country (New Mexico and Colorado): New Mexico Geological Society, 17th Annual Field Conference, Guidebook, p. 43–50.

Leininger, R. L., 1982, Cenozoic evolution of the southernmost Taos plateau, New Mexico [M.S. thesis]: Austin, University of 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.C., ed., Rio Grande Rift: Tectonics and Magmatism: Washington, D.C., American Geophysical Union, p. 289–311.

Long, P.E., 1976, Precambrian granitic rocks of the Dixon–Peñasco area, northern New Mexico—A study in contrasts: New Mexico Bureau of Geology and Mineral Resources Open-File Report 71, 533 p.

Miller, J.P., Montgomery, A., and Sutherland, P.K., 1963, Geology of part of the southern Sangre de Cristo Mountains, New Mexico: New Mexico Bureau of Geology and Mineral Resources Memoir 11, 106 p.

Nielsen, K.C., 1972, Structural evolution of the Picuris Mountains, New Mexico [M.S. thesis]: Chapel Hill, University of North Carolina, 47 p.

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

Rehder, T.R., 1986, Stratigraphy, sedimentology, and petrography of the Picuris Formation in Ranchos de Taos and Tres Ritos quadrangles, north-central New Mexico [M.S. thesis]: Dallas, Southern Methodist University, 110 p.

Steinpress, M.G., 1980, Neogene stratigraphy and structure of the Dixon area, Española Basin, north-central New Mexico [M.S. thesis]: Albuquerque, University of New Mexico, 127 p.

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.