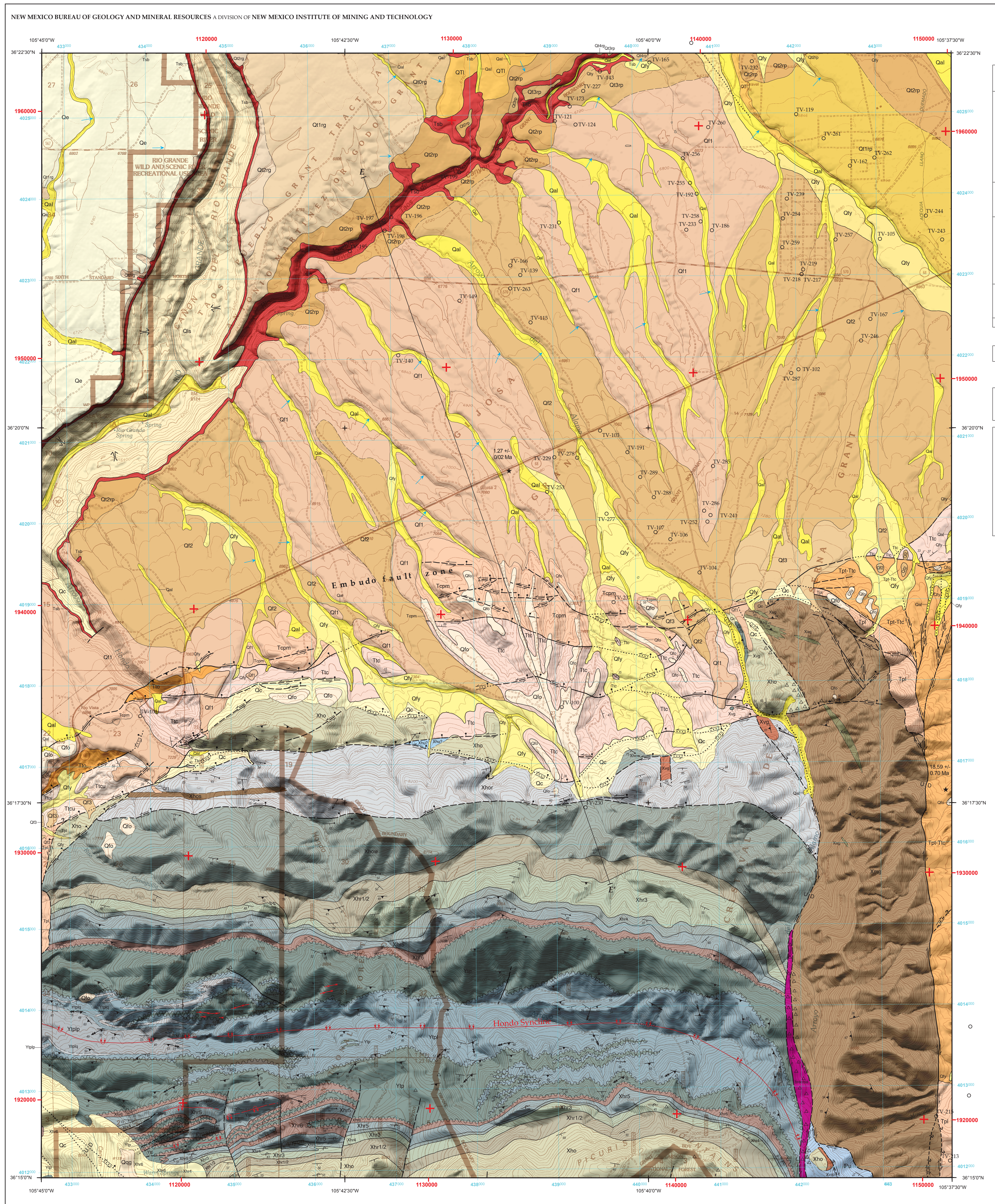
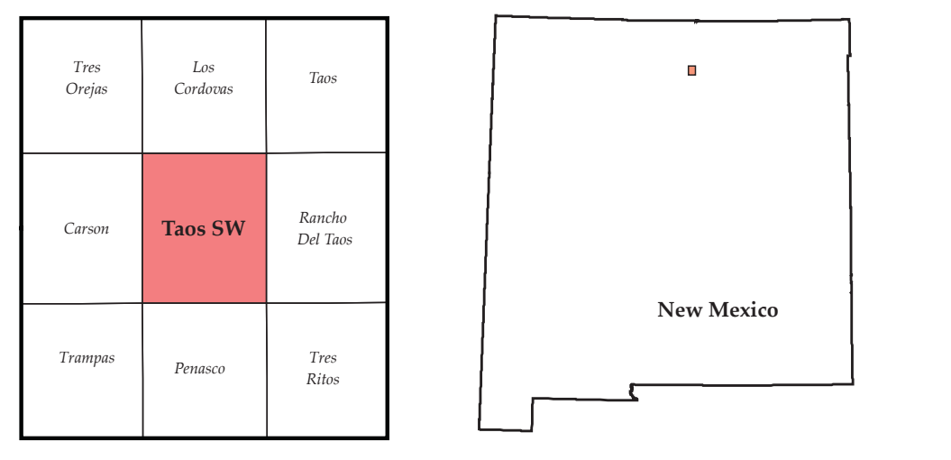
**NMBGMR Open-File Geologic Map 22**

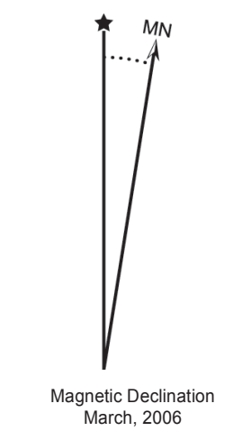
**Last Modified July 2019**



Base map from U.S. Geological Survey 1961, from photographs taken 1958, field checked in 1961.
1927 North American datum, UTM projection -- zone 13N
1000-meter Universal Transverse Mercator grid, zone 13, shown in blue.



## Quadrangle Location



Magnetic Declination
March, 2006
9° 33' East
At Map Center

1:24,000

Contour Interval 20 Feet

North American Vertical Datum of 1929

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This and other STATEMAP quadrangles are available
for free download in both PDF and ArcGIS formats at:

*http://geoinfo.nmt.edu*

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Mapping of this quadrangle was funded by a matching-funds grant from the STATEMAP program of the National Cooperative Geologic Mapping Act (Fund Number: 06HQPA0003, administered by the U. S. Geological Survey, and by the New Mexico Bureau of Geology and Mineral Resources, (Charles Chapin, *Director and State Geologist*, Dr. Paul W. Bauer, *Assoc. Director for Mapping Programs*).

# Geologic Map of the Taos SW 7.5-Minute Quadrangle, Taos County, New Mexico

May 1997

by
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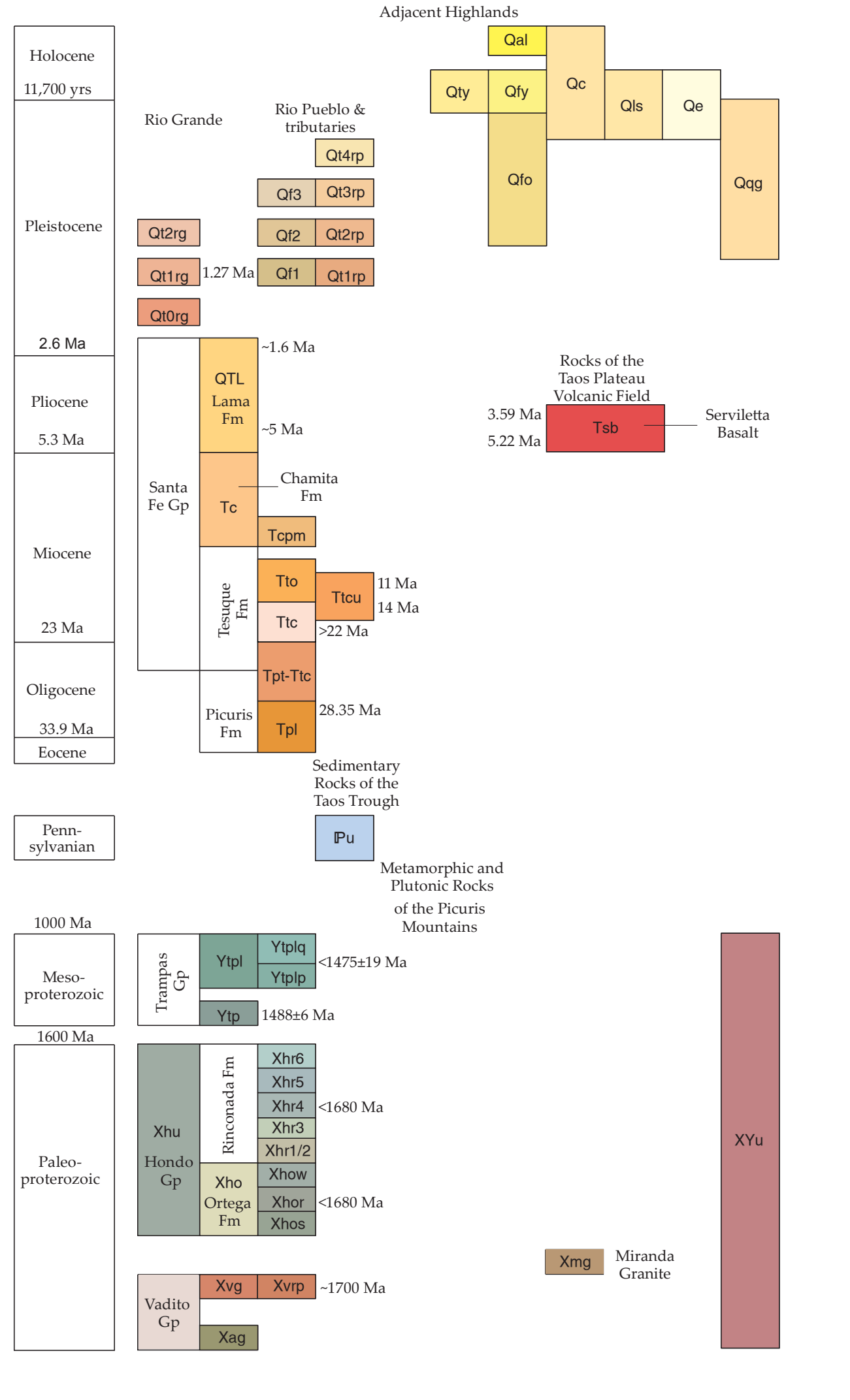
## Correlation of Map Units



## Comments to Map Users

A geologic map displays information on the distribution, nature, orientation, and age relationships of rock and deposits and the occurrence of structural features. Geologic and fault contacts are irregular surfaces that form boundaries between different types or ages of units. Data depicted on this geologic quadrangle map may be based on any of the following: reconnaissance field geologic mapping, compilation of published and unpublished work, and photogeologic interpretation. Locations of contacts are not surveyed, but are plotted by interpretation of the position of a given contact onto a topographic base map; therefore, the accuracy of contact locations depends on the scale of mapping and the interpretation of the geologist(s). Any enlargement of this map could cause misunderstanding in the detail of mapping and may result in erroneous interpretations. Site-specific conditions should be verified by detailed surface mapping or subsurface exploration. Topographic and cultural changes may not be shown due to recent development.

Cross sections are constructed based upon the interpretations of the author made from geologic mapping, and available geophysical, and subsurface (drillhole) data. Cross sections should be used as an aid to understanding the general geologic framework of the map area, and not be the sole source of information for use in locating or designing wells, buildings, roads, or other man-made structures.

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## Explanation of Map Symbols

| | |
|---|---|
| E ⊢—⊣ E′ | Location of geologic cross section. |
| | Geologic contact—Identity and existence certain; location accurate where solid, approximate where dashed, concealed where dotted. |
| | Unconformable contact—Identity and existence certain; location approximate where dashed, approximate where dashed. |
| | Fault—Identity and existence certain; location accurate where solid, approximate where dashed, concealed where dotted. |
| | Scarp on fault—Identity and existence certain, location accurate. |
| D U U D | Normal fault—Identity and existence certain; location approximate where dashed, concealed where dotted. Sense of slip suggested: U = upthrown block, D = downthrown block. |
| | Normal fault—Identity and existence certain; location accurate where solid, approximate where dashed, concealed where dotted. Identity and existance uncertain where queried. Bar and ball on downthrown side. |
| D U D U U D | Oblique-slip fault, left lateral offset—Identity and existence certain; location accurate where solid, approximate where dashed, concealed where dotted. Identity and existance uncertain where queried. Vertical sense of slip suggested: U = upthrown block, D = downthrown block. |
| | Thrust fault—Identity and existence certain, location accurate. |
| | Ductile shear zone. |
| 83 | Minor inclined fault, tic showing dip. Diamond-headed tic shows orientation of inclined slicklines, grooves, or striations on fault surface. |
| ⊙/⊕ | Fault in cross section showing strike slip offset. Decorations show relative movement along the fault, where the circled dot shows movement toward the observer and the circled plus shows movement away from the observer. |
| xxxxxxxxxxxxxxxxx | Pegmatite exposed in fault trace. |
| △ △ △ △ △ △ | Broken or brecciated rock around fault. |
| | Overturned syncline—Identity and existence certain, location accurate where solid, concealed where dotted. |
| | Overturned anticline—Identity and existence certain, location accurate where solid, concealed where dotted. |
| → | Direction of downslope movement of landslide. |
| 49 | Strike and dip of inclined bedding. |
| 76 | Strike and dip of inclined joint. |
| 25 | Strike and dip of inclined bedding, where top direction of beds is known from local features. |
| 60 | Strike and dip of inclined flow banding, lamination, layering, or foliation in metamorphic rock. |
| → | Paleocurrent vector; tail of arrow is located at measurement. |
| ★ 34.5 Ma | Location of $^{40}$Ar/$^{39}$Ar geochronologic sample with resultant date. |
| ⚒ | Open pit, quarry, or glory hole. |
| TV-196 ○ | Water-supply well. |

## Description of Map Units

### Surficial Deposits

**Qal** **Alluvium**—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; a single piece of charcoal from the northern fork of the upper Rito Cieneguilla on the Carson quadrangle (432630, 4016250 UTM 13S, NAD27), about 2 m above the floor of the modern wash, returned a conventional 14C age of 2795 ± 50 yrs BP; three charcoal samples from the Trampas quadrangle yielded conventional $^{14}$C ages of 3275 ± 150 (3999279, 428922 UTM13S NAD27), 2645 ± 125 (4002886, 426399 UTM 13S NAD27), and 1800 ± 55 yrs BP (3998300, 427458UTM 13S NAD27); up to 7 m estimated thickness.

**Qc** **Colluvium**—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.

**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 indicate that the predominant wind direction was from the southwest; up to several meters 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 rocks, granitic rocks, and Tertiary granitic and volcanic units; 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.

**Qt4rp** **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 are primarily granitic and metamorphic rocks north of the Rio Pueblo de Taos, and granitic, metamorphic, and sedimentary rock types south of the Rio Pueblo de Taos; clasts also include basaltic rock types along Arroyo Seco and along the Rio Pueblo de Taos downstream of Los Cordovas.

**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 the Rio Pueblo de Taos, and granitic, metamorphic and sedimentary rocks south of the 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; 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 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; locally mantled by unit Qe; estimated thickness of 1 to 10 m.

**Qfo** **Alluvial fan, 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 is typically 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.

**Qf1** **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 QTl 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.

**Qt1rp** **Qt1rg** **Stream terrace deposits of the Rio Grande (early to middle? Pleistocene)**—Poorly sorted sand, pebbles, and cobbles; clasts of basalt, quartzite, slate, schist, and other metamorphic rock types, volcanic rock types, and rare sandstone and limestone; overlies Servilleta Basalt (Tsb) north of Pilar Mesa, but is inset into Tsb on Pilar Mesa on the Carson quadrangle; locally may contain clasts of Amalia Tuff; where preserved, associated relict soils have stage III to IV calcium carbonate development, thick argillic Bt soil horizons, and 7.5YR hues in soil Bt horizons; upper soil horizons commonly affected by surface erosion; may be mantled locally by unit Qe; $^{40}$Ar/39Ar date of 28.03 ± 0.08 Ma on sanidine from a volcanic cobble in the Los Cordovas quadrangle indicates that some clasts originated in the San Juan volcanic field; estimated thickness 1 to 10 m.

**Qqg** **Quartzite-rich alluvial and colluvial(?) deposits (late? Quaternary)**—Distinctive deposit composed of Proterozoic quartzite clasts from 2 mm to about 3 m in diameter, rare Pilar Formation slate clasts to about 7 cm in diameter, and extremely rare schist clasts to about 5 cm in diameter; thickness unknown.

**Qt0rg** **Stream gravel deposited by ancestral Rio Grande (early? 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 the broad, highest terrace west of the Rio Grande gorge; upper soil horizons are commonly affected by surface erosion; locally mantled by eolian sand; estimated thickness of at least several meters.

### Volcanic Rocks of the Taos Plateau

**Tsb** **Servilleta Basalt (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 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; locally subdivided into lower Servilleta Basalt (Tsbl), middle Servilleta Basalt (Tsbm), and upper Servilleta Basalt (Tsbu) by Dungan et al., (1984); flow packages are separated by sedimentary intervals as much as 70 m thick in the southern part of the map area (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); 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 communication, 2014), whereas a lava flow at the base of the section south of Cerro Chiflo yielded an $^{40}$Ar/$^{39}$Ar age of 3.78 ± 0.08 Ma (sample RT08GM02 - M. Cosca, personal communication, 2014).

**QTl** **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 crossbedded, 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 the Rio Pueblo de Taos, with northwesterly flow direction in area southeast of the 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 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 from the lowermost Lama formation 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 Bed 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.

**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 include 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.

**Tcpm** **Pilar Mesa member of Chamita Formation (Miocene)**—Very pale brown to light yellowish-brown, moderately to well-sorted, subangular to rounded, mostly tabular, thin- to thick-bedded, loose to weakly cemented(?), very fine to coarse sand and silty sand interbedded with dark-colored, moderately to very poorly sorted, angular to subrounded (often platy), medium- to thick-bedded, mostly clast-supported lenses and beds of sandy conglomerate; conglomerates contain clasts of Proterozoic quartzite, Tertiary volcanic rocks, Pilar Formation slate, Paleozoic sandstone, siltstone, and limestone, granitic rocks, and rare amphibolite, carbonate nodules, and rip-ups of fines resembling adjacent sandstone interbeds; this unit was informally described as the Cieneguilla member of the Tesuque Formation by Leininger (1982); estimated age range is ~11 to 4.5 Ma based on the age of overlying and underlying units; thickness is approximately 230 m.

**Tt** **Tesuque Formation, Santa Fe Group (Miocene)**— In cross section only; basin-fill deposits of clay, silt, sand, pebbles, cobbles, and boulders of the Rio Grande rift.

**Tto** **Ojo Caliente Sandstone Member of Tesuque Formation (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 brown, CaCO3 concretions are 1.3 to 5.0 cm thick; $QF_L$ 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, this unit underlies 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 Member and/or sand derived from the same source during Pilar Mesa member time; age range of 13.5 to 10.9 Ma is based on regional relationships (Koning et al., 2005); approximately 250 m thick.

**Ttcu** **Upper part of Chama-El Rito Member of Tesuque Formation (Miocene)**—Very pale brown to light yellowish brown, moderately to poorly sorted, subangular to subrounded, thinly to thickly bedded, tabular, loose to moderately carbonate-cemented, fine to coarse, silty sandstone interbedded with moderately to poorly sorted, subangular to subrounded, medium- to thick-bedded, tabular to broadly lenticular(?), sandy conglomerate composed of variable amounts of Proterozoic quartzite, Pilar Formation slate, schist, Tertiary volcanic rocks, Paleozoic sandstone, limestone and siltstone, granitic rocks, and rare rip-up clasts; lower contact gradational (interfingering?) with rest of Chama-El Rito Member; lower contact is drawn at approximately 10% Paleozoic clasts; upper contact is not exposed but is probably gradational and interfingering with Ojo Caliente Sandstone Member; largely covered by Quaternary alluvium but some moderately good exposures overlie Ttc in Agua Caliente Canyon; some beds of Ttc near the contact contain anomalously high numbers of sandstone and granitic clasts and some Pilar Formation slate (Table 1); age range of 14 Ma to 11 Ma is based on the age of overlying and underlying units; at least 200 m thick.

**Ttc** **Chama-El Rito Member of Tesuque Formation (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 member 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 that 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 34.6 Ma to less than 25 Ma; thickness unknown, but at least 450 m in the Picuris Mountains area.

**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) for exposures near the Village of Pilar, 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 the maximum age of the unit is unknown; at least 250 m thick where not faulted.

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

### Sedimentary Rocks of the Taos Trough

**IPu** **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 Member 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 Posada 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 colluvium, 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 Tres Ritos quadrangle, 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

### Proterozoic Rocks of the Picuris Mountains

**Ytu** **Trampas group, undivided (Mesoproterozoic)**—In cross section only. Schist, quartzite, metaconglomerate, phyllite, and slate deposits of the Piedra Lumbre and Pilar Formations; previously considered to be part of the ca. 1680 - 1700 Ma Hondo Group; this informal group name was proposed by Daniel et al. (2013) based principally on ages of detrital zircons in the Piedra Lumbre and Pilar Formations.

**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, the 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.

**Ytplp** **Piedra Lumbre Formation quartzite, Trampas group (Mesoproterozoic)**—Massive to layered, light-colored, crossbedded micaceous quartzite; locally garnet-bearing; approximate thickness of 25 m.

**Ytplq** **Piedra Lumbre Formation phyllite, Trampas group (Mesoproterozoic)**—Dark gray to black, fine-grained, garnet-bearing phyllite; crops out in the core of the Hondo syncline east of the Pilar-Vadito fault.

**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, the 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; displays small isoclinal folds locally; basal 1.5-m-thick, black to blue-black, medium-grained, garnet quartzite is distinctive; garnet porphyroblasts are anhedral, oxidized, and red-weathered; gradational with Ytpl; Daniel et al. (2013) calculated a mean $^{207}$Pb/$^{206}$Pb zircon age of 1488 ± 6 Ma for a 1- to 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.

**Xhu** **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 were 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 significant 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; near Copper Hill, Hall (1988) reported a measured section, from top to bottom, as follows: 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-thick massive blue medium-grained quartzite; 4) tan, thinly layered, micaceous quartzite layered with quartz-rich muscovite schist with 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 with abundant crossbedding; detrital zircons near the top of the unit yielded a 206Pb/207Pb detrital zircon age peak of 1763 Ma (Daniel et al., 2013); gradational contact with Xhr6; thickness is approximately 75 m

**Xhr4** **R4 schist member, Rinconada Formation (Paleoproterozoic)**—Medium- to coarse-grained, silvery gray, quartz-muscovite-biotite-staurolite-garnet schist containing one or more distinctive, 0.5- to 2.0-m-thick layers of glassy blue quartzite, rusty red weathering garnetiferous white quartzite, massive, extremely hard, red weathering, olive-brown biotite-staurolite-garnet-orthoamphibole rock, white, glassy, hornblende quartzite, gray biotite-hornblende calc-schist, mylonitic blue to pink and blue, glassy quartzite, and white to gray calcite marble; the latter four rock types are not present on the south limb of the Copper Hill anticline, but are present in the Trampas quadrangle on both the upright and overturned limbs of the Hondo syncline in Sections 7, 8, 9 and 10; a well-exposed reference section of this thicker Xhr4 sequence can be found on the south-facing slope and crest of the ridge making up the northern half of the SW quarter of Section 8 on the Trampas quadrangle (Hall, 1988); sharp contact with Xhr5; thickness ranges from about 50 to 175 m

**Xhr3** **R3 quartzite member, Rinconada Formation (Paleoproterozoic)**—Interlayered crossbedded quartzites and pelitic schists; distinctive marker layer near the center of the unit is a 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 (<2 mm) and scattered euhedral staurolite twins (<1.5 cm); near the base are black biotite books (<2 cm) and on the upright limb of the Hondo syncline in Section 7 are spectacular, andalusite porphyroblasts up to 8 cm across; an upper unit of gray to tan, red-weathering, coarse-grained quartz-muscovite-biotite-staurolite-albite-garnet schist contains interlayers of 1 to 10 cm, red-, gray-, or tan-weathering, fine-grained, muscovite-garnet quartzite; abundant staurolites are twinned, euhedral, and up to 3 cm in diameter; abundant garnets are euhedral and small (<2 mm); the unit shows strong parting along foliation planes; 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-crossbedded, 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 were interpreted to constrain the unit to be less than about 1700 Ma in depositional age (Daniel et al., 2013); thickness is 800-1200 m

**Xhow** **Massive white quartzite, Ortega Formation (Paleoproterozoic)**—Massive, white to light gray, vitreous quartzite with dark layers of rutile, hematite, and ilmenite that define crossbedding; fine muscovite commonly is present on quartz grain boundaries, and kyanite commonly is associated with the dark layers; northeast of the Pilar-Vadito fault, most of the Ortega Formation consists of this unit plus the underlying reddish quartzite (Xhor)

**Xhor** **Reddish quartzite, Ortega Formation (Paleoproterozoic)**—Reddish, coarse-grained quartzite; probably equivalent to some of the Xho2/Xho3 section southwest of the Pilar-Vadito fault; generally sharp contact with Xhow

**Xhos** **Quartz-mica schist, Ortega Formation (Paleoproterozoic)**—White to pink, quartz-muscovite schist with and quartz eyes; typically contains kyanite and andalusite; this unit has mineralogy and textures transitional between Vadito Group feldspathic schist and Hondo Group quartzites

**Xmg** **Miranda granite (Paleoproterozoic?)**—Exposed east of the Picuris-Pecos fault only; 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.

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

**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; in the Pilar cliffs, the contact with overlying Ortega Formation is a south-dipping ductile shear zone; an pervasive extension lineation in the schist plunges south; the upper 40 m of schist is pinkish, and contains anomalous manganese and rare earth elements, and 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 is unexposed, but the minimum thickness is about 200 m.

**Xvrp** **Rio Pueblo Schist (Paleoproterozoic)**—East of the Picuris-Pecos fault only; well-bedded, white, gray, and pink feldspathic quartz-muscovite quartz-eye schist; locally composed of up to 40% coarse, white muscovite flakes in a matrix of granular quartz and feldspar; quartz-eyes are abundant and are consistently flattened in the dominant foliation plane; the Miranda granite intrudes and crosscuts layering in Xvrp; along the southern contact with a massive gray quartzite, a Mn-rich horizon occurs stratigraphically below the quartzite, and piemontite and altered porphyroblasts that might be pseudomorphs after Mn-andalusite are found along the schist-quartzite contact; this mineralized horizon is similar to that exposed in the Glenwoody Formation of the Pilar cliffs in the Carson and Trampas quadrangles.

**Xag** **Amphibolite in granite (Paleoproterozoic)**—Includes a variety of amphibolite bodies, lenses, and layers within the Miranda granite; the predominant rock type is fine- to medium-grained, dark gray-green to black, weakly foliated amphibolite composed of blue-green to olive-green hornblende, interstitial quartz and plagioclase, sphene, and epidote; faint compositional layering is formed by 1- to 2-mm-thick white layers; epidote veins and zones are common.

**XYu** **Proterozoic rocks, undivided (Paleoproterozoic and Mesoproterozoic)**—In cross section only. Supracrustal metamorphic, metaplutonic, and plutonic rocks of the Picuris Mountains.

## Geologic Cross Section