

# Geologic Map of the Penasco Quadrangle, Taos County, New Mexico

By

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

October, 2005

New Mexico Bureau of Geology and Mineral Resources  
*Open-file Digital Geologic Map OF-GM 062*

Scale 1:24,000

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# GEOLOGIC MAP OF THE PENASCO 7.5-MINUTE QUADRANGLE, TAOS COUNTY, NEW MEXICO

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The Precambrian geology, Paleozoic rocks, and Picuris-Pecos fault were mapped by P. Bauer between 1982 and 2003. Portions of the Tertiary rocks and Quaternary deposits were mapped by K. Kelson and P. Bauer from 2001 to 2003. All of the Tertiary rocks and portions of the Quaternary geology were mapped by S. Aby from 2002 to 2005.

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 NMBGMR.**

Mapping of this quadrangle was funded by a matching-funds grant from the 2001 and 2002 STATEMAP program of the United States Geological Survey National Cooperative Geologic Mapping Program and the New Mexico Bureau of Geology and Mineral Resources.

## DESCRIPTION OF MAP UNITS

### SURFICIAL DEPOSITS

- Qal Stream channel and valley-floor alluvium, and active floodplains (Holocene)**-Poorly to well-sorted sand, pebbles, and boulders. Light-brownish sand, gravelly sand, and sandy gravel with minor mud and silt that underlie modern ephemeral or active channels. Beds are typically very thin to thin and planar or cross stratified. Gravel is mostly poorly sorted, subangular to subrounded pebbles. Sand is typically coarse- to very coarse-grained, poorly to moderately sorted, and subrounded to subangular. There is no soil development and the sediment is loose. Estimated thickness is 1-3 m.
- Qc/Xu Colluvium and talus over Proterozoic bedrock (late Pleistocene to Holocene)**-Colluvium and talus on the southern slopes of the Picuris Mountains derived locally from Precambrian bedrock and Quaternary gravel deposits. The colluvium includes pebbles, cobbles, and boulders. The clasts are poorly sorted and are typically angular to subangular, except for the rounded quartzite cobbles and boulders derived from Qqg. Boulders are up to 2 m in diameter. Clasts are mostly metavolcanic and plutonic rocks, but include pebbles and cobbles of metasedimentary rocks. The matrix is brownish silt to fine-grained sand with some medium- to coarse-grained sand. The colluvium and talus unconformably overlie the Precambrian crystalline bedrock of the Vadito Group. Thickness is typically 2-5 m.
- Qls Landslide deposit (late Pleistocene to Holocene)**-Poorly sorted sand to boulders, may include large, coherent blocks of bedrock. Identified based on geomorphic features such as hummocky topography, arcuate headscarps, and discontinuity in bedrock orientations.

- Qlb **Landslide deposits of basalt (late Pleistocene to Holocene?)**-Small landslide blocks that are composed of intact blocks of Tertiary basalt flows (Tb) and subangular to angular boulders of basalt. Found on slopes below the basalt flows of Vadito mesa.
- QfyQty **Young alluvial-fan and stream terrace deposits (late 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 Tertiary volcanic or sedimentary rocks, rarely Proterozoic rocks. Clasts are primarily Pennsylvanian sedimentary rocks, Proterozoic quartzite, slate, schist, metavolcanic, and granitic rock types, and Tertiary granitic and volcanic rocks. Uppermost sediments are commonly silty sand probably deposited from overbank flow. 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 3 m.
- Qfo, Qto **Alluvial fan and terrace deposits (middle Pleistocene)**-Poorly sorted deposits of silt, sand, and pebbles. Deposits are typically matrix-supported and poorly bedded. Clasts are primarily Paleozoic sedimentary rocks and Precambrian granitic and metamorphic rock types. Moderate pedogenic development, including A, Bt, Btk and Bk soil horizons and stage III and IV calcium carbonate development. Where preserved, upper soil horizons are commonly affected by surface erosion. Map unit Qto typically occurs as isolated remnants on ridge crests, whereas Qfo exists as mountain-front fans. Thickness up to 3 m.
- Qg **Undifferentiated Quaternary gravel deposits (middle to early Pleistocene)**-Typically buff to brownish, rounded to well rounded, crudely bedded, uncemented, quartzite-rich conglomerate and sandy conglomerate. Deposits are typically clast-supported; clasts are pebbles, cobbles, and boulders. Map unit typically exists as isolated remnants on ridge crests or hill tops; soil characteristics are unknown. Thickness is estimated to be as much as 5 m.
- Qqg/Tpl(?) **Quartzite-rich alluvial (and colluvial?) deposits that overlie Tpl (late(?) Quaternary?)**-Surface is covered with Precambrian quartzite clasts from 2 mm to about 3 m, rare Pilar slate clasts to about 7 cm, and extremely rare schist clasts to about 5 cm. Apparently formed as a lag deposit over Tpl. No exposures were found in this area that unequivocally identify Tpl, but rare accumulations of fine material in the 'lag' are more consistent with the greenish and pale grayish color of fines in Tpl, rather than the orange and brownish color of Quaternary fines exposed elsewhere on the quadrangle. These deposits exist at 8000-9000 ft elevation and are shaded in winter.

### TERTIARY ROCKS AND DEPOSITS

- QTg **Older alluvium (Pliocene to early Pleistocene)**-Poorly sorted sand and gravel deposits, typically with layers containing large rounded boulders of Proterozoic quartzite. Found on high erosional pediment surfaces, and commonly forms colluvial veneer on underlying units. Maximum thickness of 10 m.
- Tb **Ocate basalt (Pliocene)**-Dark-gray, vesicular, olivine tholeiite basalt flow found on high mesa in east-central map area, and as scattered, isolated remnants to the west. This unit was considered equivalent to 2.8-4.5 Ma flows of the Taos plateau volcanic field by Miller et al. (1963). However, Rehder (1986) cites a 1986 personal communication from R.L. Nielsen (Stephen F. Austin State University) that states that this basalt is equivalent to a 5.7 Ma (O'Neill and Mehnert, 1980) basalt flow of the Ocate volcanic field to the east. A new whole-rock  $^{40}\text{Ar}/^{39}\text{Ar}$  date of 5.67 +/- 0.12 Ma confirms that Tb is time equivalent to rocks of the Ocate volcanic field to the east. Locally up to

10 m thick. East-to-west trace of scattered exposures may indicate the original course of the basalt flow along a Pliocene paleovalley.

**Tg High alluvial gravel (Pliocene?)**-Poorly exposed, coarse-grained, gravel to boulder deposit that is mapped only near the top of Vadito Hill, below the Ocate basalt flow. The deposit appears to be composed entirely of well-rounded, fairly well-sorted, sub-rounded cobbles and boulders of coarse-grained, reddish, Pennsylvanian sandstone derived from the Sangre de Cristo Mountains to the west. Field relations indicate that Tb basalt flowed down a paleovalley that was mantled by these gravels. Thickness is estimated at a few meters.

**Td Dixon member of Tesuque Formation of Santa Fe Group (middle Miocene)**-Red, tan, beige, and locally greenish and/or yellowish sandy to clayey silt and silty clay. Loose to slightly friable, moderately well sorted to moderately poorly sorted, mostly massive(?) but locally thinly to moderately thickly laminated and/or in beds approximately 0.1-6(?) m thick. Locally moderately carbonate cemented. Interbedded with tan, brownish, reddish, and characteristically light olive green conglomerate to fine arkosic sandstone that is very friable to nonfriable, very fine lower to very coarse upper, moderately to very poorly sorted, generally subangular to subrounded, thinly to thickly bedded, and locally carbonate cemented. Conglomerates contain abundant poorly to moderately rounded clasts of Precambrian quartzite and Paleozoic sandstone, limestone, and siltstone. Locally, conglomerates also contain clasts of Tertiary volcanic rocks, especially in the coarser fraction, but quartzite and Paleozoic sedimentary clasts everywhere predominate (by definition). Sedimentary features other than plane lamination are not common but include ripple marks, cross beds, and lateral accretion (point-bar) foresets. Contacts between beds are typically abrupt and bases of sandstones and conglomerates are commonly scoured, with 0.01-1 m of relief. Imbrication of clasts is not common and often chaotic, but is locally well developed (e.g., in Canada de los Alamos exposures). Sandstones and conglomerates are preferentially cemented with calcium carbonate. Carbonate cement commonly forms a sparry white matrix between grains and helps to explain the overall rarity of sedimentary features. Exposures range from excellent in the coarse-grained beds exposed along the southern scarps of the Llano de la Llegua and on the northwest side of Canada de Los Alamos, to almost non-existent in dominantly fine-grained beds south and west of Chamisal Creek. Even where the unit is coarse-grained, good, natural exposures are limited to south- or southwest-facing slopes. Paleocurrent indicators (imbrications and the strikes of channel walls) indicate transport from the south, southeast, and southwest. Exposed thickness is 75-100 m.

**Tpu Upper volcanoclastic member of Picuris Formation and/or Chama-El Rito member of Tesuque Formation (early to middle Miocene)**-Red to purple pebble and gravel conglomerate. Very friable to nonfriable, very poorly to moderately well sorted, poorly rounded to rounded, thickly to thinly bedded, typically carbonate cemented. Composed predominantly of Tertiary volcanic clasts, rounded Precambrian quartzite clasts, tan, pinkish, and whitish, loose to slightly friable, very fine lower to very coarse upper, moderately well to very poorly sorted, subangular to subrounded and rarely rounded, thinly to thickly bedded, locally carbonate-cemented, arkosic to lithic sandstone beds, and brick-red to pink, tan to brown, orange, and whitish, loose to slightly friable, moderately well to poorly sorted, thinly to thickly bedded, locally weakly carbonate cemented, sandy silt to silty clay beds. Most contacts between beds are abrupt and the basal contacts of the coarser beds are commonly scoured. Exposures become more and more rare upward in the section due to an increase in the proportion of fine beds(?). Upper contact is not exposed in the map area, but appears to be depositional and possibly gradational and/or interfingering (or the base of the overlying Dixon member of the Tesuque Formation may contain reworked Tpu). The upper contact is placed at the top of the highest conglomerate bed that is dominated by Tertiary volcanic clasts rather than by Paleozoic sedimentary clasts. Weathering of volcanic clasts within this unit is highly variable. In many exposures, volcanic clasts are well preserved and coherent, whereas in others, various stages of decomposition exist. In some exposures, pumice lapilli within welded tuff clasts are completely weathered, whereas the welded matrix is relatively pristine. Where Tpu is exposed beneath terrace deposits, such as south of

Picuris Pueblo and at the northwest tip of the Llano surface, 90% of volcanic clasts are highly weathered. Approximately 10-100 m thick. Stratigraphic relations between these strata and others mapped as Chama El Rito Member of Tesuque Formation by Steinpress (1980) and Koning and Aby (2003) are discussed in Aby et al. (2004). A basalt clast from the basal part of the upper member at Hill 7751' was dated at 19.78 +/- 0.24 Ma (Aby et al., 2004) and the unit is overlain by the Dixon member of the Tesuque Formation which is estimated to be 12.5 to 14.5 Ma regionally (Koning and Aby, 2003). Current age constraints, based on  $^{40}\text{Ar}/^{39}\text{Ar}$  geochronology and regional depositional patterns, indicate that Tpu spans a range from less than 19.8 Ma (or ~18 Ma) to approximately 15 Ma (based on inferred age of overlying Dixon member of Tesuque Fm).

**Tpmc Cemented part of middle tuffaceous member of Picuris Formation (early Miocene)**-This unit is characterized by silica cementation and is here informally defined as the interval between the lowest and highest pervasively silica-cemented beds within the Picuris Formation. Some beds in this interval, in some locations, are either poorly cemented or cemented with both calcium carbonate and silica. Buff to white and/or pinkish silty sandstone to fine cobble conglomerate. Nonfriable to strong, very fine lower to very coarse upper, very poorly to moderately sorted, rounded to subangular, thinly to thickly bedded, silica-cemented. Locally contains a basal portion of poorly sorted pebbly/gravelly sandstone and/or cobble/boulder conglomerate composed exclusively of Precambrian clasts. This portion of the unit grades upward (or laterally?) into pebbly/gravelly sandstone and conglomerate composed of an increasing proportion of Tertiary pumice and/or Tertiary volcanic clasts relative to Precambrian clasts. In exposures along NM-76 between Chamisal and Penasco (The 'Chamisal exposures' of Aby et al., 2004) the lowest, exposed, cemented part of the middle member is at least 13 m of moderately to moderately well sorted, thickly bedded, sub-rounded to angular cobble and boulder conglomerate composed of Precambrian granite(46%), quartzite(26%), amphibolite (26%), phyllite (1%), and schist (1%). Although the lowermost 1-3 m of this conglomerate are not silica-cemented, and thus should be part of Tpm, these exposures are not map scale and are therefore shown as Tpmc on the map. In areas to the east and north of the Penasco quad, Rehder (1986) mapped a Precambrian-derived basal conglomerate beneath beds equivalent to our middle member. It is possible that the lowest part of the cemented section in the Chamisal exposures is correlative to these beds. Soft-sediment deformation features exist in uncemented parts of the middle member, particularly at its upper contact, but are spectacularly preserved by silica cementation in the Chamisal exposures. The upper contact of the Tpmc (and Tpm) is the top of the last silica-cemented bed. This contact locally displays flame structures. Rare paleocurrent indicators show transport from the northwest, north, and northeast. Approximately 10-35 m thick. Tpmc is everywhere found at the top of the Tpm and sometimes includes all or part of the gradational and/or interfingering contact with Tpu. Assignment of Tpmc to the middle member is a matter of convenience, as some beds are dominated by Tertiary volcanic clasts and are therefore sedimentologically more similar to Tpu. However, Tpmc is a mappable and useful field unit. In discussing the Picuris Formation as a whole, Aby et al. (2004), did not differentiate this silica-cemented portion as a separate unit and therefore parts of Tpmc as mapped here would be either Tpm or Tpu by definitions used in that report. Current age constraints, based on  $^{40}\text{Ar}/^{39}\text{Ar}$  geochronology indicate that Tpmc is younger than approximately 23 Ma.

**Tpm Middle tuffaceous member of Picuris Formation (late Oligocene to early Miocene)**-Light buff, yellowish, and locally white ashy/quartzose, silty, fine sand to pebbly sandstone. Very friable to somewhat friable, moderately(?) to very poorly sorted, commonly bimodal, massive. Very thickly to thinly bedded, and with locally well-developed fining upward sequences a few to tens of cms thick, particularly at Cerro Blanco. Most sandstone beds contain a small percentage of medium lower to coarse upper grains of Pilar slate and quartzite. Thin to thick (5 cm-1.5 m) interbeds and channel-fills of buff and black, friable, moderately to poorly sorted, subangular to subrounded, Precambrian Pilar slate and quartzite-rich, and/or Tertiary pumice-rich conglomerate. Lower portion, just west of Cerro Blanco and just east of granitic highland in Section 29, is poorly sorted, fine- to coarse-grained, grussy, pebbly sand. Near abandoned power substation in Section 32, southwest of Vadito, it contains rare pebbly/gravelly channels that are

rich in granite, epidote, slate, amphibolite, and schist(?), and a single exposure of boulder conglomerate composed of Precambrian Penasco quartz monzonite porphyry, quartzite, and amphibolite. White ash beds (15-65 cm) are in exposures north of the Rio Pueblo drainage. Some ash layers distinctly bioturbated. Conglomerate beds seem to increase in abundance towards the upper contact. Some conglomerate beds contain abundant, rounded Tertiary pumice lapilli. Lapilli in lower portions of unit are white or pink, mafic-poor, with phenocrysts of quartz and plagioclase. Near, and at, the upper contact (and also within parts of Tpmc) is a biotite-rich pumice. Lower contact is not exposed in map area. Upper contact is mapped as the base of the first silica-cemented bed in the section. Sedimentary features and bedding are absent to very poorly expressed, except where coarse-grained or ashy beds exist. Coarse-grained beds have scoured basal contacts with 0.1-1 m of relief. At least 150 m thick (base not exposed) in northern exposures. Primary ash fall from the Amalia Tuff eruption has been identified within the middle member at Cerro Blanco and similar ash beds exist at Hill 7751' on Picuris Pueblo lands. Pumice from the Amalia Tuff eruption(s) have been identified at several places along the southeastern edge of the Picuris Mountains (Peters, 2005). Two additional populations of pumice of approximately 23 and 27 Ma have been identified within the Tpm (Aby et al., 2004; Peters, 2005). These pumice clasts are presumed to be derived from pre-and post-caldera eruptions in the Latir volcanic field. Aby et al. (2004) overemphasized the carbonate-poor nature of the Tpm due to a bias toward examination of primary ash beds. Although the bulk of this unit is somewhat less effervescent than other Tertiary units in the area, it is mostly moderately reactive in hydrochloric acid. Aby et al. (2004) also failed to recognize small-scale fining upward sequences indicative of fluvial deposition in the upper half(?) of this unit. These fining-up sequences are best seen on the slopes of Cerro Blanco. Current age constraints, based on  $^{40}\text{Ar}/^{39}\text{Ar}$  geochronology, indicate that Tpm was deposited approximately between 28.3 Ma and less than about 23 Ma.

**Tpl Lower conglomerate member of Picuris Formation (late(?) Eocene to late Oligocene)**-Not exposed on Penasco Quadrangle, but probably underlies areas within the Agua Caliente Canyon drainage in the northwest map area and in Picuris Canyon. Where exposed on adjacent quadrangles Tpl consists of greenish and pale yellowish, loose to strong, poorly sorted, moderately to well rounded, sandy/silty conglomerate that is dominated by Precambrian Hondo Group quartzite clasts from 2 mm to >2 m. See Aby et al. (2004) for a regional discussion of this member. Current age constraints, based on  $^{40}\text{Ar}/^{39}\text{Ar}$  geochronology, indicate that Tpl ranges from more than about 34.5 Ma to less than about 28.3 Ma.

## PALEOZOIC ROCKS

**/P/M Undivided Mississippian and Pennsylvanian sedimentary rocks of the Tererro Formation of Arroyo Penasco Group (Mississippian, Meramecian and Chesterian), Espiritu Santo Formation of Arroyo Penasco Group (Mississippian, Osagean), Alamitos Formation (late Desmoinesian), and Flechado Formation (Morrowan-Atokan-Desmoinesian)**-Consists chiefly of Pennsylvanian, poorly exposed, olive, brown, red, and dark gray shale and siltstone plus fine- to coarse-grained sandstone with lesser amounts of conglomerate and limestone. Alamitos Formation is equivalent to the "upper arkosic limestone member" of the Madera Formation to the south. Flechado Formation is equivalent to La Posada Formation to the south, which is equivalent to the Sandia Formation and the "lower gray limestone member" of the Madera Formation. Fusilinids collected from the exposures southeast of Taos Pueblo are Desmoinesian in age (B. Allen, personal communication, 2000). To the north, in the Ranchos de Taos Quadrangle, the Tererro Formation consists of 1-2 m of basal stromatolitic limy sandstone overlain by about 7m of dolomitic limestone, overlain by about 12m of calcitic dolomite with stromalites and bedded and nodular chert (Armstrong and Mamet, 1990). Thickness is approximately 20 m. The Espiritu Santo Formation consists of the basal Del Padre Sandstone member of basal conglomerate, quartz sandstone, siltstone, shale, and minor limestone beds at top. It grades into the overlying Tererro Formation. Thickness of the Pennsylvanian section is unknown, but a minimum of approximately 2000 m.

## PROTEROZOIC IGNEOUS ROCKS

- dd **Diorite dike (age unknown, but probably Middle Proterozoic)**-Dark green-gray quartz diorite dike intruded into Proterozoic rocks. Dike is vertical, with strikes clustered around an azimuth of 150°. Composed of pale green clinopyroxene (Cr-diopside?), zoned plagioclase (labradorite?), and minor quartz, magnetite, and ilmenite. Commonly altered to chlorite and clay. Pyroxene and feldspar show normal plutonic textures. Locally, dike is laced with carbonate veins. Generally less than 1 m wide. Contacts between diorite and country rock are sharp and commonly correspond with local fracture zones. Similar dikes have been mapped in the Carson Quadrangle of the northwest Picuris Mountains.
- xxx **Pegmatite**-Predominantly simple pegmatites of quartz, K-feldspar, plagioclase, and muscovite. Pegmatite bodies typically are dikes or lenses, locally aligned parallel to country rock foliation. Thicknesses range from 2 cm to 15 m. 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).
- Ypqm **Peñasco Quartz Monzonite**-Biotite quartz monzonite to granodiorite. Composed of quartz, plagioclase, microcline, and biotite. Euhedral 1 mm sphene crystals common. Accessory minerals are muscovite, allanite, epidote, magnetite-hematite, apatite, and zircon. Locally contains tabular megacrysts of Carlsbad-twinned microcline up to 9 cm in length. Myrmekite and albite rims on plagioclase are common. Massive to weakly foliated, except locally along contacts where foliation is well developed. Generally concordant with country rock contacts and foliation. No compositional border zone. Mafic microgranitoid enclaves are common, especially near borders. U-Pb zircon isotopic age of about 1450 Ma in Trampas quadrangle (Bell, 1985).
- Xpgp **Puntiagudo Granite Porphyry**-Quartz monzonite to granodiorite. Phenocrysts of Carlsbad-twinned microcline (<1cm) and rounded quartz in fine- to medium-grained matrix of plagioclase, K-feldspar, biotite, and muscovite. Accessory minerals are epidote, allanite, sphene, and zircon. Pervasive, moderately to well-developed foliation is parallel to regional foliation. U-Pb zircon isotopic age of 1684 Ma (Bell, 1985) in the Trampas quadrangle. Exposed only in southwestern corner of map area.
- Xg **Picuris Pueblo granite (informal name)**-West side of the Picuris-Pecos fault. Medium- to coarse-grained granitic rocks which show a variety of local textures ranging from coarse-grained, pink feldspar-rich rock to white, quartz-rich rock. In thin section, these rocks show interlocking mosaics of microcline, plagioclase, quartz, biotite, and iron-oxide minerals. Most samples exhibit considerable alteration of feldspars and mica. These granitic rocks are intimately interlayered with supracrustal Vadito Group country rock. Blocks of orthoquartzite within the plutonic rock strongly suggest an intrusive relationship between the two. Contacts between granitic rock and supracrustal rock invariably trend east, parallel to bedding in the country rock. This name supersedes the informally named Granite of Picuris Peak of Bauer (1988). Age unknown, but texturally similar to ca. 1680 Ma granitoids of the western Picuris Range.
- Xm **Miranda granite (informal name)**-Northeastern map area, east of the Picuris-Pecos fault. Generally 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. In places, this rock could be mistaken for an arkose. Appears to intrude the Rio Pueblo schist along 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. This name supersedes the informally named Granite of Alamo Canyon of Bauer (1988). Age unknown, but similar in occurrence and texture to Tres Piedras Granite of east-central Tusas Mountains.

## EARLY PROTEROZOIC HONDO GROUP

- Xhpl **Piedra Lumbre Formation**-Small exposure in northwest corner of map. Includes quartz-muscovite-biotite-garnet-staurolite phyllitic schist and finely laminated light gray phyllitic quartz-muscovite-biotite-garnet schist and darker bluish gray fine-grained biotite quartzite to metasilstone. Calc-silicate layers exist locally. Original sedimentary structures such as crossbedding and graded bedding are locally 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.
- Xhp **Pilar Formation**-Exposed only in northwest corner of map and as fault-bounded sliver in section 14 of northwestern map area. Dark gray to black, carbonaceous phyllitic slates. Extremely fine-grained homogeneous rock except for rare 1- to 2-cm-thick light colored bands of quartz and muscovite that probably represent true 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, altered, and red-weathering. Contact with Piedra Lumbre Formation is gradational.
- Xhr6 **Rinconada Formation, R6 schist member**-Small exposure in northwestern map area. Tan, gray, silver quartz-muscovite-biotite-staurolite-garnet schistose phyllite interlayered with fine-grained garnetiferous 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 Hp. Thickness is approximately 90 m.
- Xhr5 **Rinconada Formation, R5 quartzite member**-Small exposure in northwestern map area. Variety of white to blue medium-grained quartzites interlayered with fine-grained schistose quartzites and quartzose schists. Gradational contact with Hr6. Thickness is approximately 75 m.
- Xhr4 **Rinconada Formation, R4 schist member**-Small exposure in northwestern map area. Medium- to coarse-grained, silvery gray, quartz-muscovite-biotite-staurolite-garnet schist containing one or more distinctive, 0.5-2.0 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. Sharp contact with Hr5. Thickness ranges from about 50-175 m.
- Xhr3 **Rinconada Formation, R3 schist member**-Small exposures in northwestern map area. White, gray, bluish-green and blue, medium-grained, thinly to thickly bedded, resistant quartzite with abundant crossbeds. Distinctive marker layer near center of member is 25 m-thick white, thinly bedded, ridge-forming quartzite. Sharp contact with Hr4. Thickness is approximately 75 m.
- Xhr1,2 **Rinconada Formation, R1-R2 schist member**- exposed? 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 base are black biotite books (<2 cm) and local 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 (<2 mm). Strong parting along foliation plane. Sharp to gradational contact with Hr3. Lower and upper unit have previously been subdivided into R1 and R2, respectively, based on mineralogy (Nielsen, 1972). Thickness is approximately 265 m.



- Xho **Ortega Formation, undivided**-Gray to grayish-white, medium- to coarse-grained quartzite. Generally massive and highly resistant. Locally well-crossbedded, and kyanite-bearing. Crossbeds defined by concentrations of black iron-oxide minerals. Aluminum silicate minerals are concentrated in thin muscovite schist horizons. Common accessory minerals are ilmenite, hematite, tourmaline, epidote, muscovite, and zircon. Gradational contact with Rinconada Formation. Thickness is approximately 800-1200 m.
- Xhow **Ortega Formation massive white quartzite**-Northeast of the Pilar-Vadito fault. 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 dark layers. Northeast of the Pilar-Vadito fault, most of the Ortega Formation consists of this unit plus the underlying reddish quartzite (Hor).
- Xhor **Ortega Formation reddish quartzite**-Northeast of the Pilar-Vadito fault. Reddish, coarse-grained quartzite. Probably equivalent to some of the Ho2-Ho3 section southwest of the Pilar-Vadito fault. Generally sharp contact with How.
- Xhosq **Ortega Formation schistose quartzite**-Northeast of Pilar-Vadito fault, west of Picuris Canyon. Thin horizon of white, muscovite-rich, well-bedded quartzite. May be equivalent to part of Hos.
- Xhos **Ortega Formation quartz-mica schist**-Northeast of Pilar-Vadito fault, near Picuris Canyon, north-central map area. White to pink, quartz-muscovite schist with porphs and quartz eyes. Typically contains kyanite and andalusite. This unit has mineralogy and textures transitional between Vadito Group feldspathic schist and Hondo Group Ortega Formation.
- Xhog **Ortega Formation gray quartzite**-Northeast of Pilar-Vadito fault, near Picuris Canyon, north-central map area. Medium-gray, fine-grained, vitreous quartzite with well-developed south-plunging kyanite extension lineation. Much of this unit is a quartz mylonite, with abundant evidence for grain size reduction and dynamic recrystallization. Shearing is related to adjacent ductile Plomo fault.
- Xho3 **Ortega Formation mixed quartzites**-Southwest of the Pilar-Vadito fault. Various quartzites including reddish coarse-grained quartzite, brown medium-grained quartzite, gray quartzite, garnet-bearing dark quartzite, and tan cross-bedded quartzite. Thickness is approximately 250 m.
- Xho2 **Ortega Formation black quartzite**-Southwest of the Pilar-Vadito fault. Dark gray to black, massive, medium-grained quartzite. Commonly crossbedded, and generally contains a well-developed extension lineation defined by kyanite. Thickness is approximately 200 m.
- Xho1 **Ortega Formation laminated schist**-Southwest of the Pilar-Vadito fault. Reddish to orange-brown to white quartz-muscovite schist containing thin interlayers of light quartz-rich and darker mica-rich schist. Exposed only in a small area in the core of the Copper Hill anticline in the northwestern map area. Base is unexposed.

#### EARLY PROTEROZOIC VADITO GROUP

- Xvht **Transitional Vadito Group-Hondo Group rocks**-North-central map area on east side of Picuris Canyon. Includes a variety of rock types intermediate in mineralogy and texture between the metavolcanic rocks of the Vadito Group and metasedimentary rocks of the Hondo Group. Conglomeratic schistose quartzite, white quartz-muscovite feldspathic schist, gray quartzite and metaconglomerate, conglomeratic quartzite and schistose quartzite with clasts of bull quartz, quartzite, and fine-grained black rock, schistose metaconglomerate, and quartz-eye conglomerate. Gradational eastward along strike with feldspathic schists (Vvf) of the Vadito

Group. Might be equivalent to part of transitional section south of Kiowa Mountain in the Tusas Mountains (Bauer and Williams, 1989), however, in this map area VHT has been disrupted by the Plomo fault.

- Xvrp **Rio Pueblo schist**-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 consistently flattened in the dominant foliation plane. Along the northern contact the Miranda granite intrudes and crosscuts layering in the schists. 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.
- Xvf **Felsic schist, undivided**-Includes a variety of quartz-muscovite-plagioclase schists. Coarser-grained felsic rocks are tan to pinkish quartz-plagioclase-muscovite-biotite-opaque slightly schistose units with polycrystalline quartz eyes (2-8mm). Eyes are slightly flattened in foliation, and probably represent relict phenocrysts in felsic volcanic rock. Trace minerals include sphene, apatite, monazite, zircon, and tourmaline. Finer-grained felsic rocks are similar in mineralogy to coarser units, but lack the abundant quartz eyes. Small red idioblastic garnets are rare. Small lensoidal bodies of tan to orange-red, garnet-bearing, quartz-muscovite-opaque schist are found locally. Many of the felsic schist bodies appear to be intrusive into Vadito Group schists. Includes some intermediate(?) feldspathic schists in the Picuris Canyon area.
- Xvm **Marqueñas Formation, undivided**-Fine- to medium-grained, grayish, texturally immature, schistose quartzite. Crossbeds are small-scale features defined by black mineral laminae. Also includes a variety of metaconglomerates containing dominantly rounded quartzose clasts in a quartz-mica matrix. The Marqueñas Formation may be equivalent to the Big Rock Formation of the Vadito Group in the Tusas Mountains.
- Xvm3 **Marqueñas Formation northern metaconglomerate**-Predominantly composed of flattened quartzite pods. Micaceous quartzite matrix contains scattered clasts, up to 10 cm long, of metasedimentary quartzite (66%), felsic schist (34%), and traces of vein quartz. Alternating lithologic layers that might indicate original bedding are absent. This unit was described as a flaser-bedded quartzite in the Trampas quadrangle (Nielsen and Scott, 1979). However, it is probably a sheared, originally thinly bedded pebbly quartzite (Holcombe and Callender, 1982). Gradational with Marquesnas Formation quartzite to the south.
- Xvm2 **Marqueñas Formation quartzite**-Fine- to medium-grained, grayish, texturally immature, schistose quartzite. Abundant crossbeds ranging from small-scale features defined by black mineral laminae to large festoons with cross laminations several cm thick. Crossbeds consistently young to the north. Pebble-rich layers also define bedding. Contacts with adjacent metaconglomerates are gradational.
- Xvm1 **Marqueñas Formation southern metaconglomerate**-Polymictic metaconglomerate containing rounded clasts of quartzite (54%), silicic metavolcanic rock and quartz-muscovite schist (40%), and white vein quartz in a muscovite quartzite matrix. Clasts are flattened and constricted in the dominant foliation; aspect ratios average 1:2:3 to 1:2:6, with extremes of 1:2:16 or greater. Matrix averages about 30% of volume of rock. Minor phases in matrix include ilmenite, biotite, magnetite, hematite, zircon, and tourmaline.
- Xvmix **Mixed metavolcanic rocks**-In the northern map area, north of Picuris Pueblo. Includes a variety of interbedded mafic to intermediate, schistose to gneissic to amphibolitic rocks.

- Xvs **Schists, undivided**-Includes a variety of pelitic to semi-pelitic schists. Relatively massive, light gray, fine-grained quartz-muscovite schist with scattered flakes of black biotite (<1 mm) and compositional layers defined by alternating quartz-rich and mica-rich horizons 1-25 mm thick. Quartz-muscovite schist with porphyroblasts of biotite, garnet, and andalusite. Fine-grained quartz-muscovite schist with scattered porphyroblasts of biotite. Also includes local horizons of interlayered amphibolite.
- Xvsa **Andalusite schist**-Distinctive, black, biotite schist containing large knobs of andalusite. This unit is only a few meters thick and appears to pinch out laterally in both directions.
- Xva **Amphibolite**-Includes a wide variety of amphibolite bodies, lenses, and layers, and textures. 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 (0.1-0.7 mm), interstitial quartz and plagioclase (0.1 mm), sphene, and epidote. Faint compositional layering is formed by 1-2 mm-thick white layers. Epidote veins and zones are common, especially near pluton margins. Fragmental amphibolites containing white felsic fragments and gray lithic fragments, elongated and flattened in foliation of fine-grained hornblende matrix, occur locally. Subangular gray quartzite clasts, black basaltic fragments, and epidote clasts also exist within the matrix. Smaller layers and lenses within Vadito schist are mainly fine- to medium-grained amphibolites that range considerably in texture and mineralogy.