Preliminary Geologic Map of the Jarosa Quadrangle, Rio Arriba County, New Mexico

By

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Geology of the 7.5-Minute Jarosa Quadrangle, Northwestern Jemez Mountains, New Mexico

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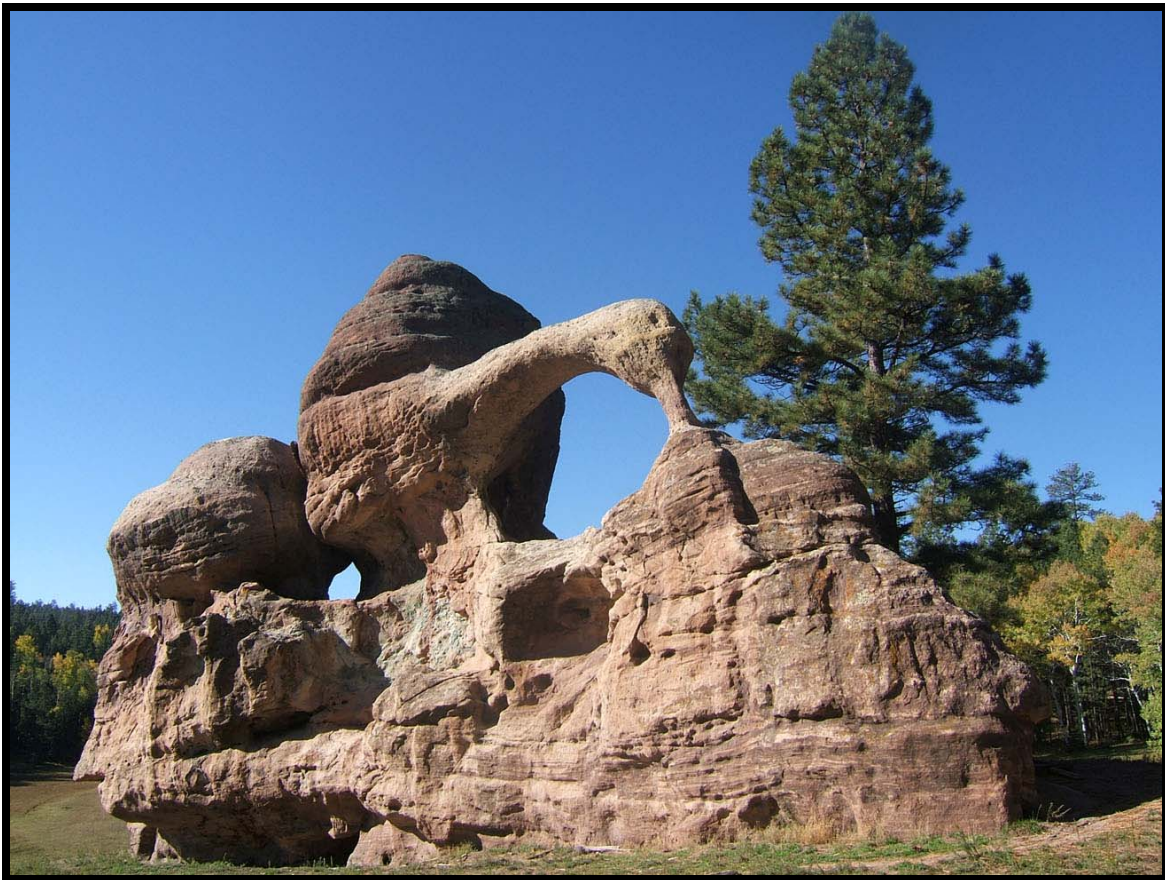
Teakettle Rock – El Cobre Canyon Formation, Cutler Group

Geologic Overview

The Jarosa 7.5-minute quadrangle in the northern Jemez Mountains lies at a zone of major geologic boundaries, including the Nacimiento uplift, the Chama Basin, the Rio Grande rift, and the Jemez volcanic province. Outflow facies of the Bandelier Tuff, both the Otowi and Tshirege members, cap the stratigraphic sequence in the eastern half of the quadrangle while exposures in the Rio Puerco and Rito Resumidero in the northwest portion of the quadrangle provide a rare glimpse into the underlying Precambrian rock, a muscovite- and biotite-bearing granite. The granite is nonconformably overlain by Late Paleozoic strata of the Guadalupe Box Formation (Arkosic Member of the Madera Limestone), Cutler Group, and the Yeso Formation, with an Upper Triassic sequence (Chinle Group) resting unconformably above these units. The Tertiary Abiquiu Formation and Ritito Conglomerate are stratigraphically sandwiched between the Upper Triassic Chinle Group and the Quaternary Bandelier Tuff, capping the highest ridges and mesas in the southern half of the quadrangle. The northwest-trending Mesa Pinabetal fault represents the structural boundary between the Chama Basin to the northeast and the Nacimiento uplift to the southwest. This fault, along with 3 significant east-facing monoclines, provide over 500 meters of down-to-the-east structural offset.

Geologic mapping of the Jarosa quadrangle has provided several insights into the geologic history of the region, including:

1) The Bandelier Tuff has been broken out into its two members, the Tshirege (**Qbt**) and Otowi (**Qbo**), revealing the major flow pathways and paleotopography that existed at the time of each eruption.

2) Mapping of the Tertiary Abiquiu Formation and Ritito Conglomerate reveals their distribution and relative thicknesses in the quadrangle. The Pedernal Chert is pervasive at the contact between these two units and typically forms a cap rock for the Abiquiu Formation where still preserved. Discontinuous chert lenses occur within both the Abiquiu Formation and the Ritito Conglomerate.

3) Identification of the Permian Yeso Group sediments in the northern portion of the quadrangle. Exposures in Puerco and Jarosa canyons reveal up to 30 meters of eolian

sandstone (De Chelley Sandstone = Meseta Blanca Member) and are unconformably overlain by basal strata of the Triassic Chinle Group.

4) Differentiation of the Chinle Group, showing the extent, distribution and thickness of its members, including the Shinarump Formation, the Salitral Formation, and the Poleo Formation. Possible exposures of the Petrified Forest Formation, including the Mesa Montosa member, were lumped as upper Triassic deposits above the Poleo sandstone (TRcu).

5) Mapping of major structures in the quadrangle, including the Mesa Pinabetal fault and three major east-facing monoclines, reflecting structural trends related to Laramide compression and subsequent extension during further uplift of the Nacimientos in the Miocene.

Unit Descriptions for the Jarosa 7.5-minute Quadrangle

Quaternary Units

Qal – Alluvium. Late Pleistocene to Holocene. Alluvial deposits in modern drainage bottoms and elevated basins. Deposits include conglomerates, sands, and silts. Holocene terrace deposits less than 2 meters above drainage bottoms are included.

Qc – Colluvium. Late Pleistocene to Holocene. Poorly sorted talus, debris, and other rock fragments derived from local volcanic and sedimentary rocks. Often occurs as wedge-shaped hillslope deposits. Although pervasive throughout the quadrangle, colluvium was seldom mapped. Maximum thickness is approximately 5 meters.

Ql – Landslides. Pleistocene to Holocene. Unsorted, chaotic debris emplaced during a single detachment event from a steep slope or cliff, generally containing a sediment matrix. Also, slump or block slides, especially along the flanks of steep hillslopes such

as Coyote Creek canyon. Fan-shaped deposits occur where debris spread out on valley floor. Thickness can exceed 20 meters.

Figure 1. Locally-derived anthrogenic colluvium.

Qbt – Upper Bandelier Tuff, Tshirege Member. Quaternary. White to orange non-welded to welded ash-flow tuff containing abundant phenocrysts of quartz and sanidine, with rare microphenocrysts of clinopyroxene and hypersthene. Ash-flow tuff beds consist of multiple flow units in a compound cooling unit with thin surge beds (less than 0.5 meters thick) locally exposed. Erupted at approximately 1.25 Ma during the formation of the Valles Caldera (Goff et al., 2011; Spell et al., 1996). In rare exposures, the Tsankawi tephra deposit was found underlying the Tshirege tuff (up to 2.2 meters thick –photo of Dick Buffler and Tsankawi tephra below).
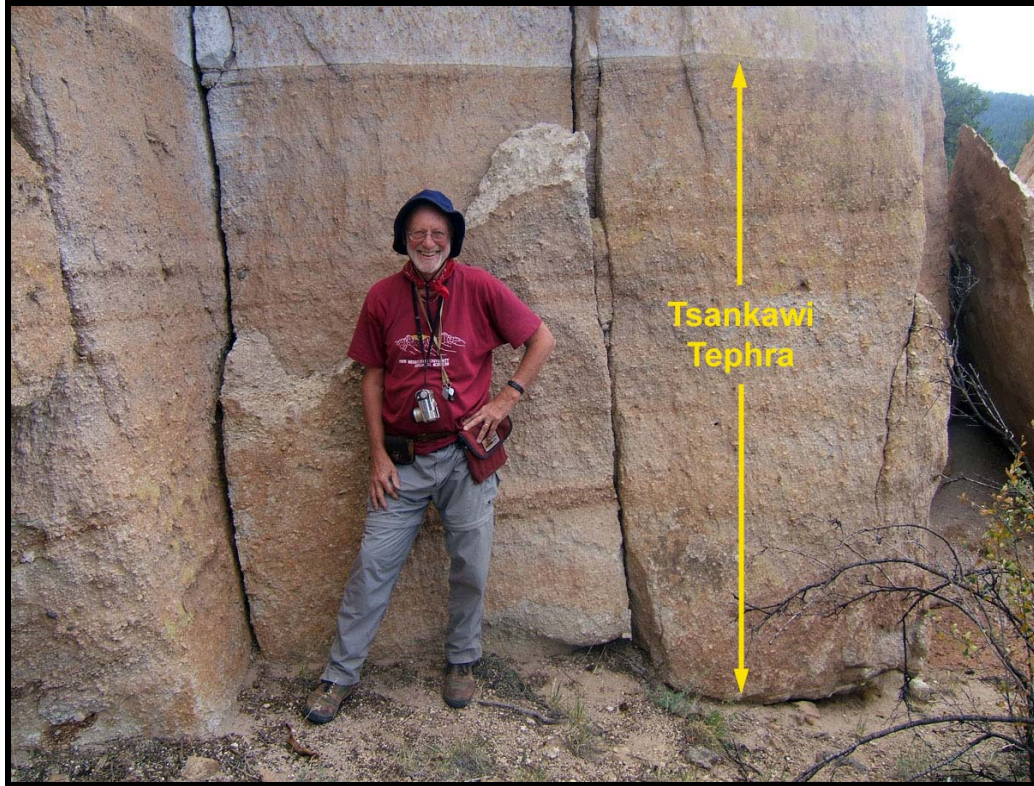
Figure 2. Approximately 3 meters of Tsankawi tephra preserved at the base of the
Tshirige member of the Upper Bandelier Tuff.

Exposures of Qbt along tributary systems of Coyote Creek canyon often appear auto
brecciated, possibly due to remobilization after tuff solidification. Maximum thickness is
approximately 80 meters.

Two photos (Figure 3a and 3b) show **Qbt** autobreccias typical in tributaries of
Coyote Creek and Jaquez Canyons.   Many exposures in these canyons are younger
landslide deposits. However, several exposures display clasts of tuff in a tuff matrix
(autobrecciated) that appears to be indurated more than landslide deposits – possibly
representing tuff remobilized during the solidification process.

Figure 3a and b. Autobrecciated Upper Bandelier Tuff that might represent tuff that was remobilized during the solidification process.

Qbo – Lower Bandelier Tuff, Otowi Member. Quaternary. White to medium gray non-welded to welded ash-flow tuff containing abundant phenocrysts of quartz and sanidine with rare mafic phenocrysts. Multiple cooling units typically with abundant lithic fragments, although lithic poor horizons do occur, especially in more densely welded cooling units. No deposits of Guaje tephra were found at the base of the unit. A gray welded unit in the lower part of the Otowi Member dips 5 to 10° south in the southeastern corner of the quadrangle, lapping onto the south side of paleohighs underlain by Abiquiu Formation. $^{40}Ar/^{39}Ar$ ages 1.61± 0.01 to 1.62±0.04 Ma (Izett and Obradovich, 1994; Spell et al., 1996). Maximum thickness is approximately 100 meters.

Tertiary Units

QTg – Alluvial gravels. Late Pliocene to Early Pleistocene. Unconsolidated alluvial deposits including conglomerates, sands and silts. Generally occur as poorly exposed alluvial and colluvial deposits beneath exposures of Bandelier Tuff (**Qbt** and/or **Qbo**). Clasts of Proterozoic granite and quartzite, recycled Ritito Conglomerate (Tr) are common. These gravels may correlate with the Cerro Toledo interval and Puye Formation of the Pajarito Plateau area. Approximately 1 to 5 meters thick.

Ta – Fine-grained sandstones, shale and tuffaceous and arkosic limestone. Abiquiu Formation. Late Oligocene to Early Miocene. Poorly exposed calcareous and tuffaceous mudstone, limestone, and fine-grained sandstone that has a gradational contact with the underlying Ritito Conglomerate (**Tr**). Some tuffaceous layers appear to be primary, or slightly reworked tepra (Figure 4). The unit fines upwards with increasing volcaniclastic material. The most pervasive Pedernal Chert horizons occur at the boundary between the upper and lower members, but is also common capping the Abiquiu Formation. Lenticular, chert horizons occur sporadically within the formation and the underlying Ritito Conglomerate. Maximum thickness is approximately 70 meters.

Figure 4. Photomicrograph of vitric tephra from the Abiquiu Formation (Ta) near Cerro Jarocito showing bubble-wall glass shards and sanadine in dusty, glass matrix.

Tpc/Tpcu – Pedernal chert. Uncertain age. Chert horizons occur primarily at the boundary of the Abiquiu Formation and Ritito Conglomerate, and capping the Abiquiu Formation. In general, the chert is white to translucent with bands of black, yellow and orange coloration. Generally, the pervasive chert horizon at the boundary was too thin to map, but where thicker is mapped as **Tpc**. An extremely thick section occurs on the NE flank of Cerro Jarosito (approximately 25 meters thick). Locally, chert capping the Abiquiu Formation was mapped (**Tpcu**), forming benches on the highest peaks in the study area. Where broad and continuous, chert layers typically form relatively flat-lying benches, highly resistant to erosion. Discontinuous lenses of chert also occur within both the Abiquiu Formation and the Ritito Conglomerate. Pedernal Chert is a common component of younger alluvial and colluvial deposits throughout the quadrangle, often preserved as a lag component on mesas and hillslopes. Maximum thickness of approximately 25 meters.

Tr – Alluvial conglomerate and sandstone. Ritito Conglomerate. Late Oligocene. Beige to gray fluvial deposits, commonly conglomeratic and arkosic. Typically poorly consolidated. Weathered, finer grained sandstone intervals produce an orangy soil. Clasts in the conglomerate are typically subrounded to rounded (up to 28 cm across), consisting of Proterozoic granite, metarhyolite and quartzite, as well as Paleozoic limestone, shale, and chert (Figure 5). In general, granite and metarhyolite clasts are twice as abundant as sedimentary clasts and four times more abundant than quartzite in the conglomerate. The unit is typically expressed as colluvium on hillslopes. Maximum thickness exceeds 60 meters.

Figure 5. Photo of consolidated Ritito Conglomerate, including clasts of Proterozoic granite, metarhyolite, and quartzite.

Triassic Units - All Triassic strata in the quadrangle are assigned to the Upper Triassic Chinle Group (Lucas, 1993). The Chinle Formation was first named and described by Gregory (1917) for exposures in the Chinle Valley of northwestern Arizona. Triassic stratigraphy in the Jarosa quadrangle follows Lucas and Hunt (1992) and Lucas et al. (2003, 2005b). Three informal units are mapped at the 1:24,000 scale.

TRcu – **Petrified Forest Formation.** Poorly exposed, thinly bedded red mud, siltstone, and sandstone occurs in sporadic exposures at the top of the Triassic sequence in the NE quadrant of the Jarosa quadrangle. These deposits most likely represent thin remnants of the Painted Desert Member and Mesa Montosa Member of the Petrified Forest Formation. The deposits are exposed primarily above the Poleo Formation (Trcp) and beneath the Bandelier Tuff (Qbt and Qbo). Maximum thickness is approximately 15 meters.

TRcp – **Poleo Formation.** Yellow-brown, yellow- gray, white and red, medium to fine-grained, micaceous, cross-bedded, quartzose sandstone, conglomeratic sandstone and conglomerate. Planar and trough cross stratification common. Layers containing abundant petrified wood fragments are common (Figure 6). The conglomerate in the Poleo Formation is often black and contains both intrabasinal siltstone and nodular calcrete clasts and extrabasinal siliceous (chert and quartzite) clasts. This unit forms prominent white cliffs. The base of the unit is sharp (corresponds to the Tr-4 unconformity of Lucas (1993)) and the upper contact is gradational into the overlying Painted Desert Member of the Petrified Forest Formation. Maximum thickness is approximately 100 meters in Jarosa Canyon along the SW flank of Mesa Pinabetosa.

Figure 6. Petrified wood and plant fragments in the Poleo Formation

TRcsa – **Salitral Formation.** The Salitral Formation is a slope-forming unit that
consists of an upper reddish-brown to orange shale with thin beds of tan limestone
(Youngsville member) and a lower unit of mottled shale with lenses of gray to reddish
brown medium- to coarse-grained sandstone (Piedra Lumbre) member. Exposures are
generally poor, thickness varies significantly, and blocks of overlying Poleo sandstone
frequently occur as slide blocks on hillslope exposures. Maximum thickness is
approximately 30 meters.

TRcs – **Shinarump Formation.** The Shinarump Formation (previously called the Agua
Zarca Formation) consists of white, coarse-grained to medium-grained pebbly sandstone
with conglomeratic lenses (Figures 7-9). Low to medium scale channel crossbeds are
common. Extrabasinal conglomerate includes clasts of quartz, chert, and quartzite.

Where well exposed, the base of the unit typically overlies Permian Yeso Formation in a striking disconformity.

Figure 7. View looking north up Puerco Canyon (into the Arroyo del Agua quadrangle) with white to yellow Shinarump conglomerate unconformably above mottled Yeso Group eolian sandstone. Abundant pebbles of quartzite and chert.
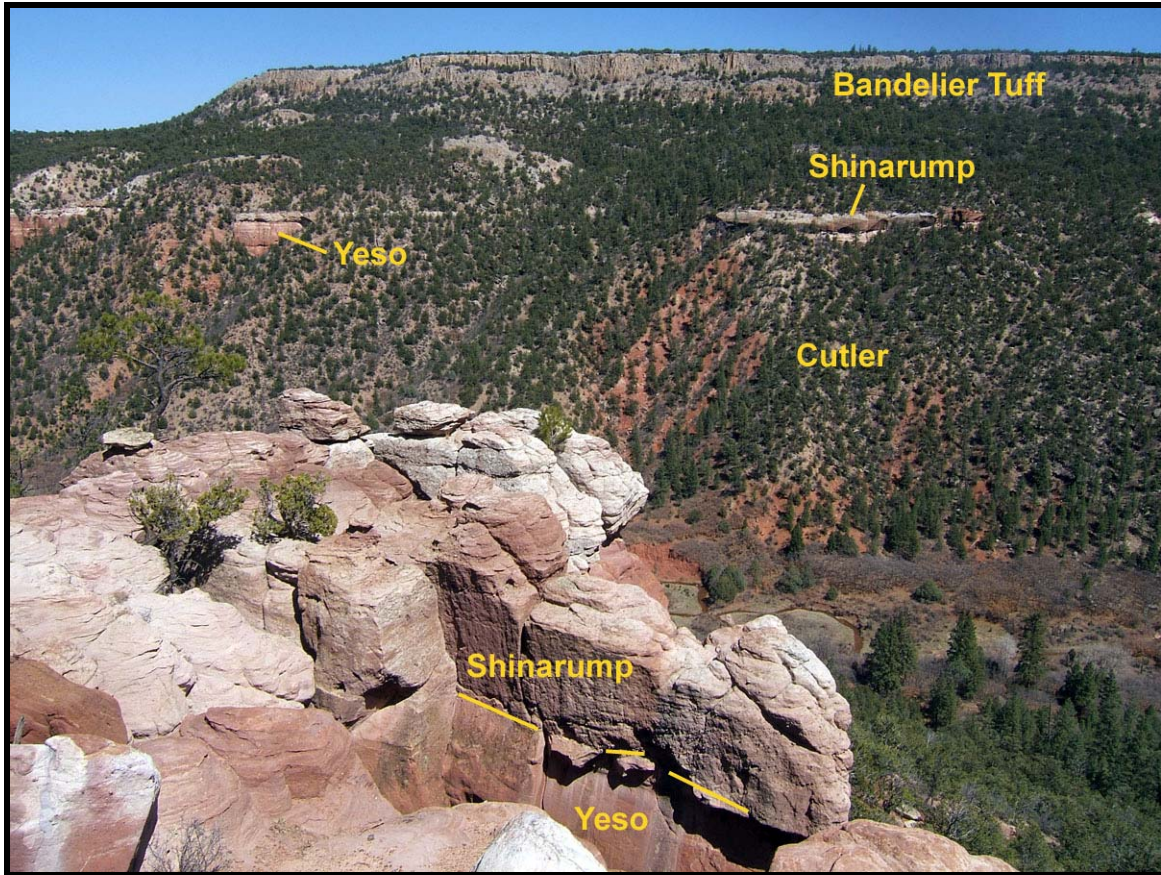
Figure 8. View looking eastward across Puerco Canyon in the northern part of the quadrangle. The Shinarump conglomerate forms a fairly continuous bench on both sides of the canyon, resting unconformably above Permian Yeso Group.

Local mineralization (copper, uranium) produces colors that range from black to yellow to green. Trough crossbeds are the dominant bedform, indicating a southwesterly paleocurrent direction. Petrified wood is rare. Maximum thickness is approximately 18 meters.

Figure 9. Thickness of the Shinarump Formation reaches at least 18 meters locally.

Pennsylvanian - Permian Units. The oldest sedimentary unit exposed on the Jarosa quadrangle is the Madera limestone - recently classified as the Guadalupe Box Formation based on exposures in the Jemez Springs area (Krainer et al., 2005). Overlying the limestone are siliciclastic red beds of the Cutler Group (Cutler Formation of Smith et al., 1961) and mottled red and beige sandstones of the Yeso Group.

Py – **Yeso Group.** Early Permian. Eolian and alluvial sandstones. Typically, deposits in the study area include orange-red sandstone with large-scale eolian crossbeds. Laminated sand sheet bedding is also common, gradational with fluvial, arkosic, and cross-bedded

deposits near the base. A purple-red shale is common above the eolian cross-bedded sequence. The unit is typically capped by a paleo-weathering horizon.

Figure 10. Variegated eolian sandstone of the Yeso De Chelly sandstone.

These strata (Figure 10) most likely belong to the De Chelly Sandstone of the Yeso Group (=Meseta Blanca Member of the Yeso Formation) and are unconformably overlain by basal strata of the Triassic Chinle Group. Maximum thickness is approximately 30 meters.

Pc – **Cutler Group.** Late Pennsylvanian to Early Permian. Siliciclastic redbed alluvium. The Cutler group has recently been subdivided into the El Cobre Canyon and Arroyo del Agua Formations by Lucas and Krainer (2005). However, these formations were not subdivided during mapping of the quadrangle. In general, the underlying El Cobre Canyon Formation is exposed south of the Mesa Pinabetal fault while the Arroyo del

Agua Formation is exposed north of the fault. The contact with the underlying Madera limestone (Guadalupe Box Formation) is gradational and consists of intercalated, thin-bedded and nodular fossiliferous limestone, red shale and reddish-brown sandstone.

Roads crossing the Cutler Group can be adventurous after a rain…

The El Cobre Canyon Formation consists of brown and reddish-brown sandstone, shale and lesser amounts of limestone-pebble conglomerate. Lenticular, multilateral sand bodies are common. A gray to green coarse-grained arkosic conglomerate with limestone pebbles (up to 1 meter thick) is a characteristic unit throughout the study area. The Arroyo del Agua Formation consists of reddish-brown medium-grained sandstone with shale interbeds. Sandstones are arkosic and contain subrounded, iron-oxide stained quartz.

IPm – **Madera Group - Guadalupe Box Formation.** Late Pennsylvanian. Arkosic limestone. Recent work by Krainer et al. (2005) defines the upper arkosic limestone member of the Madera Group as the Guadalupe Box Formation. In general, deposits consist of gray, intercalated, thin-bedded limestone, arkosic limestone and shale. Many beds are fossiliferous with spherical ovoids and subrounded quartz grains with calcite-filled fractures and anhedral calcite crystals. A basal calcareous sandstone and thinly-bedded limestone rests nonconformably above muscovite-biotite granite of Precambrian age in exposures along the Rio Puerco in the northwest corner of the quadrangle (Figure 11). The contact with the overlying Cutler group is gradational and placed at the top of the highest, laterally continuous limestone bed.

Figure 11. Basal limestone of the Guadalupe Box Formation (center) nonconformably overlying Precambrian granite (under pack) along the Rio Puerco.

A discussion of the Guadalupe Box Formation by Spencer Lucas is provided below:

On the Jarosa quadrangle, an essentially complete local section of Upper Pennsylvanian strata is exposed in the N1/2 sec. 33 and S1/2 sec. 28, T22N, R2E near

the Rio Puerco Campground. Here, the Pennsylvanian strata are in depositional contact with underlying Proterozoic granite and are overlain by siliciclastic red beds at the base of the Cutler Group. Wood and Northrop (1946) first mapped this outcrop, and their stratigraphic section of the Pennsylvanian rocks (their section 7) indicates about 250 ft of mixed red-bed siliciclastics and limestones between Precambrian granite and Cutler Formation red beds. They referred to the Pennsylvanian strata as the upper arkosic limestone member of the Madera Limestone. Woodward and Timmer (1979) referred these strata to the Madera Formation, describing them as "light-gray commonly fossiliferous limestone, gray to buff orthoquartzite; pink arkose; reddish and minor gray shale; arkosic limestone; thickness about 700 ft."

A measured section of these rocks was determined to be ~ 217 m (~ 661 ft) thick, which is essentially identical to the thickness of 670 ft that Woodward (1996, his control point 3) reported for this section. Although no basal sandstone bed of the Pennsylvanian section was observed directly on granite at the section base along the bank of the Rio Puerco (UTM [NAD 27] 344760E, 3996241N), the contact appears to a depositional nonconformity. About 10 m above the section base, a Late Pennsylvanian brachiopod assemblage is present. About 67% of the 217 m of Pennsylvanian section we measured are covered, and exposed strata (except in the uppermost 5-10 m of the section) are ledge- and cuesta-forming beds of arkosic sandstone (14% of the section thickness) and limestones--wackestone (12% of the section) and sandy wackestone (6% of the section). Only resistant beds more than 1 m thick, and usually 2-5 m thick, crop out. Nevertheless, dips are very consistent through most of the section: 25-30° to directions between N20^{o}W and N20^{o}E. In the uppermost part of the section, a normal fault alters dips to ~5° to N60^{o}E. It is not clear how much, if any, section is missing at the fault, but there is no obvious evidence of a large stratigraphic gap. The base of the Cutler Group (base of El Cobre Canyon Formation) is placed at the highest bed of limestone where it is overlain by red-bed siltstones and sandstones.

Sandstone beds in the Pennsylvanian section are generally orange to light brown, coarse-grained arkoses with some lenses of arkosic conglomerate. Trough crossbeds are the dominant bedform. Limestone beds are mostly wackestones rich in brachiopods with lesser numbers of bryozoans and crinoids, or crinoidal wackestones. Many limestone beds have arkosic sand grains in their matrix. Typically, the limestone beds are medium bedded and locally nodular. In the upper 5-10 m of the Pennsylvanian section, slope-forming green shale with nodular limestone beds is exposed, suggesting that this lithology may underlie some of the covered intervals of the section. In these upper beds, fusulinids of a large species of *Triticites* indicate a Virgilian age. Similar large *Triticite*s are also known from the upper part of the Pennsylvanian section near Gallina and in the Jemez Springs area (Krainer et al., 2005).

The Pennsylvanian section on the Jarosa quadrangle is a mixture of shallow water marine carbonate lithofacies and nonmarine fluvial clastics that were deposited proximal to a basement- (granite-) cored uplift of the ancestral Rocky Mountain orogeny. These strata have been assigned to the broadly conceived Madera Formation, a term long applied to most Pennsylvanian strata in northern New Mexico, but a more precise nomenclature is now available. Thus, Krainer et al. (2005) named lithologically similar and age equivalent Pennsylvanian strata in the Jemez Springs area the

Guadalupe Box Formation, and we assign the Upper Pennsylvanian strata on the Jarosa quadrangle to that unit.
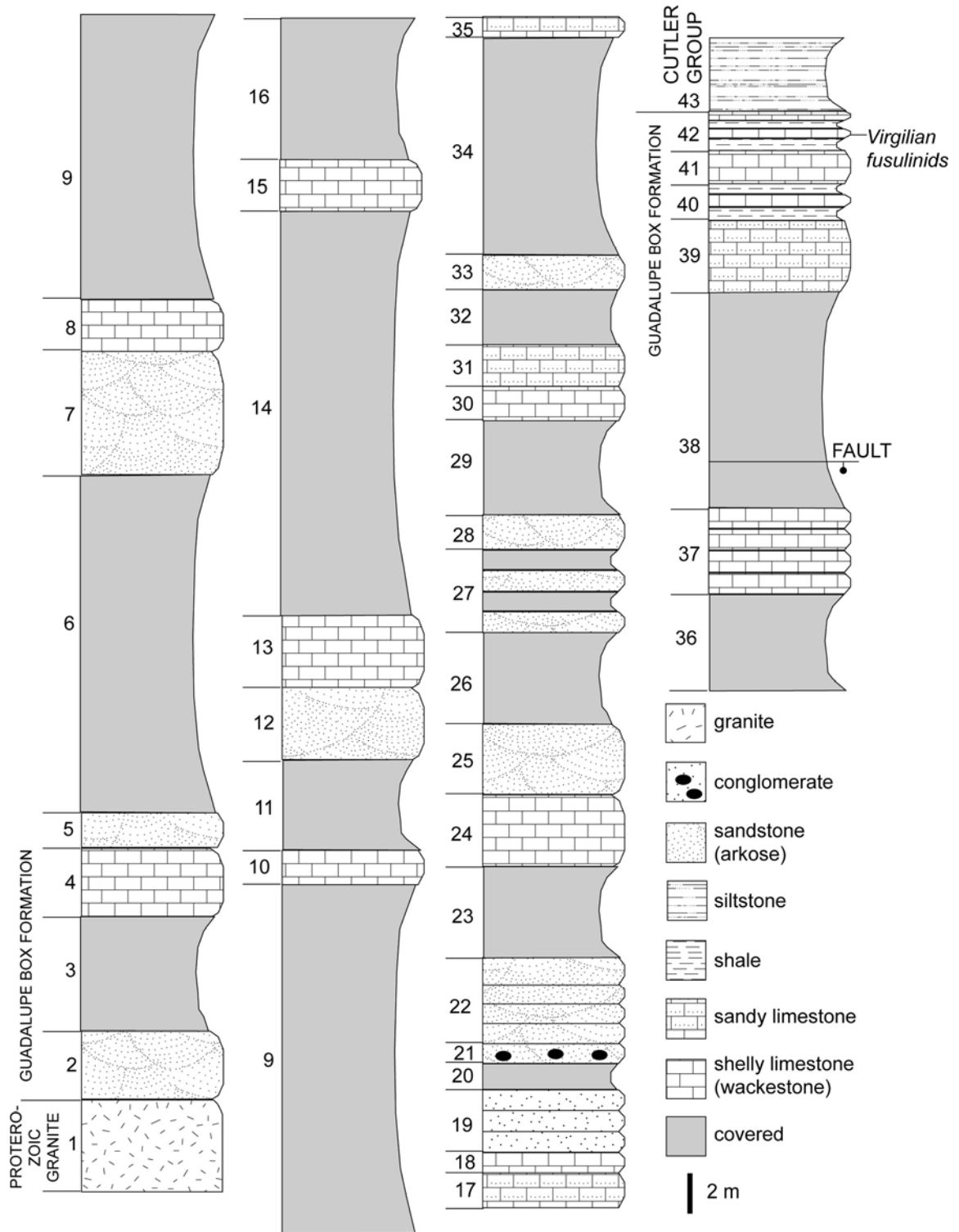
Rio Puerco measured section through the Guadalupe Box Formation

Precambrian Unit

pCg – Precambrian Muscovite-Biotite Granite. Mesoproterozoic. Pink, medium-grained granite with microcline, quartz, muscovite, and biotite phenocrysts. Three separate exposures occur in the northwest corner of the Jarosa quadrangle – The beveled, realtively unaltered and nonconformable surface of the granite is well exposed along the Rito Resumido and Rio Puerco (Figure 12) and is overlain by arkosic limestone of the Madera Group (**IPm**). There is a distinctive horizontal foliation to the granite, parallel to erosional surface (evident in photo below). Woodward and Timmer (1979) document a series of NW-trending high-angle faults (parallel to the Mesa Pinabetal fault) along the contact of the Precambrian and Madera limestone, downdropping the section to the northeast. Displacement along these faults may be related to closely-spaced, steeply-dipping shear fractures.
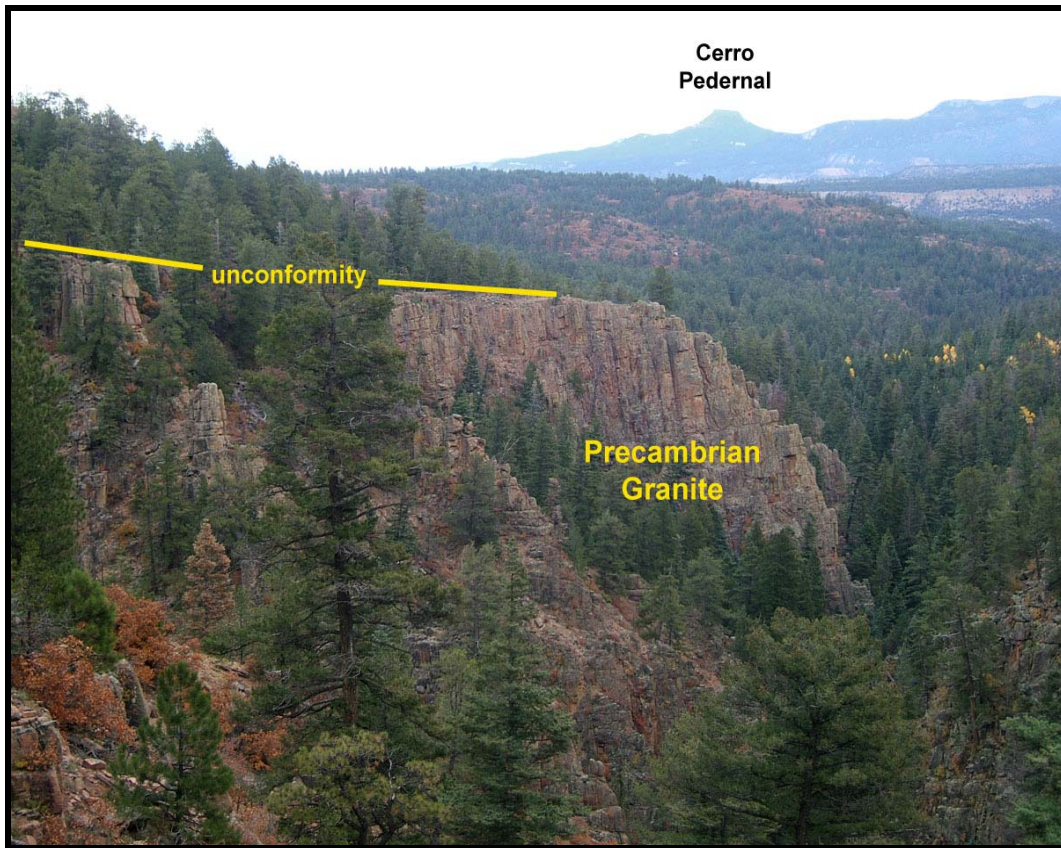
Figure 12. Nonconformity on the Proterozoic, capped by Guadalupe Box Formation.

Structure

Several structural features dictate the topography and landscape evolution in the Jarosa quadrangle. The most significant is the Mesa Pinabetal fault, a southeasterly trending, high-angle to vertical fault that marks the boundary between the Nacimiento uplift (to the southwest) and the Chama Basin (to the northeast). The fault is pervasively covered by alluvium, colluvium and landslide deposits, so the exact inclination of the fault plane has not been determined. However, the manner in which it strikes unbending across topography suggests a near vertical orientation. On both sides of the fault, strong fault drag is observed in strata within 50 meters of the fault (see photo below). Parallel to Jarosa Canyon the fault juxtaposes Guadalupe Box Formation of the Madera Limestone (**IPm**) against Permian Cutler Group (**Pc**) with a minimum of 210 meters of structural relief (since the basal contact of the Guadalupe Box Formation on the southwest side of

the fault is at the same elevation as the upper portion of the Cutler Group to the northeast).

Timing of fault displacement is difficult to determine. The highest strata clearly displaced by the fault are Upper Triassic. The fault does not appear to offset Bandelier Tuff (**Qbt** and **Qbo**) which conceals the extension of the fault to the southeast. No offset of the Abiquiu Formation or Ritito Conglomerate (**Ta**, **Tr**) along the eastern boundary of the quadrangle, or in the adjacent quadrangle (Cerro del Grant) are documented (in fact, the location of the fault to the southeast is undetermined). Possibly, the fault has experienced two episodes of activity. Most recently, Miocene uplift of the Nacimiento Mountains relative to the Chama Basin may have occurred, with the Mesa Pinabetal fault serving as a detachment boundary in a tensional setting. Initial development, however, may be related to Laramide compression in Latest Cretaceous to Early Tertiary time, when many of the monoclines and faults in the region formed. Development of the Mesa Pinabetal fault is most likely related to vertically oriented stress, similar to structures in the Sierra Nacimientos (Woodward et al., 1974). Both episodes would have resulted in down to the northeast structural displacement.

Qbt
(Upper Bandelier Tuff)

Cutler

Mesa Pinabetal Fault

Madera limestone

Fault drag beds
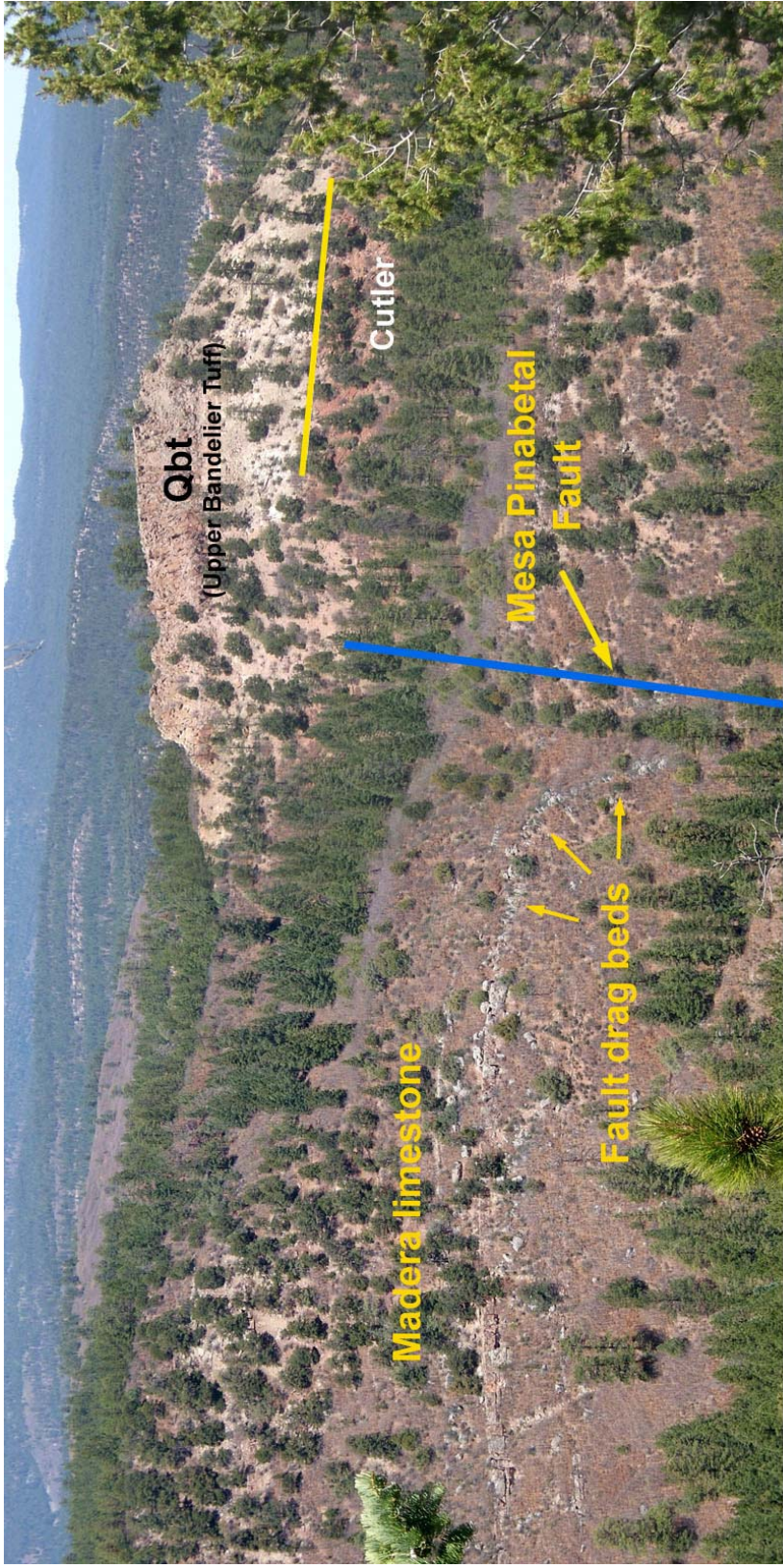
View looking NE up the Mesa Pinabetal Fault (Jarosa Canyon on the right out of view). Outlier of Upper Bandelier Tuff overlies Cutler Group deposits on the right. No offset of the Upper Bandelier Tuff was observed. Note the steeply deeping (fault drag) beds of Madera limestone on the left (SW) side of the fault.

A sub-parallel fault to the Mesa Pinabetal fault occurs to the southeast, where approximately 23 meters of stratigraphic separation can be documented (offsetting the contact of the Guadalupe Box Formation and Cutler Group). An additional parallel fault may occur to the northeast of the Mesa Pinabetal fault in Jarosa Canyon, where steeply dipping beds (both in the Guadalupe Box Formation and the Cutler Group) occur. Three significant monoclines occur in the quadrangle, each east-facing. None of the monoclines appear to have affected the Abiquiu Formation, and are clearly older structural events. The westernmost monocline axis is dominantly N-S trending and passes through Cerro Jarocito, extending southward to the southern boundary of the quadrangle. A sub-parallel monocline just to the east (trending NNW-SSE) extends through most of the quadrangle, passing just west of the Rio Puerco campground. This monocline, termed the Jarosa monocline, is best exposed where it crosses the Rio Puerco canyon, exhibiting a minimum structural relief of 240 meters. This monocline can be traced southward through deposits of the Cutler Group until it becomes buried by Bandelier Tuff deposits along the southern boundary of the quadrangle (headwaters of the Rito Peñas Negras). Both of these monoclines yield eastward to shallow-dipping synclines.

A third monocline occurs along the eastern escarpment of Mesa Pinabetosa, trending NNE-SSW. This monocline is documented by relatively flat-lying Triassic strata (in particular the Poleo Formation) directly underneath the Bandelier Tuff along mesa, yielding to steep east-plunging dips down canyon. The axis of the monocline is difficult to document northwards as Quaternary landslide and colluvial deposits cover up the bedrock. The monocline may join with a N-S trending fault that runs near the bottom of Jaquez Canyon, where steeply dipping Poleo sandstone beds occur along the eastern margin of the fault (Figure 13).

Figure 13. Steeply tilted strata of Chinle Poleo Formation strata adjacent to fault in Jaquez Canyon.

Economic Geology

Twenty small copper prospects and occurences, mostly in the Cutler Group, were noted in the Jarosa quadrangle. These prospects consist of copper sulfides that have replaced carbonaceous material and are surrounded by halos of copper carbonates (Figure 12). The mineralized strata are gray arkose, and they are enveloped in reddish-brown, non-mineralized arkose, sandstone, and shale. Detailed descriptions of the copper

occurrences are given by Timmer (1976). Cenoweth (1974) reported several minor uranium occurrences in the Cutler Group in the Jarosa quadrangle.

Figure 12. Copper mineralization, mainly malachite, occurs along and around thin seams of carbonaceous material in sandstone of the Cutler Group at Mining Mountain Prospect.

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