Geologic Map of the Youngsville Quadrangle, Rio Arriba County, New Mexico

By

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Scale 1:24,000

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Geologic Map of the Youngsville 7.5-Minute Quadrangle, Rio Arriba County, New Mexico

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Abstract

Geologic features on the Youngsville quadrangle in north-central New Mexico include classic Colorado Plateau stratigraphy and monoclinal structures, N-to NE-trending down-to-the-east Rio Grande rift normal faults , and volcanic rocks in northern Jemez volcanic field. A rich and complex history of late Paleozoic through Mesozoic deposition, late Cretaceous to Eocene Laramide compressional deformation and associated deposition, Oligocene to Miocene Rio Grande rift deposition and deformation, and eruption of late Miocene mafic to intermediate lavas and Pleistocene rhyolitic tuff from the Jemez volcanic field is recorded here.

The two most significant findings of this work are the discovery of the northernmost pinchout of the Mesita Blanca member of Permian Yeso Formation in this part of New Mexico, and recognition of a possible deformation event during the deposition of the Poleo sandstone member of the Triassic Chinle Group. We also recognize possible reactivation of Laramide faults during Rio Grande rift extension.

Physiography

The most prominent landmark in the area is Cerro Pedernal, a flat-topped (9862 ft.) peak capped by 9 Ma Lobato Formation basalt. Cerro Pedernal is part of the heavily-forested highlands of the northern Jemez Mountains that make up the southern third of the map area. The main drainages in the Jemez Mountains are the north-flowing Coyote Creek and the northwest-flowing Rito Encino. The northern two thirds of the area consists of the spectacular red, yellow, and white mesa country of the Colorado Plateau. The plateau rocks generally dip to the southeast to east and are part of the Chama basin, which is primarily the product of Laramide deformation. The northeastern part of the area is a large pediment, the La Joya del Pedregal, that basically formed at the contact between the top of the sandstone in the Poleo Formation of the Chinle Group and the overlying soft, mudstone-rich Petrified Forest member of the Chinle Group.

The northern portion of the quadrangle is incised by the northeast-flowing Rio Puerco, a tributary of the Rio Chama, which is located just to the northeast of the quadrangle. Portions of the valley of the Rio Puerco in the northeastern part of the area were flooded with the waters of Abiquiu Reservoir after Abiquiu Dam was built in 1963; however, the lake does not flood this area today. The area was mapped in the summer of 2004 and the spring of 2005, at a time when the lake level in Abiquiu Reservoir was low as the result of the ongoing drought at the turn of the twenty-first century. According to the locals, this portion of the Rio Puerco has not been occupied by Abiquiu Reservoir for the last fourteen years because lake water was released to honor interstate water compacts in the lower reaches of the Rio Chama-Rio Grande drainage system.

Previous Work

A reconnaissance map of the Youngsville area is available at the 1:250,000 scale on the Aztec 1° x 2° sheet (Manley et al., 1987) The westernmost part of the area along Coyote Creek is included on the map of Wood and Northrop (1946) and the southern part of Youngsville quadrangle was mapped by Smith et al. (1970) as part of the geologic map of the Jemez Mountains. Lawrence (1979) mapped the southern third of the quadrangle at the 1:24,000 scale as part of his master's thesis and portions of that map are used here. The Lobato Formation on Encino Point at the very southern edge of the quadrangle was mapped in detail by Singer (1985). The northern two-thirds of the area was not been mapped in detail prior to this study.

Most Significant Findings of this Project

Yeso Formation Pinchout

Wood and Northrup (1946) arbitrarily designated that the red Permian fluvial rocks exposed in the Jemez Mountains be called Abo Formation south of 36° latitude and Cutler Formation to the north of this line. The Permian section in the southwestern Jemez Mountains, which is best exposed in Cañon de San Diego, is composed of, from oldest to youngest, the fluvial Abo Formation, the eolian to fluvial Yeso Formation, and the marginal marine Glorieta Formation. Prior to this study, only the fluvial Cutler Formation, which correlates with the Abo Formation, had been recognized in the Youngsville area in the northwestern Jemez Mountains. Pinchouts or facies changes that may have occurred from south to north in the Yeso and Glorieta formations in the western Jemez Mountains are largely obscured by the Miocene to Pleistocene Jemez volcanic field.

During the course of this work, we found a thin section of the eolian Mesita Blanca member of the Yeso Formation preserved on top of the fluvial Cutler Formation and below the Shinarump Formation of the Triassic Chinle Group along Coyote Creek. The northern pinchout of the eolian sandstone is between UTM coordinates (NAD27) 353840 4001217 and 353707 4001501 on the west side of Coyote Creek and UTM coordinates 354745 4001270 and 354771 4001419 on the east side. The top of the Mesita Blanca member is marked by a pronounced weathering horizon; the normally red, crossbedded sandstone is bleached to white or stained yellow, and in places, a thin (<30 cm) orange chert bed is present at the contact. This same paleo-weathering horizon and chert is present on top of the fluvial Cutler Formation north of the pinchout. This paleo-weathering horizon is not present in the southwestern Jemez Mountains. The best exposures of the Yeso Formation in the northwestern Jemez Mountains (Figure 1) are in an east-west trending drainage in the far southwestern corner of the Youngsville quadrangle, extending into the southeastern part of the Arroyo del Agua quadrangle.

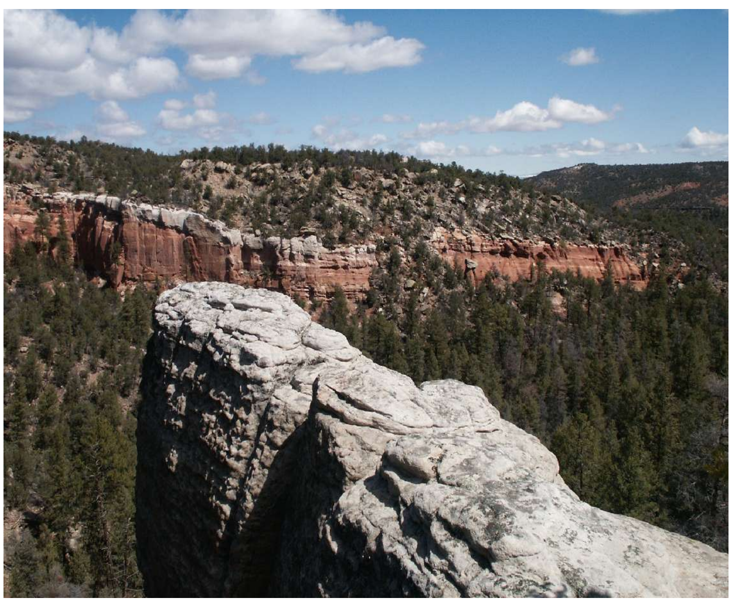

Figure 1. Photo of cliff of eolian Mesita Blanca member of Permian Yeso Formation below a channel sandstone in the Shinarump Formation of the Triassic Chinle Group. Shinarump channel in foreground. Photo taken looking north from 353738 3999244 (NAD 27).

Figure 2. Photograph of the weathering horizon at the top of the Permian Yeso Formation (UTM coordinates 354771 4001419 (NAD 27)).

Possible Triassic Deformation (?)

An unusual 75 to 85°-striking block of Permian Cutler white fluvial sandstone and Triassic Poleo Formation conglomerate that dips steeply (75 to 90°) to the south is apparently overlain by relatively flat-lying Triassic Poleo conglomerate and sandstone at UTM coordinates (NAD 27) 358330 4008670 and 358160 4008640 (Figure 3). We have come up with three hypotheses to explain this structure. Hypothesis number two makes the most sense in terms of the regional geologic setting, although the orientation of the structure is unusual for a Laramide feature.

1. The block represents syn-Poleo Formation deformation. This hypothesis would require the Poleo conglomerate to deform as a coherent, well-lithified block during Triassic time and suggests that Poleo Formation deposition occurred over a long span of time.
2. The structure formed during Laramide deformation, involving slip below on the underlying mudstone of the Salitral Formation of the Chinle Group and fortuitous placement of a mudstone within the Poleo Formation to facilitate slip at the top of the block.
3. Although the overlying conglomerate appears to be Poleo Formation, the unit could possibly be Eocene El Rito Formation composed of recycled Poleo Formation material. However, this hypothesis would require considerable exhumation of this part of the Chama Basin during Laramide time compared to areas in the southern part of the quadrangle, where the Eocene El

Rito Formation typically rests on Cretaceous Dakota Sandstone and Mancos Shale or on Jurassic Morrison Formation.

We are in the process of testing these ideas.

A second block of steeply tilted (strike 45°, dip 68° E) Poleo Formation is present at UTM coordinates 358890 4001550 (NAD 27) along a north-northeast trending fault (Figure 4). Here again is a suggestion of flat-lying Poleo Formation resting on deformed Poleo Formation, but the interpretation of the exposure is even more ambiguous (Figure 5).

Figure 3. Photograph of steeply dipping Poleo Formation sandstone and conglomerate apparently overlain by a relatively flat-lying Poleo conglomerate in the background above the backpack. View toward the east. UTM coordinates 358160 4008640 (NAD 27).

Figure 4. Photograph of steeply dipping Poleo Formation near fault at UTM coordinates 358890 4001550 (NAD 27). View to the northeast.

Figure 5. Photograph of Poleo Formation conglomerate apparently sitting on the northeastern end of the block shown in Figure 4.

Largo Fault

Lawrence (1979) recognized several likely Laramide-age faults to the west of the Banco Largo that were reactivated during Rio Grande rift extension. One of these faults, herein informally named the Largo fault, is a major reactivated Laramide structure that may continue into the northern part of the quadrangle. This fault is currently a down-to-the-west normal fault with an inferred dip to the west, offsetting the Oligocene to Miocene Abiquiu Formation along the east side of Banco Largo and defining the Banco Largo escarpment (Lawrence, 1979). This fault may project to the north into a significant down-to-the east-fault that places Jurassic rocks to the west against Cretaceous rocks to the east. This major structure appears to continue to the north and join a significant down-to- the-east fault in the northern part of the area.

In most places across the Youngsville quadrangle and the adjoining Cañones quadrangle to the east, the Eocene El Rito Formation, a synorogenic Laramide-age conglomerate and sandstone, was deposited on Cretaceous Dakota Sandstone and Mancos Shale; however, on the ridge at about 357500 3999500 (NAD 27), to the west of the Largo fault, lower Abiquiu Formation and overlying Pedernal Chert rest directly on Dakota Sandstone. This relationship suggests that this ridge may have been a high during Eocene time, preventing deposition of the El Rito Formation, and the west-dipping Largo fault may have been a reverse fault. Furthermore, to the northeast along the inferred projection of the Largo fault, a reddish siltstone that could be El Rito Formation appears to sit on Jurassic Morrison Formation (~UTM coordinates 358700 400110). In this general vicinity the Cretaceous Burro Canyon and Dakota formations have been stripped away, probably as the result of Laramide deformation.

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Unit Descriptions for Youngsville 7.5 Minute Quadrangle

Qal Alluvium (Holocene). Unconsolidated clay, silt, sand, and gravel deposited in major modern drainages and tributaries; up to 5 m thick.

Qe Eolian silt (Holocene). Unconsolidated windblown tan to brown silt and clay deposited in low-elevation spots and on pediment surfaces. Usually 1 to 3 m thick, but can be 10 m thick.

Qc Colluvium (Holocene). Hillslope colluvial deposits composed of pebble to boulder size unconsolidated debris derived from local volcanic and sedimentary rocks. **Qcb** designates colluvium composed mainly of Lobato basalt, **Qc-a** is colluvium made of Lobato andesite; **Qcbt** is Bandelier Tuff colluvium. Qc refers to colluvium made up of a variety of lithologies. Up to 35 m thick.

Qt Terrace deposits (middle Pleistocene to Holocene). Alluvial silt, sand, cobble, and boulder deposits of rounded to subrounded Lobato Formation, Pedernal Chert, Mesozoic sandstone, as well as recycled Proterozoic quartzite, granite, and metamorphic pebbles from the Oligocene Lower Abiquiu Formation and the Permian Cutler Formation. At least two terrace levels are present along the Rio Puerco, one at ~60 feet above modern grade, and one at ~100 feet above modern grade. 1 to 3 m thick.

Qp Pediment gravels (middle Pleistocene to Holocene). Unconsolidated deposits of angular to subangular pebble to boulder size blocks of Lobato Formation, Pedernal Chert, Mesozoic sandstone, as well as rounded recycled Proterozoic quartzite, granite, and metamorphic pebbles from the Oligocene Lower Abiquiu Formation and the Permian Cutler Formation resting on surfaces graded to the level of the highest terraces. The largest surface, covering several square kilometers, is on La Joya del Pedregal, which is cut on the approximate contact between the Poleo Formation and Petrified Forest Formation of the Chinle Group. Most of the pediment surfaces are covered with eolian silt (**Qe**). Approximately 1to 10 m thick.

Q1s Landslide deposits (middle Pleistocene to Holocene). Unconsolidated, unsorted deposits composed of locally derived, relatively cohesive blocks of bedrock. The base often rests on shales of the Eocene El Rito or Triassic Chinle formations and top of the deposit is typically hummocky. Landslides on the northern and western flanks of Encino Point cover several square kilometers, appear to run over a rugged pre-existing topography, and often involve distinct concentrations of all three members of the Abiquiu Formation, as well as Lobato Formation. Landslides along the escarpment of the Rio Puerco are composed of Poleo Formation, typically are rotated so that top of the blocks dip toward the canyon rim, and the slides sole into the underlying shales of the Salitral Formation. Similarly, the northwest side of Naranjo Mesa is covered with a slide of Poleo Formation sandstone blocks moving on the underlying Salitral mudstone and shale. Massive landslides coming off the mesa in the northwest corner of the quadrangle sole into the Petrified Forest Formation of the Chinle Group. These deposits may be up to 35 m thick.

Qb Bandelier Tuff (Pleistocene). pumaceous air-fall tephra, nonwelded to weakly welded rhyolitic ash-flow tuff, and local volcaniclastic sediments; divided into two members, from younger to older:

Qbt Tshirege Member. White to orange to pink non-welded to weakly welded rhyolitic, ash-flow tuff (ignimbrite). The tuff contains abundant phenocrysts of sanidine and quartz, rare microphenocrysts of black clinopyroxene, trace microphenocrysts of hypersthene and fayalite, and pumice fragments in a fine-grained matrix of vitric ash. The sanidine typically displays blue iridescence. The tuff is composed of multiple flow units in a compound cooling unit (Smith and Bailey, 1966; Broxton and Reneau, 1995; Gardner et al., 2000); includes basal white pumiceous tephra deposits (1-2 m thick) of the Tsankawi Pumice. Qbt forms conspicuous orange to tan cliffs on a knob east of Coyote Creek and on the east side of Rito Encino south of Temoline Canyon, where the tuff infills a rugged paleotopography. $^{40}Ar/^{39}Ar$ age is 1.22 ± 0.01 Ma (Izett and Obradovich, 1994; Spell et al., 1996). Up to 30 m thick.

Qbo Otowi Member. White to pale pink, generally poorly welded rhyolitic ash-flow tuff containing abundant phenocrysts of sanidine and quartz, and sparse mafic phenocrysts; sanidine may display a blue iridescence. Contains abundant accidental lithic fragments; consists of multiple flow units in a compound cooling unit. The stratified pumice fall and surge deposit at base of unit (Guaje Pumice) is not found in this area. Qbo discontinuously fills in rugged topography on a pre-Toledo caldera age volcanic surface and the upper surface can be quite undulatory due to erosion. Very difficult to distinguish from upper Bandelier Tuff in hand samples; best distinguished by poorer degree of welding, greater tendency to form slopes instead of cliffs, more abundant lithic fragments, less abundant iridescent sanidine, and stratigraphic position beneath the Tsankawi Pumice. $^{40}Ar/^{39}Ar$ ages 1.61± 0.01 to 1.62±0.04 Ma (Izett and Obradovich, 1994; Spell et al., 1996). Up to 100 m thick in the southeast corner of the quadrangle but more generally on the order of 2 to 10 m thick.

QTg Fluvial gravel (Pleistocene to Pliocene). Unconsolidated round to subround fluvial gravel . A thin gravel (<0.5 m) is present under the Otowi member of the Bandelier Tuff in the vicinity of Coyote Creek and south of Youngsville and sits on Triassic Chinle Formation. The gravel is composed primarily of clasts of rounded local Mesozoic sandstone, as well as subrounded Pedernal Chert, and Proterozoic granite and quartzite clasts recycled out of the lower Abiquiu Formation. In contrast, a gravel dominated by rounded Lobato Formation clasts and Tschicoma dacite, as well as Pedernal Chert and quartzitie, underlies the Tshirege member of the Bandelier Tuff along Rito Encino south of Temoline Canyon and sits on Abiquiu Formation. This gravel, which is up to 25 m thick, may correlate with the Puye Formation in the northeastern Jemez Mountains.

T1 Lobato Formation (7.2 Ma to 8.7 Ma). Includes andesite, basalt, and local dacite occurring as lavas, dikes, and vents exposed in the escarpment of Encino Point, and on Banco Largo, Cerro Pedernal, and Mesa Escoba. K-Ar ages are 7.8 ± 0.7 Ma on Cerro Pedernal and 7.9 ± 0.5 on Mesa Escoba (Manley and Mehnert, 1981). The unit sits on the Ojo Caliente member of the Tesuque Formation. In the Youngsville area, nothing caps the Lobato Formation except for occasional pockets of eolian silt (Qe).

Tld Lobato dacite (late Miocene, <7.85 Ma). Gray, weakly porphyritic, plagioclase-augite-hypersthene±biotite dacite exposed as dikes on Banco Largo (Singer, 1985).

Tla Lobato andesite (late Miocene). Dark gray, fine-grained, weakly porphyritic, plagioclase-clinopyroxene-olivine basaltic-andesite and andesite with quartz xenocrysts (Singer, 1985). Individual flows are typically 7 to 20 m thick with thin (<2m) basal pyroclastic and scoria layers associated with a shield cone at Encino escarpment (Singer, 1985). Includes remnant andesitic dikes and pyroclastic debris on Banco Largo. Singer (1985) determined a K-Ar age of 7.85 ±0.22 Ma for an andesite flow near the top of the flow sequence at Encino Point. The maximum thickness of the andesitic sequence, which includes as many as 8 flows, is ~100m (Singer, 1985).

Tlb Lobato basalt (late Miocene). Porphyritic olivine basalt on Cerro Pedernal. Phenocrysts include 23% subhedral zoned labradorite (An_5 , 12%, 1.5 mm); subhedral to euhedral olivine (9%, 2.5 mm), with strong iddingsite replacement and magnetite rims; subhedral augite (2%, 2.5 mm) containing poikilitic plag, partly twinned or with orthopyroxene reaction rims. Basal flow, 17-m thick, in a series of flows and interlayered pyroclastic beds totaling 80 m thick (Lawrence, 1979).

Th Debris flow deposit (late Miocene). Local deposit north of Encino Point, along the southern edge of the quadrangle that contains volcaniclastic sediments of round pebble- to cobble-size Tertiary volcanic (rhyolite, andesite, and basalt) clasts, Precambrian clasts, upper Abiquiu sandstone and Ojo Caliente sandstone. Fine- to coarse-grained, tuffaceous, pebbly sandstone interbedded with volcaniclastic conglomerate of fluvial or alluvial fan origin. Sequence contains angular fragments of Lobato Formation basalt. The deposit is capped with bombs from a phreatomagmatic basaltic eruption and the entire sequence is altered and contains calcite veins. Sits on Ojo Caliente sandstone, capped by phreatomagmatic Lobato Formation. 33 m thick (Lawrence, 1979).

Tst Tesuque Formation of the Santa Fe Group (late Miocene)

Tsto Ojo Caliente Member of the Tesuque Formation (late Miocene). Pink to tan-colored, well-sorted, fine-grained, cross-bedded, feldspathic and quartzo-feldspathic sandstone of eolian origin; is well-cemented and forms cliffs in the vicinity of faults, but otherwise is poorly cemented. Underlain by Abiquiu Formation with an angular unconformity of up to 10° (Lawrence, 1979) and overlain by Lobato Formation; both contacts are sharp. Up to 100 m thick.

Tstc Chama-El Rito Member of the Tesuque Formation (late Miocene). Poorly exposed tan to gray medium to coarse-grained fluvial sandstone and granule to pebble conglomerate interbedded with orange-red to red siltstone. Clasts in the conglomerate are dominated by rounded andestitc volcanics, flow-banded rhyolite, ash flow tuff (much of which is lithic-rich Amalia Tuff), rare chert and basalt.

Ta Abiquiu Formation (late Oligocene to early Miocene). Informally divided into three subunits including, from younger to older:

Tau Upper sandstone member. White, light gray, and buff-colored fine- to medium-grained, tuffaceous and volcaniclastic sandstone and mudstone, locally conglomeratic. The upper sandstone is a slope-forming unit comprised of moderately sorted, moderately indurated volcanic detritus representing diverse lithologies including pumice, basalt, intermediate volcanics and 25 Ma Amalia Tuff. A K-Ar age of 18.9 Ma from a basalt near the top of the unit and an Ar/Ar age of an Amalia Tuff clast of 25 Ma near the base bracket the age of the unit (Smith et al., 2002, Moore, 2000). ~150 m thick (Lawrence, 1979) to 315 m thick (Moore, 2000).

Tap Pedernal Chert Member. Varicolored, white, blue to gray, black, cryptocrystalline, massive chert, limey chert, and limestone containing nodular chert, conspicuous ledge former, 2 to 35 m thick. The chert is locally interlayered with thin beds of arkosic sandstone and conglomerate and is typically more limey at its base.

Tal Lower conglomerate member. Pinkish tan to gray, generally coarse arkosic conglomerate and fine- to medium-grained sandstone, slope forming. The lower conglomerate member is poorly sorted, weakly to moderately indurated, calcareous, and characterized by well rounded pebble to boulder-size (up to 50 cm) clasts composed of Precambrian quartzite, granite, pegmatite, gneiss and schist, as well as fine-grained (Madera?) limestone and mudstone. K-Ar ages on a basalt near the base of the unit northeast of the quadrangle and $^{40}Ar/^{39}Ar$ ages on Amalia Tuff in the upper Abiquiu bracket the age of the unit between 25.1 and 27 Ma (Smith et al., 2002, Moore 2000). ~100 m thick

Ter E1 Rito Formation (Eocene). Orange-red to brick-red, hematitic, micaceous mudstone and siltstone and lenses of fine- to medium-grained arkosic sandstone, slope forming. The E1 Rito Formation locally has a 2- to 10-m-thick basal conglomerate section made up of very well rounded hematitic Proterozoic Ortega quartzite, as well as Proterozoic schist and gneiss cobbles and boulders (up to 1 m) in a weakly to well indurated matrix of coarse ferruginous sand. Underlies the Abiquiu Formation and overlies Cretaceous Mancos Shale, Dakota Sandstone, or Jurassic Morrison Formation with erosional unconformity. Estimated 50 to 140 m thick

Km Mancos Shale (Late Cretaceous). Dark gray and brown, weakly consolidated, calcareous, carbonaceous shale and interlayered thin beds of fossiliferous orange silty limestone, slope forming. Only the lowermost part of the section is locally present; upper contact is an erosional unconformity of moderate relief. 0 to 65 m thick

Kd Dakota Sandstone (Late Cretaceous). Tan to yellow-brown, fine-grained quartzose sandstone, well sorted, locally kaolinitic. The lowest part of the unit contains local fluvial channels with rare white to gray to tan chert pebbles, which may correspond to the Encinal Canyon member of the Dakota Sandstone (Aubrey, 1986). The Dakota Formation in the western part of the area tends to have cross-bedded sandstone at the base and interbedded shale and sandstone of the Oak Canyon Shale and Cubero Sandstone upsection. The Encinal Canyon Sandstone is not present on Cerro Pedernal. Thick to thin-bedded to massive. Locally contains thin interbeds of black, carbonaceous shale. Conspicuous as a cliff former, 60 to 67 m thick.

Kbc Burro Canyon Sandstone (Cretaceous). White to tan, fine-grained, kaolinitic, quartzose sandstone, moderately to well indurated. Contains abundant thin beds of chert and quartz pebble conglomerate. The rounded chert pebbles are usually tan, white, and gray, and rarely black to red and much of the chert is tripolitized (Saucier, 1974; Aubrey, 1986). Locally exhibits medium-scale cross bedding. Thin light green to pink mudstone is interbedded with the conglomeritic sandstone, indicating recycling of the underlying Brushy Basin mudstones (Saucier, 1974). Conspicuous cliff-forming unit, thick bedded to massive, 57 to 67m thick.

We follow the Jurassic stratigraphy for the Chama Basin outlined by Lucas and Anderson (1998).

Jm Morrison Formation (Late Jurassic)

Jmb - Brushy Basin Member. Variegated green to reddish orange to dark reddish brown siltstone and grayish-white to gray, very fine-grained subarkosic, cross-bedded sandstone, slope forming, 110 m thick.

Js Summerville Formation (Late Jurassic). The basal 8 to12 m of this unit consists of white to light gray, fine- to very fine grained quartzose sandstone, thin-bedded, containing small-scale ripple marks, gypsum blade casts, and soft-sediment deformation. The basal sandstone is overlain by variegated maroon and gray quartzose to subarkosic siltstone. This unit tends to form slopes. The upper contact is the stratigraphically highest maroon siltstone that contains abundant pedogenic carbonate concretions, located above the Bluff Sandstone interval. The Bluff Sandstone, a tan fine grained, cross-bedded sandstone that is about 10 m thick, is included in the Summerville Formation on this map. Approximately 60 m thick.

Jt Todilto Formation. (Late Jurassic). White to gray, dominantly fine-grained, massive gypsum, sloping-forming unit; with a 2- to 3-m-thick basal section of gray, laminated, fissile shale and/or thin-bedded limestone. In one locality, a limestone breccia with angular to subrounded clasts overlies the gypsum. Hilpert (1969) describes the uranium mine in Box Canyon. Mineralization at Box Canyon is associated with a fault and includes tyuyamunite/metatyuyamunite (W. Berglof, personal communication, 2004), hematite, chalcopyrite, and calcite. Total unit thickness up to 26 m (Lawrence, 1979).

Je Entrada Sandstone (Late Jurassic). White, pink, and yellowish tan, fine- to very fine-grained quartzose sandstone, well sorted, moderately indurated, exhibits large-scale eolian dunal cross-bedding; a cliff former. The sandstone is 61 m thick in the NE1/4, sec. 22, T. 22N, R3E on the east side of Coyote Creek (Lawrence, 1979).

TRc Chinle Group (Late Triassic). Three informal units are mapped at the 1:24,000 scale, from younger to older:

TRcu an upper unit that contains the Rock Point Formation and Painted Desert Member of the Petrified Forest Formation. The Petrified Forest Formation is composed of an upper red-brown mudstone-dominated section (Painted Desert member) (Lucas et al. 2003). Both the upper and lower contacts of this formation are gradational. The Petrified Forest Formation is up to 176 m thick. The stratigraphically highest unit in the Chile Group is the Rock Point Formation, reddish brown to gray-red siltstone and fine-grained sandstone that is 0-70 m thick (Lucas et al., 2003). 100 m of this upper unit is exposed in NW1/4, sec. 22, T22N, R3E on the east side of Coyote Canyon (Lawrence, 1979).

TRcp Mesa Montosa Member of the Petrified Forest Formation and the Poleo Formation. The basal red-brown to green laminated sandstone-dominated section of the Petrified Forest Formation (Mesa Montosa member) was lumped with the yellow-brown, yellow-gray, white and red medium- to fine-grained, micaceous, quartzose sandstone, conglomeritic sandstone and conglomerate of the Poleo Formation because the contact is between the two is gradational and thus hard to map. The conglomerate in the Poleo Formationis often black and contains both intrabasinal siltstone clasts and extrabasinal siliceous clasts; locally cross-bedded. This unit forms prominent 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. The Poleo Formation is about 48 m thick and the Mesa Montosa member is 4 m thick at the Piedra Lumbre section of Lucas et al., 2003 located along the Rio Puerco just north of the quadrangle boundary. However the Poleo thins dramatically toward the southwest of this measured section and the Mesa Montosa member thickens in concert. This unit marks the beginning and end of sandstone deposition in the Chama Basin during Chinle time.

TRcl a lower unit that contains the Salitral Formation and the Shinarump Formation (TRcs). The Shinarump Formation consists of white quartz sandstone, conglomeritic sandstone, and extrabasinal conglomerate that includes clasts of quartz, chert, and quartzite (Lucas et al., 2003). Petrified wood is common. Both the basal and upper contacts are sharp; the basal contact corresponds to the Tr-3 unconformity of Lucas (1993). In places on the map, the Shinarump Formation (**TRcs**) is shown as a distinct unit. The Salitral Formation is an olive-gray to brown sandstone to silty mudstone near the base (Piedra Lumbre member) and a reddish brown mudstone (Youngsville member) near the top. Upper bed of the Piedra Lumbre member, called the El Cerrito Bed, is a local yellow to brown intraformational conglomerate (Lucas et al. 2003). In places an orange chert that formed on a paleo-weathering horizon marks the contact between the Piedra Lumbre member mudstone and the Youngsville member siltstone units. The Salitral Formation varies greatly in thickness, ranging from 3 to 30 m.

Py Yeso Formation (Permian)

Pym Mesita Blanca Member. Red to red-brown, cross-bedded, fine-grained, moderately sorted quartz sandstone with angular to subrounded grains. Pinches out toward the north in Coyote Creek. Capped by a paleo-weathering horizon. Lucas and Krainer (2005) recommend following the suggestion of Baars (1962). Baars (1962) suggests that Permian eolian sandstone in northern New Mexico be assigned to the De Chelly Sandstone. 0 to 10 m thick.

Pc Cutler Group (Late Pennsylvanian - Early Permian). Two formations are recognized in the Chama Basin (Lucas and Krainer, 2005):

Pca Arroyo del Agua Formation. Orange-red micaceous siltstone with thin, trough cross-bedded sheet arkosic sandstone. Contains extensive calcrete nodule horizons. Little conglomerate is present in this formation; both intraformational and extraformational (quartzite other Proterozoic rocks) clasts are present in the rare conglomerate beds. This unit tends to form slopes. Conformably overlies the El Cobre Canyon Formation. Underlies the Triassic Shinarump Formation with a slight angular unconformity. Up to 120 m thick.

A thick channel that contains well-rounded quartzite, metaconglomerate, granite, and granitic gneiss cobbles is exposed at the top of the formation on the east side of Mesa Naranja. Quartzite is gray, green, yellow, and rarely white, some clasts are from a highly strained quartzite source. Eberth (1987), Eberth and Miall (1991), and Eberth and Berman (1993) referred to this unit as megasequence 3.

Pce El Cobre Canyon Formation. Dark brown siltstone and sandstone with extrabasinal conglomerate containing clasts of quartzite and other Proterozoic metamorphic rocks. The sandstone bodies are multistoried with relatively thin brown siltstone interbeds. The top of the unit is defined as the base of the first orange siltstone bed (Lucas and Krainer, 2005). Up to 500 m thick (Lucas and Krainer, 2005).

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