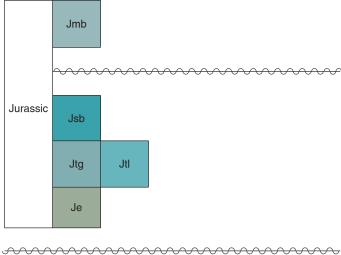


# 

Correlation of Map Units



**Explanation of Map Symbols** 

point down scarp.

Horizontal bedding

A Cross section line and label

4,000 feet abo

Direction of downslope movement of landslide

Inclined bedding—Showing strike and dip.

Sediment transport direction determined from cross-beds

Contact—The identity and existence are certain. The location is accurate where solid,

approximate where long-dashed, inferred where short-dashed, or concealed where dotted.

Head or main scarp of landslide—Active, sharp, distinct, and location is accurate. Hachures

.—...— Internal contact—The identity and existence are certain. The location is approximate.

——— Fault (generic)—The identity and existence are certain. The location is approximate.

Quaternary colluvium—Light-tan to brownish; loose to friable; coarse to fine-grained; very poorly sorted; massive(?); sometimes weakly calcite cemented; sandy, silty, pebble to boulder conglomerate and pebbly silty sand. Colluvium is mapped only where it obscures bedrock units and/or unit contacts—mostly within the drainage of the Canada Del Potrero, which is at a relatively high elevation and beneath Ponderosa Pine forest. Contacts between **Qls** and **Qc** in the Canada del Potrero are somewhat arbitrary as no exposures are available, and these two units present very similar surfaces. Although included in **Qls** as mapped, colluvium/talus is relatively common along the upper contact of landslide deposits below Dakota and/or Burro Canyon outcrops and on the steep slopes above the heads of landslides.

**OUATERNARY SEDIMENTS** 

Chama and Canillon Creek.

them.  $\approx 2-25(?)$  m thick.

margins of landslides.

Quaternary alluvium—Generally poorly exposed; light to dark brown and/or

dark grey and/or orangish; loose to friable; fine to coarse-grained; poorly sorted,

medium to thick-bedded, sometimes weakly calcite cemented; clayey, silty,

pebbly sand and sandy silt. Clasts are composed mostly of local Triassic through

Cretaceous rocks, sometimes with variable amounts of quartzite clasts. Pebbles

and small cobbles of gypsum are particularly distinctive downstream of Todilto

Formation outcrops. The unit includes sediment in the active channels and valley

bottoms, adjacent 'valley-fill,' tributary alluvium graded to within ≈2 m of the

present river level, and active stream terraces and gravel bars. On this

quadrangle, Qal also includes some areas of active alluvium found at higher

elevations (such as within landslides), but these are only mapped where they are

particularly extensive and/or clearly active. Quaternary alluvium is only mapped

where it is clearly >2m thick and/or it obscures large areas of bedrock units and/or

unit contacts. Chestnut (written communication, 2020) obtained a calibrated

radiocarbon age of 978 ± 39 ybp for a terrace 1.4 m above the Rio Chama on the

Laguna Peak Quadrangle (immediately to the West of the Echo Amphitheatre

Quad). Generally, the unit is 1–10 m thick but possibly thicker beneath the Rio

Quaternary fans—Poorly exposed; light to dark brown and/or blackish or

orangish; loose to friable; fine to coarse-grained; poorly sorted; medium to

thick-bedded; sometimes weakly calcite cemented; clayey, silty, pebbly-to-cobbly

sand and sandy silt. This unit includes Quaternary fans of multiple ages/heights

above grade. These fans likely have a similar origin to **Qal/Qf**, but base-level fall

and the subsequent incision has left them above current grade. Some sub-map

scale (generally =75 m wide) fans and fan remnants have not been mapped. Qf

deposits sometimes grade up-slope into **Qls** and have often been derived from

Quaternary landslides—Landslide deposits consisting of a chaotic, non-bedded,

friable assemblage of very poorly sorted gravel, sand, silt, and clay derived

mostly from Cretaceous rocks and Jurassic rocks younger than the Entrada

Sandstone and semi-intact blocks of Jurassic rocks up to several tens of meters

across. Terrace gravels are sometimes found on/in the lower parts of landslide

deposits even when no terrace remnants are preserved. Landslides commonly

have the form of Toreva blocks (rotational slumps) where they overlie Cretaceous

and Jurassic Rocks above the Todilto Formation. Below the Todilto Formation,

they often appear to be earthflows. The surface of the landslides is commonly

littered with large blocks of Cretaceous sandstone. Earthflow(?) deposits

sometimes seem to have a rough stratigraphy consisting of (from bottom to top):

chaotic material occasionally including gypsum blocks and slabs up to 100± m; a

middle zone of sandstone boulders and deformed-to-relatively intact masses of

**Jsb** and **Jmb**, and an upper layer characterized by large boulders of Cretaceous

sandstone from the Dakota and Burro Canyon Formations in a poorly sorted, tan

to greyish matrix of gravel, sand, silt, and some clay. Not all of these layers are

present everywhere, and near the edges of mapped deposits (especially in

landslides below the Todilto Formation), the uppermost layer is often the only

one present and/or exposed. Erosion of the uppermost layer often produces

hoodoos (boulder-capped pedestals) between <1 and ≈10 m high along the

Quaternary gravel—Gravel derived from terrace deposits but found on slopes that are either steeper than terrace surfaces or in topographic positions that make an origin as true terrace gravels unlikely. This unit represents relatively large areas of regraded terrace gravel and small and/or thin, poorly preserved terrace remnants(?). Only the thickest/most extensive parts of these 'aprons' of gravel below eroding terrace gravels are shown. Commonly the unit is 2–≈10(?) m thick. Quaternary terraces from near Pedernal Peak—Terrace deposits found in the southern part of the map and composed of a high percentage of basalt clasts and

variable amounts of Pedernal Chert, indicating they are derived from within the Rio Puerco drainage (from near Cerro Pedernal) to the south. Undivided Quaternary terraces—Generally poorly exposed; loose to friable; medium to thick-bedded; moderately to moderately well-sorted; mostly subangular; fine to coarse-grained sand, sandy gravel, and cobble conglomerate. Often includes 1-4 m of 'overbank' sand and silty sand at the top of terrace deposits and clast-supported cobble conglomerate in the first few meters above

strath. Top of some deposits may have been reworked (by eolian[?], sheetwash, and small-scale fluvial processes). Gravel is composed of pebbles through boulders. Clasts are dominated by quartzite with variable amounts of sandstone and/or limestone, small amounts of Brazos Basalt within the Rio Chama terraces (and possibly some Jarita Basalt from the Los Pinos Formation) and metamorphic clasts. This unit includes all terraces below 13 m and those that do not fall into the strath height ranges defined by Koning et al. (2006). ≈2–10 m thick. Undivided high level terraces—A sandy gravel unit that is present at several relatively high topographic levels and dominated by quartzite clasts. For this

quadrangle, rather than constructing an entirely new terrace hierarchy, we have mapped all terraces above **Qtch1/Qtca1** level (≈80m) as **Qtgh**. The dividing line between **Qtgh** gravel derived from an ancestral Rio Chama (those with basalt clasts) and that derived from an ancestral Canjilon Creek is found along the ridge that defines the northwest edge of the Llano Del Vado (in the east-central part of the quad). However, some Canjilon Creek gravel has been reworked from this ridge and redeposited as unit **Qg** to the west of this ridge. Gravel consists of pebbles through boulders. In addition to quartzite, there are subordinate clasts of Mesozoic sedimentary rocks and Proterozoic metamorphic clasts. In deposits derived from the Rio Chama Drainage, Brazos Basalt (and possibly some Jarita Basalt from the Los Pinos Formation) forms ≈1–10% of terrace deposits. The deposit is 2–10(?) m thick.

**Rio Chama Terrace level1**—Strath is located approximately 72–80 m above the Qtch1 modern stream grade. Comparison of this strath height with Koning et al. (2011, table 3 and figures 5–6) and correlations of Gonzales (1993) would suggest an age range of 330–470? ka (Koning et al., 2006).

**Rio Chama Terrace level2**—Strath is located 40–55 m above the modern stream grade. Comparison of this strath height with Koning et al. (2011, table 3 and figures 5-6) and correlations of Gonzales (1993) would suggest an age range of 200–380? ka (Koning et al., 2006). **Rio Chama Terrace level3**—Strath is located 27–30 m above the modern stream

grade. Grades into unit **Qtca3** on the northwest shores of Lake Abiquiu (Koning et al., 2006). Comparison of this strath height with Koning et al. (2011, table 3 and figures 5–6) and correlations of Gonzales (1993) would suggest an age range of 100–280? ka (Koning et al., 2006). **Rio Chama terrace level4**—Strath is located 22–26 m above the modern stream grade and mostly submerged by the waters of Lake Abiquiu. Based on its strath

height, it may correlate to the 20–40 m terrace deposit of Koning et al. (2011) and have an age of 100-160 ka (Koning et al., 2006). However, Chestnut (written communication, 2020) more recently obtained calibrated radiocarbon ages for terraces between 19 and 22 m above the Rio Chama that ranges from ≈22–41 ka. Rio Chama Terrace level5—Strath is located 16–20 m above the modern stream grade. Comparison of this strath height with Koning et al. (2011, text, table 3, and

gures 5–6) would suggests an age range of 20–100 ka. However, Chestnut (written communication, 2020) more recently obtained calibrated radiocarbon ages for terraces between 19 and 22 m above the Rio Chama that ranges from ≈22–41 ka.

Qtca1 modern stream grade. Koning et al. (2006) suggest a possible correlation with a high terrace along the lower Rio Chama that contains the 620 ka lava Creek B ash. Canjilon Creek terrace level2—Strath is located approximately 50 m above the Qtca2 modern stream grade. Relatively extensive deposit. Comparison of this strath height with Koning et al. (2011, table 3 and figures 5–6) and correlations of

Gonzales (1993) would suggest an age range of 200–380? ka (Koning et al., 2006).

**Canjilon Creek terrace level1**—Strath is located approximately 70–85 m above the

Canjilon Creek terrace level3—Strath is located 22–27 m above the modern Qtca3 stream grade. Comparison of this strath height with Koning et al. (2011, table 3 and figures 5–6) and correlations of Gonzales (1993) would suggest an age range of 100–280? ka (Koning et al., 2006). However, Chestnut (written communication, 2020) obtained calibrated radiocarbon ages for terraces between 19 and 22 m above the Rio Chama that range from ≈22–41 ka.

Canjilon Creek terrace level4—Strath is located 15–22 m above the modern stream grade near Highway 84, but this height increases to 27 m near the confluence with the Rio Chama. Comparison of this strath height with Koning et al. (2011, text, table 3, and figures 5-6) would suggest an age of 100-160 ka. However, Chestnut (written communication, 2020) more recently obtained calibrated radiocarbon ages for terraces between 19 and 22 m above the Rio Chama that range from ≈22–41 ka.

Canjilon Creek terrace level5 — Strath is located 13–17 m above the modern stream Qtca5 grade. A comparison of this strath height with Koning et al. (2011, text, table 3, and figures 5-6) would suggests an age range of 20–100 ka (Koning et al., 2006).

### Description of Map

has been provided by Kelley et al. (2006).

CRETACEOUS ROCKS retaceous stratigraphy on the Echo Amphitheatre quadrangle follows that of Owen et al. (2005) and Koning et al. (2006). An excellent geologic history of this part of the Chama Basin

Paguate and Clay Mesa Members of Dakota Sandstone—The Paguate Member is composed of yellowish to tan; Moderately strong to strong; moderately well-sorted; subrounded; medium to thick-bedded; very fine- to medium-grained; commonly burrowed; arkosic quartz sandstone. Sandstones are mostly coarse-grained near the base, and medium-grained at top. Rare pelecypod and fragmentary ammonite fossils have been found (Lucas et al., 2009). The Paguate is interpreted as middle and outer shoreface sands (Owen et al., 2005). Hand samples are difficult to distinguish from the Cubero Sandstone.

Some thin, loose Quaternary sand presumably derived from weathering of the Paguate Member is present on the Mesa de los Viejos, but this material is nowhere exposed and seems to be generally less than 1 m thick. Very rare quartzite pebbles were observed within this loose sand in Section 1 T24N:R3E and would seem to indicate the former presence of more extensive Quaternary cover.

The underlying Clay Mesa Tongue is a very poorly exposed shale and siltstone(?) that sometimes forms a narrow bench beneath the Paguate Member. The Clay Mesa Tongue is not present in the "Highway 84 Section" of Owen et al. (2005) a few miles north of Echo Amphitheatre (in the northeast part of this quadrangle). However, the Clay Mesa Tongue is identified in the western half of this quadrangle based on uncommon exposures of shale at the base of cliffs formed by the Paguate Member and is tentatively inferred in the eastern part, off the quadrangle, based on a slope break at the base of the Paguate Member in some locations. The Clay Mesa Tongue is approximately 2–3 m thick where exposed. The total thickness of **Kdpc** ≈18 m thick.

Cubero, Encinal Canyon, Oak Canyon and Cubero Members of Dakota Sandstone—Mostly poorly exposed; tan to yellow-brown quartzose sandstone, dark-gray and brown carbonaceous shale, and minor greenish- gray mudstone and bentonite. Includes, from oldest to youngest: the Encinal Canyon, Oak Canyon, and Cubero Members.

The Encinal Canyon Member is highly variable in thickness, ranging from 2–24 m and averaging 8 m regionally (Owen et al., 2005). This tan, cross-bedded quartz sandstone with thin- to medium-bedding, sometimes contains carbonized plant fragments. The Oak Canyon Member is a black, muddy siltstone interbedded with thin (<1 m) beds of ledgy and often lenticular, white to orange, cross-bedded, bioturbated sandstone. The "A bentonite" is found in the lower part of the Oak Canyon Member and recently provided a direct age of 98.1 ± 2.4 Ma (Peters, 2004). They were interpreted as offshore marine deposits (Owen et al., 2005). The Cubero Member is a sometimes well-exposed; yellowish to tan; moderately strong to strong; moderately well- to well-sorted; subrounded to rounded; medium- to thick-bedded; very fine to fine; commonly burrowed; quartz sandstone with minor silt and shale approximately 10-15(?) m thick. Bedding features are commonly obliterated by burrowing. Lower contact is sharp to gradational over about 1 m. Upper contact usually sharp. The entire thickness of

**Burro Canyon Formation**—Whitish to tan; moderately strong to strong; poorly to moderately sorted; subrounded; medium- to thick-bedded; fine to medium, sometimes pebbly; cross-laminated and plane-laminated; sometimes pebbly to cobbly sandstone and red and/or green; sometimes mottled; laminated or massive clay and siltstone. Small-scale trough cross-bedding is associated with the conglomeratic channels, which are more common near the base of the unit in the Echo Amphitheatre area. Conglomerate clasts are mostly varicolored quartzite and chert pebbles with less common sandstone and limestone(?) clasts. Clasts are usually < 3 cm in diameter but occasionally up to 20 cm. Laminar, low-angle wedge, and high-angle planar wedge cross-bedding is common in the sandier portions of the unit regionally. This unit is only rarely exposed near the top of landslides along the edge of the Mesa de los Viejos and in a few other areas, and is interpreted as coastal plain, braided stream deposits (Owen et al., 2005). The unit is up to  $\approx 50(?)$  m thick.

### JURASSIC ROCKS

Jurassic stratigraphy on the Echo Amphitheatre quadrangle follows Lucas et al. (2005a), which is based on the regional stratigraphy of Anderson and Lucas (1992, 1994, 1995, 1996, 1997) and Lucas and Anderson (1997, 1998). An excellent geologic history of this part of the

**Brushy Basin Member of Morrison Formation**—The unit is a variegated pale-greenish-gray, grayish, yellow-green, pale-olive, yellowish-brown, and pale-reddish-brown bentonitic mudstone with a few beds of trough-crossbedded pebbly sandstone. Locally, the base of the Morrison Formation is a thin (up to 8 m thick) interval of trough-crossbedded sandstone and interbedded mudstone. Above that interval, the formation is mostly mudstone. Greenish-white, medium-bedded sandstones with cross-bedding and mud-rip-up clasts and thin tabular sandstones are present in a few places near the top of the unit. The basal sandy interval is likely correlative to the Salt Wash Member of the Morrison Formation to the west and south. However, this interval is neither thick enough, persistent enough, nor lithologically distinctive enough to separate from the Brushy Basin Member here. Gastroliths (belly-stones), found mostly on the surface of unit **Qls**, are thought to be derived from this, 41–68 m thick unit.

Summerville Formation and Bluff Sandstone—The Summerville Formation is thinly and cyclically-bedded and composed of the following: maroon, grayish red and yellowish gray siltstone; sandy siltstone; fine gypsiferous sandstone; and mudstone. In the Chama Basin, the Summerville Formation is readily divided into two informal members, lower and upper. The lower member is 12 to 15 m thick and is repetitively-bedded gypsiferous sandstone and siltstone that forms a ribbed cliff or slope. It is the same unit that Goldman and Spencer (1941) termed the "Bilk Creek Sandstone Member" in southwestern Colorado. The upper member is 61 to 96 m of siltstone and thinly-interbedded gypsiferous sandstone and mudstone that forms a thick, grayish red and white, banded slope. Strata we term Summerville Formation were assigned to the Morrison Formation by Smith et al. (1961) and Ridgley (1977), though Ridgely (1989) did assign the lower member of the Summerville Formation to the Wanakah Formation.

It is often difficult to tell if exposed Summerville/Bluff Formation outcrops are in place or have been disrupted by landslides (see also Jtl, Jtg, and Qls descriptions). Directly above the Todilto Formation, beds of the Summerville are often contorted, and this may be due to mass movements. Alternatively, this deformation may be related to dewatering of the gypsum in the underlying Todilto Formation (see also Todilto Formation description for other possible mass movement features) or dissolution of gypsum within the Todilto (Kelley et al., 2006). We have included many exposures of Summerville rocks directly above the Todilto in **Qls** deposits. "Windows" of Summerville rocks surrounded by unit **Qls** have only been mapped as Jurassic bedrock where the elevation of contacts and relatively undisturbed bedding (not contorted and conformable with the low regional dip) indicate they have not been displaced. Because there are multiple possible causes for deformation of these units, the distinction between disturbed and undisturbed outcrops is sometimes a little arbitrary. Some 'windows' are too small to show at map scale, and many are queried (i.e., **Jsb**?) where mass movements may have displaced them. The unit is 74–111 m thick.

The overlying Bluff Sandstone is a light gray or pinkish, very fine-grained, well-sorted, crossbedded sandstone. This unit consists of two members not mapped separately. The lower, Junction Creek Member, comprises most of the formation (30-40 m thick) and is mostly pale-yellowish-green and light-olive-gray, very fine-grained, well-sorted sandstone with crossbeds in thick sets. These are primarily eolian deposits similar to the type section of the Junction Creek Member near Durango, Colorado (Goldman and Spencer, 1941). The overlying Recapture Member is 6–14 m thick and is mostly maroon, pale-brown, grayish-red, and light-greenish-gray gypsiferous siltstone, fine-grained sandstone, and mudstone. Recapture Member strata resemble underlying Summerville strata (Lucas and Anderson, 1997, 1998; Lucas et al., 2005) and is 44-47 m thick.

**Todilto Formation dominated by gypsum**—The Todilto Formation consists of a lower, Luciano Mesa Member composed mostly of limestone and commonly overlain by the Tonque Arroyo Member, an interval composed mostly of gypsum (Lucas et al., 1985, 1995; Kirkland et al., 1995). The ≈30 m thick, Tonque Arroyo Member, consists of white to light-gray-gypsum interbedded with carbonate that forms a prominent white cliff in this region. The Luciano Mesa Member is not always present in **Jtg**, but such areas were not mapped separately. In at least one area where the Todilto Formation seems to have slid over the top of the Entrada Sandstone and buried Quaternary hillslope deposits (see below), the Luciano Mesa Member may have been removed by mass movements. Any area where gypsum is present has been mapped as **Jtg** (Koning et al., 2006; Kelley et al., 2006).

The unit is up to 38 m thick.

\*Actually anhydrite but commonly referred to as 'gypsum' here and in the literature.

### odilto Formation dominated by limestone—In some areas, the Tonque Arroyo Member of the Todilto Formation is not present either due to nondeposition, erosion, or chemical dissolution (Koning et al., 2006; Kelley et al., 2006). The Luciano Mesa Member is 1–8 m thick\* and consists mostly of thinly laminated, dark-gray or yellowish-gray, kerogenic limestone. Beds near the base of the member are usually sandy, and microfolding of the thin limestone laminae is common. Although the Luciano Mesa Member is thin and commonly exposed in cliffs, we have sometimes exaggerated its thickness (i.e., the width of outcrop) in order to show its presence. Some small areas where only the Luciano Mesa Member is present have been lumped into Jtg because they are not able to be mapped at scale and/or relations are not clear (e.g., where the Tonque Arroyo may be present but buried by **QIs**).

We suspect that in some areas, the Tonque Arroyo Member has been removed by mass movements (leaving only the Luciano Mesa Member), but it has not been possible to prove this. Large (up to 100 m+) 'slabs' of Tonque Arroyo Member Gypsum are sometimes found within landslides and particularly near

the base of landslides.

Chinle Group (Upper Triassic)

In at least one area (in the eastern half of section 11 T24N:R3E) it can be seen that the Todilto Formation has moved en mass downslope over Quaternary(?) hillslope deposits (Figure 1) and large slabs of gypsum are seen at the base of landslide deposits below this point. The Luciano Mesa Member is not present here and may have been removed by mass movements. This sliding of the Todilto Formation seems to have occurred over at least a half kilometer of the outcrop. This relationship leads us to believe that the base of the Tonque Arroyo Member and/or the Luciano Mesa Member may have acted as the 'breakaway' surface for some landslides in the area. If this interpretation is correct, then all of the Jurassic section above the Todilto here is likely also displaced by mass movements. However, we have mapped 'windows' of the Summerville/Bluff and Morrison Formations above here as in-place bedrock because they are not obviously tilted relative to other bedrock units and are no more disturbed than many other such windows above locations where the Todilto is not obviously displaced.

\*An exception to the 2 m minimum thickness of units has been made for the

Luciano Mesa Member in some locations. Entrada Formation—Well-exposed; commonly reddish and yellowish but

sometimes light-brown, orange, whitish or grayish-orange; cross-bedded; cross-laminated; very fine- to medium-grained; moderately well-sorted and ripple laminated, eolian sandstone that commonly forms a prominent cliff. Transport direction at individual outcrops is variable, but the regional transport direction is toward the south and southwest (Tanner, 1965). The unit is 60–76 m thick.

All Triassic strata on the Echo Amphitheatre quadrangle are assigned to the Upper Triassic Chinle Group (Lucas, 1993). Triassic stratigraphy follows Lucas and Hunt (1992) and Lucas et al. (2003, 2005b). An excellent geologic history of this part of the Chama Basin has been provided by Kelley et al. (2006).

**Rock Point Formation**—Poorly to well-exposed; reddish- brown to yellowish-red beds of siltstone and very fine- to fine-grained; massive or thin to medium, tabular bedded sandstone and reddish-brown mudstone. Where deeply weathered(?), the Rock Point Formation forms an orange slope (slightly less red than the underlying Painted Desert Member of the Petrified Forest Formation). The lower contact of the Rock Point is mapped at the first persistent bed of sandstone above the mudstone of the Painted Desert Member or at the above-noted color change. The top of the Rock Point is a sharp, unconformable contact with overlying Entrada Sandstone. Width of the outcrop is sometimes exaggerated where exposed in or at the base of steep cliffs. The unit is up to 70 m thick.

Painted Desert Member of the Petrified Forest Formation-Poorly to well-exposed; brick-red to reddish-brown; thin- to thick-bedded; bentonitic(?) mudstone and claystone intercalated with minor greenish-gray to lightgreenish-gray, pebbly sandstone. Local reduction of the mudstone has resulted in cm-to-decimeter scale mottles, fracture linings, streaks, and meter-scale beds of light-gray, greenish-gray, and light-greenish-gray mudstone. Locally there are thin intervals of ripple-laminated to planar-laminated, very fine- to fine-grained sandstone. The mudstone is in thick to very thick, tabular beds, with minor thin to medium, tabular beds. The greenish pebbly sandstone bodies are lenticular, have up to 2.5 m of relief at their base, and may be as much as 3 m thick. The pebbles in these channel fills are composed of light-gray to very dark-gray limestone or calcrete(?) pebbles (or concretions?) with very minor mudstone rip-up clasts. Pebbles are up to 2 cm in diameter. Pebbles and sand grains are in a greenish, muddy matrix that imparts an overall greenish color. A few measured trends of channels in the area are W-E and SW-NE (Koning et al., 2006). The mudstone is well consolidated but weakly cemented; the coarser channel-fills are locally cemented by calcium carbonate. The base of the unit is mapped at the highest, persistent sandstone ledge of the Mesa Montosa Member, although some reddish sandstone lenses(?) or beds are found in the lowest part of the Petrified Forest Member and caution must be used to distinguish these from the underlying Mesa Montosa Member. The unit is up to 180 m thick.

andstone body within the Painted Desert Member of the Petrified Forest **ormation**—An isolated body of medium to coarse sandstone is found within the Painted Desert Member in the south-central part of the map. This body is approximately 25–30 m thick at its north end and seems to have a steep buttress unconformity on its eastern side. As this sandstone is traced to the south, it thins, and near its southern terminus, it is a bed of sandstone within **Rcpp**. An additional bed of sandstone in a similar stratigraphic position(?) was also observed just south of the Rio Chama Campground on the Laguna Peak Quadrangle (immediately north of the Echo Amphitheatre Quad). This body may represent an 'axial' stream portion of the Painted Desert Member. Hand samples of this sandstone are superficially similar to the sandstone of the Mesa Montosa Member and the Poleo Formation and could be mistaken for either.

Mesa Montosa Member of the Petrified Forest Formation-Poorly to vell-exposed; very fine- to fine-grained sandstone, siltstone, and mudstone. Siltstone ranges in color from reddish-brown to light-reddish-brown. Sandstone beds are very thin to medium, tabular, and ripple laminated, wavy laminated, or planar-horizontal laminated. Ripple-marks and troughs commonly give a northwest-to-southwest paleoflow direction (Koning et al., 2006). This unit represents a gradational facies between the Poleo Formation and the Painted Desert Member of the Petrified Forest Formation. The unit is 5–20(?) m thick.

Poleo Formation—Well-exposed; tan to yellowish; strong; medium to hick-bedded; fine- to very coarse-grained; moderately well-sorted; cross-laminated micaceous litharenite and minor pebble-conglomerate. Trough cross- stratification commonly gives a northwestward to westward paleoflow direction (Koning et al., 2006). The Poleo Formation has a sharp, scoured contact on the underlying Salitral Formation. It grades upward into the overlying Petrified Forest Formation thru the Mesa Montosa member. Up to 41 m-thick.

Salitral and Shinarump Formations—The Salitral Formation sometimes forms slope between the cliff-forming sandstones of the Shinarump and Poleo ormations. The Salitral Formation has been divided into two members that are not mapped separately here (Lucas et al., 2003, 2005b). The lower, Piedra Lumbre Member is composed of reddish-brown to light gray mudstone with a persistent sandstone bed (the El Cerrito Bed) at its top. The upper, Youngsville Member is mostly composed of reddish-brown mudstone. The lower contact of the Salitral Formation is a sharp surface where mudstone rests directly on sandstone or conglomeratic sandstone. The upper contact is a sharp, scoured surface where conglomerate/sandstone at the base of the Poleo is incised into the Salitral Formation. The unit is approximately 10 m thick.

> The Shinarump Formation consists of quartzose sandstone and siliceous conglomerate. This formation has previously been called the Agua Zarca Formation (e.g., Wood and Northrop, 1946; Dubiel, 1989; Lucas and Hunt, 1992). Above this is a mottled yellow, orange, red, purple, and white; thin; cross-bedded sandstone that appears nodular in places. Conglomerate consists of pebbles of quartz in a fine- to medium-grained quartz sandstone matrix. The basal contact is a sharp erosional scour on the underlying Cutler Group. The unit is 6–7 m thick.

### PENNSYLVANIAN-PERMIAN Arroyo del Agua Formation-Well-exposed; mostly brick- red; thin- to

CROSS SECTION ONLY UNITS

thick-bedded; fine to medium arkosic sandstone, muddy sandstone, and prick-red mudstone. Also, it contains some thick beds of yellowish-red and red mudstone that are commonly bioturbated and locally reduced to light-greenish-gray to light-gray colors. The unit is up to 130 m thick regionally.

ombined Rock Point Formation and Petrified Forest Member of the Painted Desert Formation ombined Mesa Montosa Member of the Petrified Forest Formation and

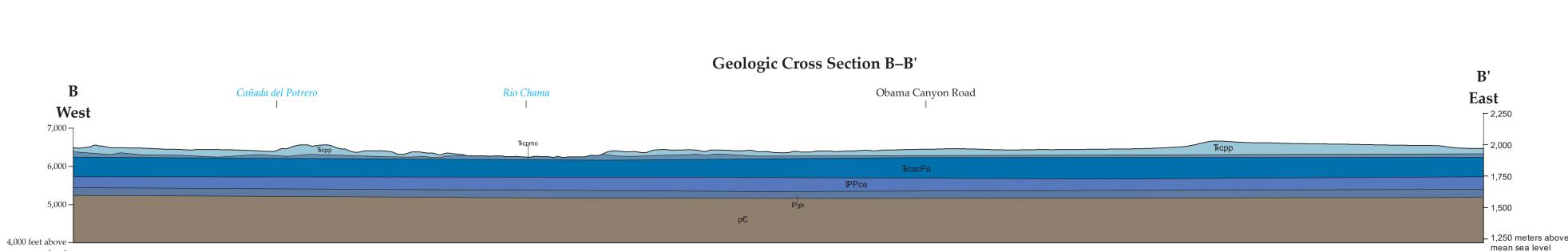
ombined Salitral, Shinarump and Arroyo del Agua Formations

El Cobre Canyon Formation—Brown siltstone, sandstone and extraformational nglomerate that overlies Proterozoic basement in the subsurface and is Cobre Canyon Formation contain numerous rhizoliths and comprise relatively thin, slope-forming units between multistoried sandstone beds that are arkosic micaceous, coarse grained and trough cross-bedded. On the Arroyo del Agua quadrangle, upper part contains numerous vertebrate fossils, primarily of Early Permian amphibians and reptiles (e.g., Langston, 1953; Berman, 1993; Lucas et al., 2005c). Up to 90 m thick.

Guadalupe Box Formation—Defined by Krainer et al. (2005) ( =Upper arkosic mestone member of the Madera Group of Northrop and Wood (1946)). terbedded red to green micaceous, arkosic sandstone, gray sandy, arkosic limestone, gray, fossiliferous, sandy arkosic, cross-bedded limestone, and red, green, and black shale and siltstone. Most common fossils are crinoid columnals. Some arkosic clasts are up to 2 cm in diameter and are angular. Upper contact gradational with clastic red beds of the overlying Cutler Group;

lower contact not exposed.

### Geologic Cross Section A-A' Continental Divide National Scenic Trail mean sea level mean sea level



## 1:24,000

1000 0 1000 2000 3000 4000 5000 6000 7000 Fee

Contour Interval 20 Feet

North American Vertical Datum of 1988

New Mexico Bureau of Geology and Mineral Resources

Open-File Geologic Map 280

Mapping of this quadrangle was funded by a matching-funds grant from the STATEMAP program of the

National Cooperative Geologic Mapping Act (Fund Number: G19AC00226), administered by the U. S.

Geological Survey, and by the New Mexico Bureau of Geology and Mineral Resources, (Dr. Nelia W.

Geologic Map of the Echo Amphitheater

7.5-Minute Quadrangle,

Rio Arriba County, New Mexico

December 2020

Muddy Spring Geology, P.O. Box 488, Dixon, New Mexico 87527

Dunbar, Director and State Geologist; Dr. J. Michael Timmons, Assoc. Director for Mapping Programs).

New Mexico

Projection and 1,000-meter grid: Universal Transverse Mercator, Zone 13S, shown in blue

10,000-foot ticks: New Mexico Coordinate System of 1983 (Central zone), shown in red

North American Datum of 1983 (NAD83)

Magnetic Declination July, 2020 8° 30' East **Quadrangle Location** 

... U.S. Census Bureau, 2015-2016

...IFSAR 4.5 m Digital Terrain Model, 2008

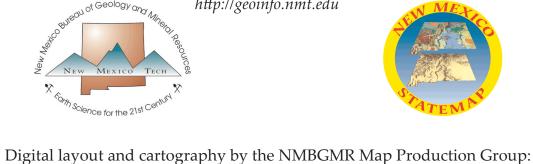
..FWS National Wetlands Inventory 1977-2014

New Mexico Bureau of Geology and Mineral Resources New Mexico Tech 801 Leroy Place Socorro, New Mexico 87801-4796

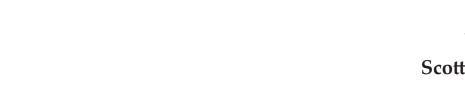
[575] 835-5490 This and other STATEMAP quadrangles are available for free download in both PDF and ArcGIS formats at:



Phil L. Miller, Amy L. Dunn, Ann D. Knight, and Justine L. Nicolette







### Comments to Map Users

The New Mexico Bureau of Geology and Mineral Resources created the Open-file Geologic Map Series to expedite dissemination of these geologic maps and map data to the public as rapidly as possible while allowing for map revision as geologists continued to work in map areas. Each map sheet carries the original date of publication below the map as well as the latest revision date in the upper right corner. In most cases, the original date of publication coincides with the date of the map product delivered to the National Cooperative Geologic Mapping Program (NCGMP) as part of New Mexico's STATEMAP agreement. While maps are produced, maintained, and updated in an ArcGIS geodatabase, at the time of the STATEMAP deliverable, each map goes through cartographic production and internal review prior to uploading to the Internet. Even if additional updates are carried out on the ArcGIS map data files, citations to these maps should reflect this original publication date and the original authors listed. The views and conclusions contained in these map documents are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the State of New Mexico, or the U.S. Government.

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

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