Triassic-Jurassic stratigraphy in southwestern Colorado

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TRIASSIC-JURASSIC STRATIGRAPHY IN SOUTHWESTERN COLORADO

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Abstract—In southwestern Colorado (south of the Uncompahgre Plateau), Triassic and Jurassic strata are locally exposed and most have been assigned parochial lithostratigraphic names that should be abandoned and replaced with the names of regional lithostratigraphic units. The Lower-Middle Triassic Moenkopi Group is divided into the (in ascending order) Tenderfoot, Ali Baba and Sewemup formations. These are mostly red-bed siliciclastic rocks typically about 107-137 m thick, but locally they are up to 400 m thick or more. Upper Triassic strata of the Chinle Group rest unconformably on the Moenkopi strata and belong to three formations (in ascending order): (1) Moss Back Formation, up to 49 m of sandstone and conglomerate; (2) Petrified Forest Formation, up to 90 m thick, mostly mudrock and some sandstone and conglomerate; and (3) Rock Point Formation, as much as 213 m of repetitively bedded siltstone and fine-grained sandstone. Sparse age data from southwestern Colorado and correlation to outcrops and age data in adjacent states indicate the Moenkopi Group in southwestern Colorado is Dienerian-Anisian in age, and the Chinle Group is Norian-Rhaetian in age. In southwestern Colorado, Middle-Upper Jurassic strata of the San Rafael Group (Entrada, Todilto, Summerville and Bluff formations) are ~ 300 m thick and consist of eolian sandstone, salina limestone and siltstone/sandstone deposited on an arid coastal plain. The Upper Jurassic Morrison Formation (sandstone-dominated Salt Wash and overlying, mudstone-dominated Brushy Basin members) is as much as 244 m thick and consists of sandstone and mudstone deposited in fluvial environments. Important regional unconformities in the Triassic-Jurassic section of southwestern Colorado are Tr-1 (base of Moenkopi Group), Tr-3/Tr-4 (base of Chinle Group), J-2 (base of Entrada Sandstone), J-3 (base of Todilto Formation), J-5 (base of Salt Wash Member of Morrison Formation) and K (base of Cretaceous strata above Morrison Formation).

INTRODUCTION

Southwestern Colorado (here, the area south of the Uncompahgre Plateau to the Four Corners) is a region of high mountains and river canyons that locally expose Triassic-Jurassic sedimentary rocks. This area includes the drainages of the Dolores and San Juan rivers across Mesa, Delta, Montrose, San Miguel, Ouray, Dolores, San Juan, Montezuma and La Plata counties, Colorado (Fig. 1).

Most of the Triassic-Jurassic strata exposed in southwestern Colorado have long been labelled with a local (parochial) stratigraphic nomenclature that belies the fact that their lithosomes continue into southeastern Utah, northeastern Arizona and northwestern New Mexico under different lithostratigraphic names (Table 1). Beginning in the early 1990s, I worked with others to unify the lithostratigraphy of the Triassic-Jurassic strata in southwestern Colorado to promote a better understanding of the regional early-middle Mesozoic lithostratigraphy. My purpose here is to review that lithostratigraphy, age assignments and the correlation of Triassic-Jurassic strata in southwestern Colorado. I conclude with a brief discussion of the regional unconformities that punctuate the Triassic-Jurassic strata of southwestern Colorado.

LITHOSTRATIGRAPHY AND BIOSTRATIGRAPHY

Triassic

Moenkopi Group

The Lower-Middle Triassic Moenkopi Group (formerly Formation, see Lucas et al., 2007b) crops out in southwestern Colorado in the Salt Anticline region to the southwest of the Uncompahgre Plateau (Shoemaker and Newman, 1959) (Fig. 2). Dane (1935, p. 51) first drew attention to an unusually thick section of strata he assigned to the Moenkopi Formation in the Sinbad Valley of Colorado (also see McKee, 1954). Shoemaker and Newman (1959) subsequently created lithostratigraphic nomenclature for these strata, assigning them to the (ascending order): Tenderfoot, Ali Baba, Sewemup and Pariott members (here considered formations) (Fig. 2; Table 1). The Pariott Formation has very local outcrops in and near the Castle Valley of Grand County, Utah but is briefly discussed here. Stewart et al. (1972b, fig. 4) depicted the limit of Moenkopi rocks in southwestern Colorado as an area from southwestern Mesa County through western Montrose County just into northwesternmost San Miguel County, Colorado (Fig. 2).

The Moenkopi strata of southwestern Colorado were deposited around, in and over already existing anticlines and synclines that had been created by salt diapirism (e.g., Shoemaker and Newman, 1959; Elston and Landis, 1960; Stewart et al., 1972b; Blakey et al., 1993). Because of this, Moenkopi thickness varies dramatically, with thick successions in what were synclines and thin-to-no Moenkopi strata over what were anticlines. Typical Moenkopi total thickness in southwestern Colorado is 107-137 m but is locally up to 400 m or possibly more (Stewart et al., 1972b). To the northeast, the Moenkopi Group pinches out over the Uncompahgre Plateau, partly due to depositional thinning and partly due to erosional truncation beneath the overlying Upper Triassic Chinle Group. Across its southwestern Colorado outcrops, Moenkopi strata rest unconformably on upper Paleozoic (Pennsylvanian or Permian) strata, in some places with angular unconformity. The Chinle Group overlies the Moenkopi Group in southwestern Colorado at an erosional unconformity. Locally, for example along the Dolores River southeast of Gateway, the Chinle-Moenkopi contact is an angular unconformity (Shoemaker, 1955).

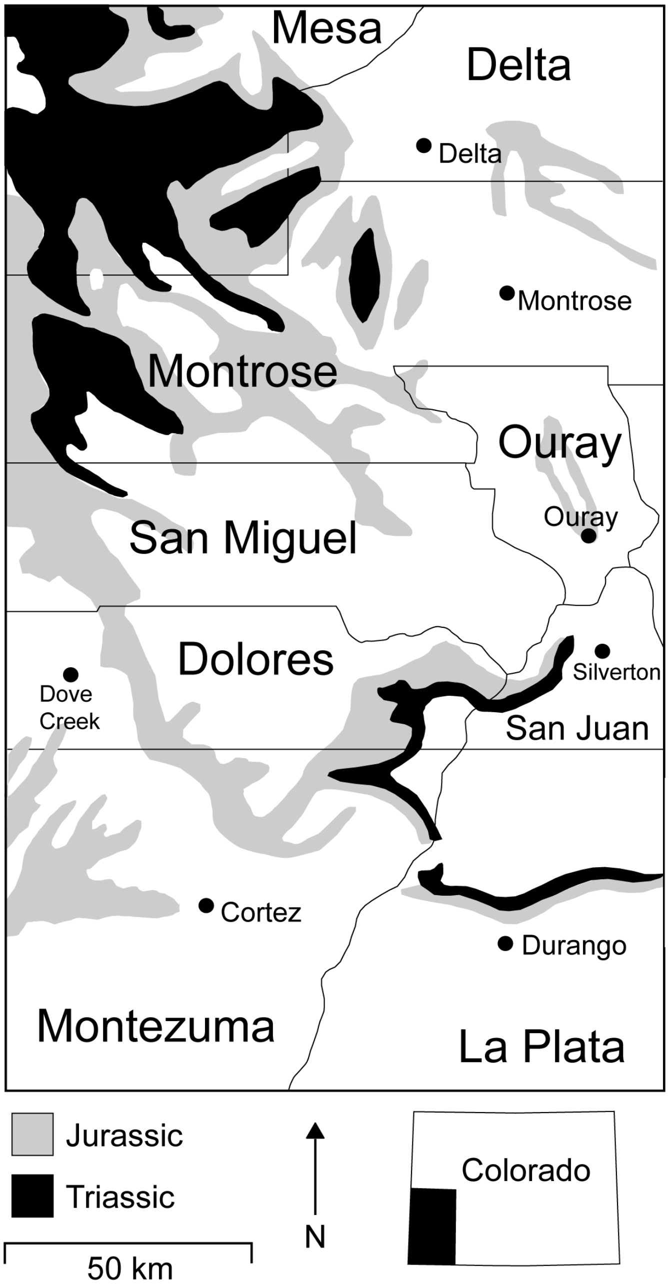

FIGURE 1. Map of southwestern Colorado showing distribution of Triassic and Jurassic strata (geology simplified from King and Beikman, 1974).

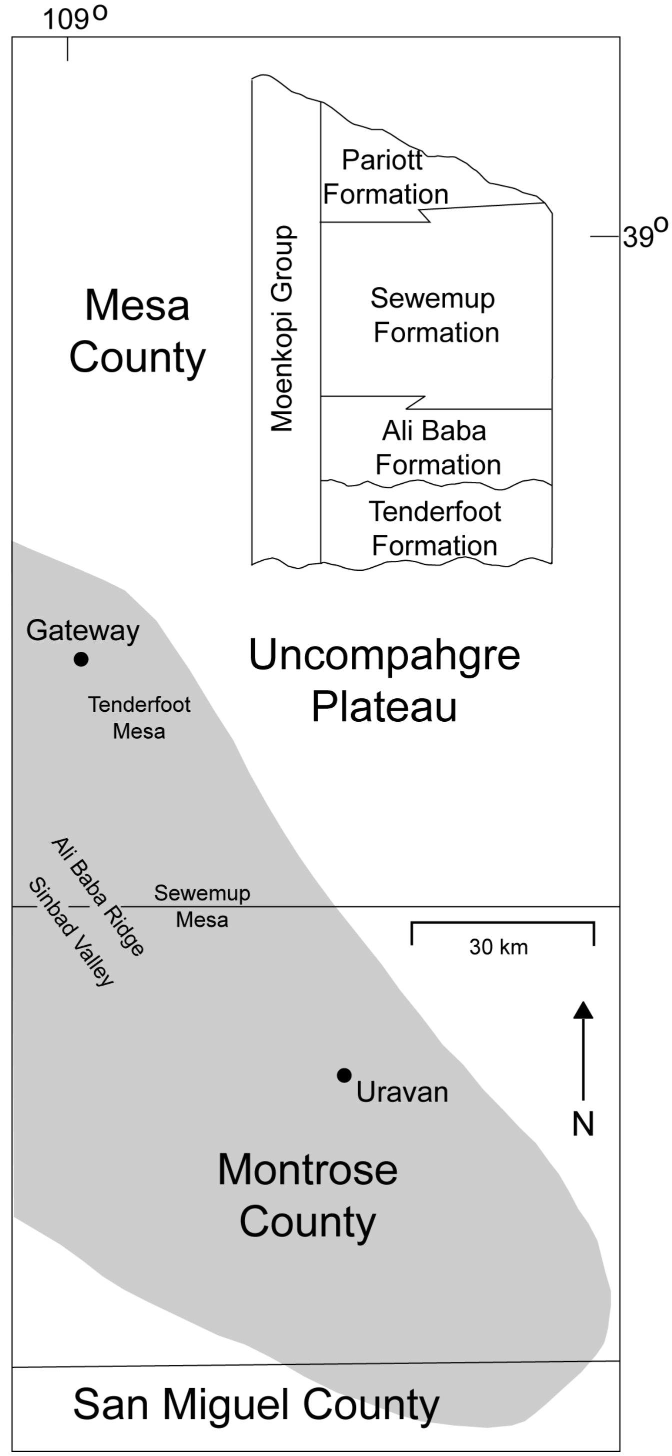

FIGURE 2. Generalized Moenkopi Group stratigraphic section and distribution of Moenkopi strata (gray area) in southwestern Colorado (modified from Stewart et al., 1972b).

The Tenderfoot Formation takes its name from Tenderfoot Mesa near Gateway (Shoemaker and Newman, 1959; Fig. 2). It is mostly reddish-brown to brown, slope-forming micaceous siltstone with some beds of conglomerate and gypsum near its base. Beds are mostly laminar, but some crossbedding is present. Thickness is typically 30-46 m.

The overlying Ali Baba Formation took its name from Ali Baba Ridge in the Sinbad Valley (Shoemaker and Newman, 1959; Fig. 2). It consists of pale red and grayish-red conglomeratic sandstone, sandstone and siltstone. Crossbedding is common, and the Ali Baba Member coarsens to the northeast toward the Uncompahgre Plateau. It has a maximum thickness of 88 m and rests on the Tenderfoot Member with evident disconformity.

The Ali Baba Formation grades upward into the Sewemup Formation, which was named for Sewemup Mesa (Shoemaker and Newman, 1959), which forms the eastern wall of Sinbad Valley (Fig. 2). The Sewemup Formation is mostly pale reddish-brown and grayish-red micaceous siltstone, and some beds of fine-grained sandstone. Laminar and ripple-laminar bedding dominate the unit, which is up to 152 m thick. In southwestern

TABLE 1. Comparison of traditional lithostratigraphic nomenclature of Triassic-Jurassic strata in southwestern Colorado and nomenclature used here.

Traditional nomenclature	Nomenclature used here	Age
Morrison Formation:	Morrison Formation:	Late Jurassic
Brushy Basin Member	Brushy Basin Member	
Salt Wash Member	Salt Wash Member	
Junction Creek Sandstone Member	Bluff Sandstone	Late Jurassic
Wanakah Marl Member	Summerville Formation	Middle Jurassic
Pony Express Limestone Member	Todilto Formation	Middle Jurassic
Entrada Sandstone	Entrada Sandstone	Middle Jurassic
Dolores Formation:	Chinle Group:	Late Triassic
upper member	Rock Point Formation	
middle member	Petrified Forest Formation	
lower member	Moss Back Formation	
Moenkopi Formation:	Moenkopi Group:	Early Triassic
Sewemup Member	Sewemup Formation	
Ali Baba Member	Ali Baba Formation	
Tenderfoot Member	Tenderfoot Formation	

Colorado, the Chinle Group overlies the Sewemup Member, but in the Castle Valley of eastern Utah the Pariott Formation is present at the top of the Moenkopi section.

The Pariott Formation was named for Pariott Mesa on the northern side of Castle Valley in Utah (Shoemaker and Newman, 1959), and its outcrops are restricted to that general area. It consists of reddish brown and purplish brown sandstone and a few conglomeratic beds, and grayish-red and orange mudstone and siltstone. Bedforms are ripple laminations and crossbeds. At the type section, the Pariott Formation is 41 m thick.

Chinle Group

Upper Triassic strata in southwestern Colorado were originally referred to the Dolores Formation of Cross (1899; Cross and Howe, 1905). Nevertheless, it has long been clear that the Dolores Formation, usually divided into three informal members (Figs. 3-4; Table 1), can be correlated with Chinle Group units in nearby southeastern Utah and northeastern Arizona (e.g., Stewart et al., 1972a; Lucas, 1993; Lucas et al., 1997b; Lucas and Heckert, 2005). Furthermore, the name Dolores Formation has never been used except in the small area of southwestern Colorado. Therefore, Lucas (1993) argued that this parochial name should be abandoned in favor of the much more widely used Chinle Formation (Group), even though Dolores has priority over Gregory's (1917) name Chinle.

The "lower member of the Dolores Formation" is 24-49 m of greenish-gray to tan, fine-grained quartzose sandstone and calcrete-pebble conglomerate, which locally contains siliceous pebbles (Fig. 4). It rests unconformably on Moenkopi Group strata (Dubiel et al., 1989) or on the Lower Permian Cutler Group (Fig. 4), and is demonstrably correlative to the Moss Back Formation of the Chinle Group in southeastern Utah, to which it is assigned (Stewart et al., 1972a; Lucas, 1993; Lucas et al., 1997b).

The overlying "middle member of the Dolores Formation" is up to 90 m of grayish red siltstone, mudstone, trough-crossbedded fine-grained sandstone and limestone-pebble conglomerate (Fig. 4). Stratigraphic position, lithotypes and paleontology correlate the "middle member" to the upper part of the Petrified Forest Formation (Painted Desert Member) of the Chinle Group in southeastern Utah/northeastern Arizona, to which it is assigned (Stewart et al., 1972a; Lucas, 1993; Lucas et al., 1997b).

The "upper member of the Dolores Formation" is as much as 213 m of repetitively bedded light brown and reddish brown siltstone and sandy siltstone (Figs. 3A-B, 4). Siltstone beds contain diverse evidence of calcrete pedogenesis (Blodgett, 1988; Tanner and Lucas, 2006), and a fluvial sandstone interval at the top of the "upper member" likely correlates to the Hite Bed in Utah (Fig. 4). The stratigraphic position, lithotypes and paleontology of the "upper member" equate it to the Rock Point Formation of the Chinle Group in adjacent states, to which it is assigned (Stewart et al., 1972a; Lucas, 1993; Lucas et al., 1997b).

Biostratigraphy and Correlation

Moenkopi Group

Very few biostratigraphic (or other age) data are available for Moenkopi Group strata in southwestern Colorado. A key to their correlation long has been their perceived stratigraphic relationships westward into southeastern Utah. Critical to this correlation is identifying the pinchout of the Sinbad Formation of the Thaynes Group into Moenkopi strata in the Canyonlands of southeastern Utah (McKnight, 1940; Lucas, 1995). Here, the Sinbad Formation pinches out into the upper part of the Ali Baba Fomation (Lucas, 1995; Lucas et al., 1997a). The Sinbad contains an ammonoid fauna of Smithian age (Lucas et al., 2007a), so this indicates the uppermost Ali Baba Formation is of Smithian age. Underlying Ali Baba strata and the Tenderfoot Formation are homotaxial with the Black Dragon Formation of the Moenkopi Group in east-central Utah and thus likely of Dienerian age. Strata of the Sewemup and Pariott formations

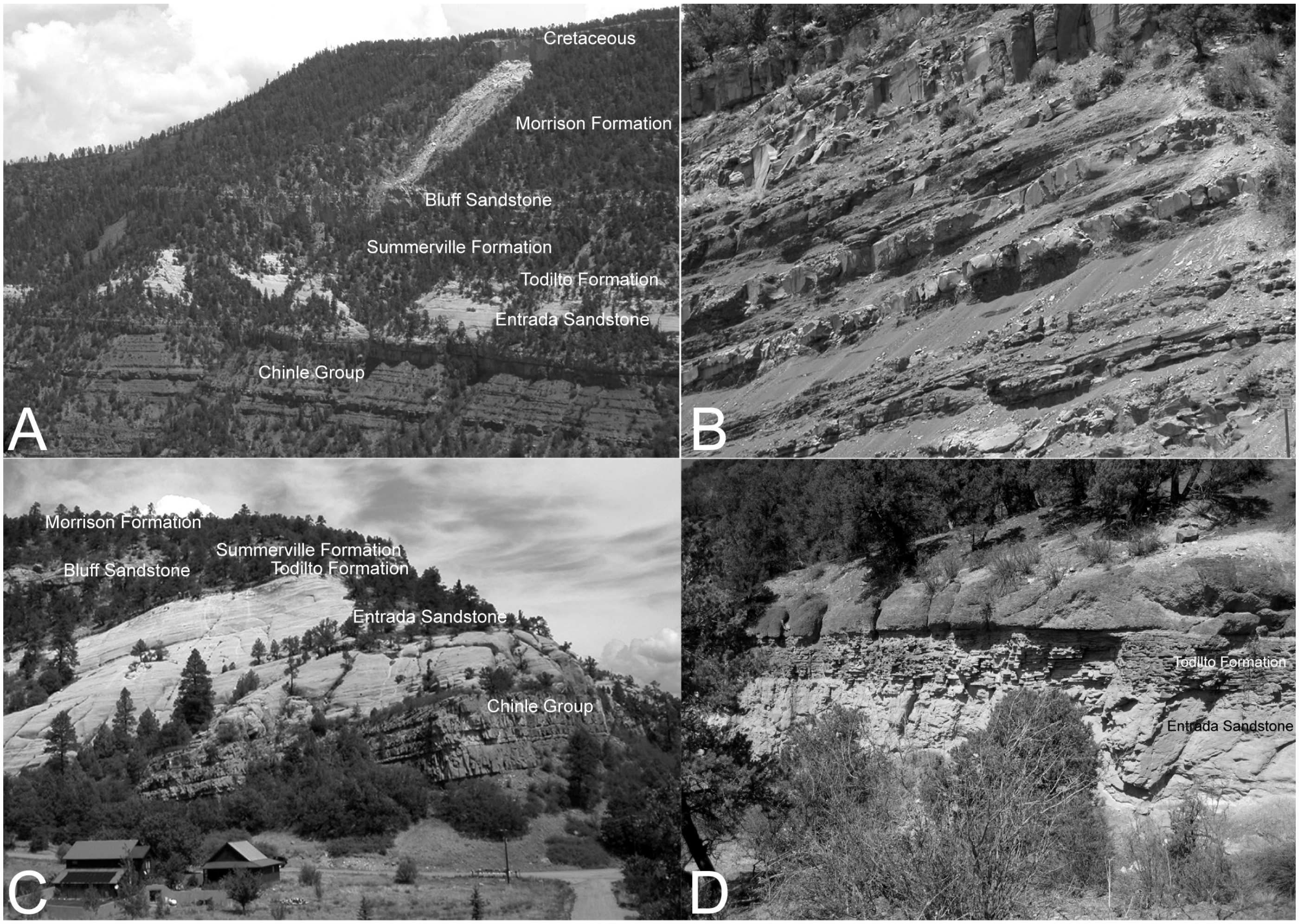

FIGURE 3. Selected Triassic-Jurassic outcrops in southwestern Colorado. **A.** Chinle Group, Entrada Sandstone, Todilto-Summerville formations, Bluff Sandstone, Morrison Formation and Cretaceous formations northeast of Animas City Mountain, east of the Animas River near Durango. **B.** Repetitively-bedded Rock Point Formation of Chinle Group in roadcut of Highway 550 near Durango in NE ¼ NE ¼ sec. 9, T35N, R9W. **C.** Chinle Group, Entrada Sandstone, Todilto-Summerville formations, Bluff Sandstone and Morrison Formation at Junction Creek near Durango, NE ¼ sec. 5, T35N, R9W. **D.** Todilto Formation above Entrada Sandstone in type area of "Pony Express Beds" near Ouray.

are homotaxial with the overlying Torrey and Moody Canyon formations. The Torrey is of Spathian age (Lucas and Schoch, 2002), and the Moody Canyon may be as young as Anisian (early Middle Triassic). Indeed, it is tempting to equate the relatively coarse-grained Pariott Formation to similar, coarse-grained uppermost units of the Moenkopi Group in northeastern Arizona (Holbrook Formation) and northern New Mexico (Anton Chico Formation). These strata are assigned an early Anisian age based on biostratigraphy and magnetostratigraphy (Lucas and Schoch, 2002).

Some workers (e.g., Shoemaker and Newman, 1959; Stewart, 1959; Stewart et al., 1972b) suggested that the Tenderfoot Formation may be of Permian age. However, Steiner et al. (1993; also see Helsley and Steiner, 1974) noted that magnetic paleopoles calculated for the Tenderfoot and overlying Moenkopi strata are essentially identical, which suggests that the Tenderfoot Formation is of Triassic age.

There was one misleading result, though, regarding the age of Moenkopi strata in southwestern Colorado. This was the claim that juvenile specimens of the Smithian ammonoid genus *Meekeoceras* were found in structurally disrupted Sewemup strata in the Salt Valley northeast of Moab in Grand County, Utah (Dane, 1935; Shoemaker and Newman, 1959; Stewart et al., 1972b). Re-examination of the locality and the fossils showed them to not be ammonoids but instead gastropods of the genus *Gyraulus* associated with other freshwater gastropods, ostracods and charophytes—a fossil assemblage of Early Cretaceous (Aptian) age from structurally disrupted strata of the Cedar Mountain Formation, not the Moenkopi Group (Lucas et al., 1997a).

Chinle Group

Chinle Group strata have much better age constraints than do strata of the Moenkopi Group (e.g., Lucas, 1993, 1997, 2010; Lucas and Tanner, 2007). Biostratigraphic data from Chinle strata outside of southwestern Colorado correlate the lower-middle "members" of the "Dolores Formation" to the Revueltian land-vertebrate faunachron of early-middle Norian age. The conglomerate beds of the "middle member of the Dolores Formation" are the "saurian conglomerates" of earlier

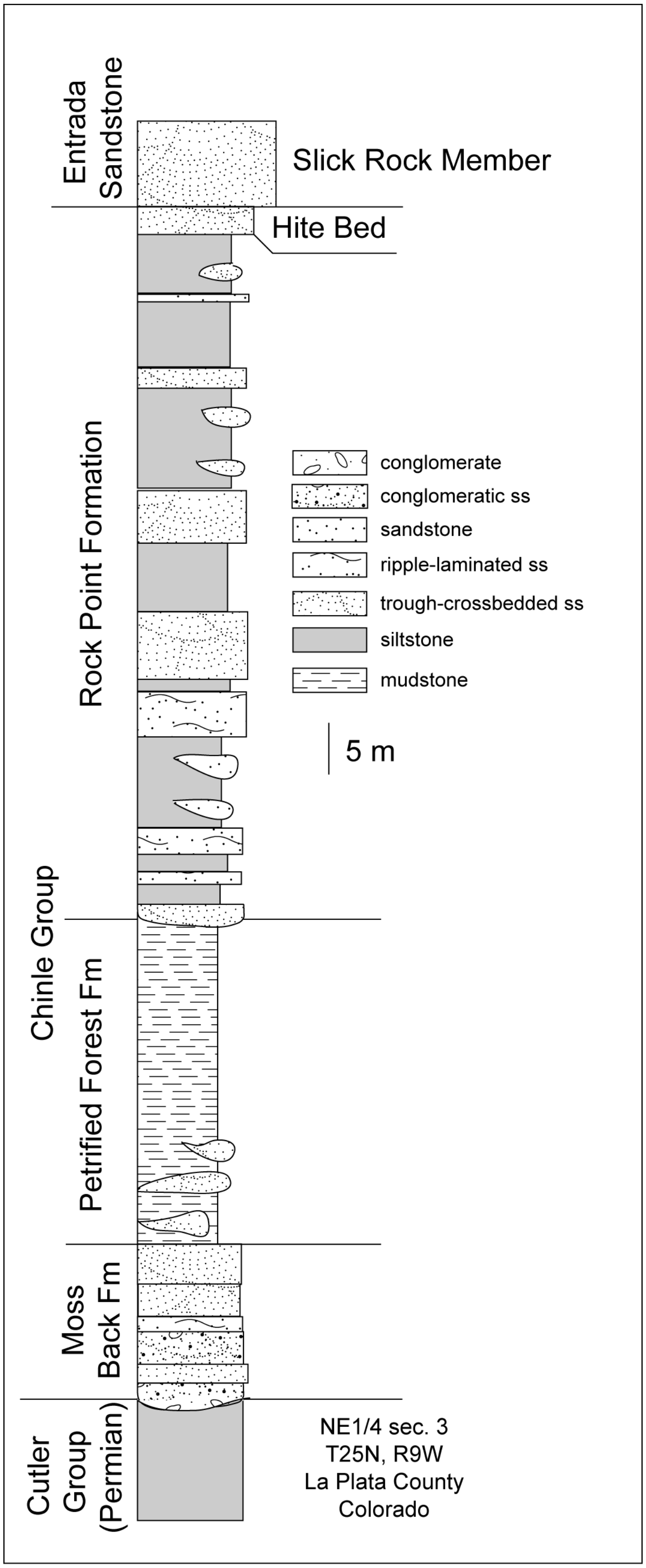

FIGURE 4. Measured stratigraphic section of Upper Triassic Chinle Group north of Durango in NW ¼ NE ¼ sec. 3, T35N, R9W.

workers (e.g., Hills, 1880) and yield phytosaurs and other vertebrate fossils of Revueltian (Norian) age (Dubiel et al., 1989; Lucas, 1993).

Regional correlations assign the "upper member of the Dolores Formation" to the Apachean land-vertebrate faunachron, of late Norian-Rhaetian age. Indeed, the "upper member" produces fossil fishes (Schaeffer, 1967; Elliott, 1983) of the Apachean (late Norian-Rhaetian) fish assemblage of Huber et al. (1993; also see Milner et al., 2006). Fossil plants from the "upper member" near Placerville and Bedrock (Brown, 1956; Arnold, 1964; Tidwell et al., 1977; Ash, 1987) are part of the youngest plant assemblage of the Chinle Group, the *Sanmiguelia* floral zone (Lucas, 2013).

JURASSIC

Lithostratigraphy

Like the Upper Triassic strata, much of the Jurassic section in southwestern Colorado has been assigned a local and unnecessary (redundant) stratigraphic nomenclature (Fig. 5; Table 1) that was created for the Jurassic rocks in this part of southwestern Colorado and can mostly be abandoned (Goldman and Spencer, 1941; Lucas and Anderson, 1997). These are units of the San Rafael Group that can now be assigned to the (in ascending order): Entrada, Todilto, Summerville and Bluff formations (Figs. 3C-D, 5-6; Table 1). The base of the San Rafael Group (= base of the Entrada Sandstone) is a regional unconformity on the Rock Point Formation of the Chinle Group. This is the J-2 unconformity of Pipiringos and O'Sullivan (1978). Deposition may have taken place in southwestern Colorado during the Early Jurassic, but erosion associated with the J-2 unconformity removed the Lower Jurassic deposits.

The base of the Entrada Sandstone is a sharp, disconformable surface above siltstone and fine sandstone of the Rock Point Formation of the Chinle Group. The top of the Entrada Sandstone also is a sharp, apparently disconformable surface overlain by limestone at the base of the Luciano Mesa Member of the Todilto Formation (Ahmed Benan and Kocurek, 2000). At Durango, the Entrada Sandstone is about 87 m of light gray to white, fine- to coarse-grained sandstone with trough crossbeds. These strata of eolian origin form a prominent cliff or bench (Fig. 3C).

In much of the Four Corners, the Entrada Sandstone consists of two or three of the members named by Wright et al. (1962). In southwestern Colorado, the lower, Dewey Bridge Member is as much as 6-7 m of red-bed siltstone and fine sandstone, overlain by the Slick Rock Member (31 m thick at its type section at Slick Rock in San Miguel County), which is the "typical" Entrada interval of crossbedded eolian sandstone as at Durango (Fig. 6). Wright et al.'s (1962) upper member, the Moab Tongue, is likely represented by the Bilk Creek Sandstone of Goldman and Spencer (1941), here included in the Summerville Formation.

Burbank (1930, p. 172) named the Wanakah Member of the Morrison Formation for the Wanakah Mine near Ouray. Eckel (1949) raised Wanakah to formation rank. The U. S. Geological

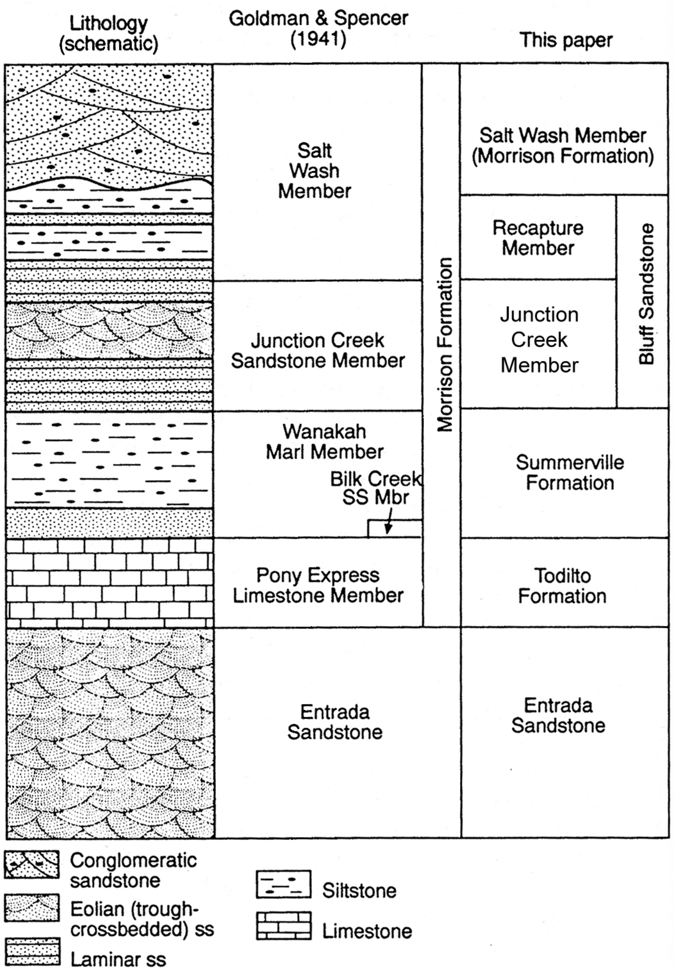

FIGURE 5. Comparison of old local and more recent regional stratigraphic nomenclature of Jurassic rocks in southwestern Colorado.

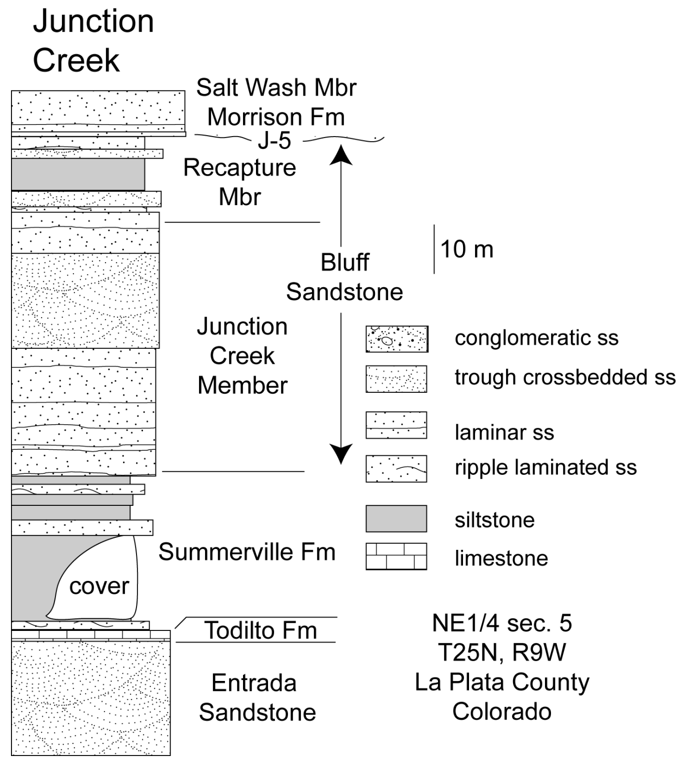

FIGURE 6. Measured stratigraphic section of Jurassic San Rafael Group strata at Junction Creek north of Durango in NE ¼ sec. 5, T35N, R9W. See Lucas and Anderson (1997, p. 131-132) for a detailed description of the section.

Survey still uses the name Wanakah Formation in southwestern Colorado and adjoining areas in Utah and New Mexico (e.g., Condon and Peterson, 1986; Condon, 1989). This, despite the fact that the name is preoccupied by Wanakah shales of Grabau (1917), still applied to Middle Devonian strata in New York state (as Wanakah Member of the Ludlowville Formation). Furthermore, the strata in southwestern Colorado called Wanakah are the same as the Summerville Formation of Gilluly and Reeside (1928), which also has priority over Burbank's name. The preoccupied term Wanakah should be abandoned as a stratigraphic name for Jurassic rocks and replaced with the name Summerville (e.g., Anderson and Lucas, 1992; Lucas and Anderson, 1997, 1998).

At the base of the Wanakah interval near Ouray is a 3- to 4-m-thick interval of limestone and limestone breccia that Burbank (1930) named the "Pony Express Beds" (Fig. 3D). This limestone interval is clearly the Todilto Formation of Gregory (1916), so the name Pony Express should be abandoned (Anderson and Lucas, 1992). Todilto has long been, and continues to be mapped as a formation rank unit, with two distinct members (Lucas et al., 1995; Anderson and Lucas, 1996; Lucas and Anderson, 1997, 1998). The outcrops at Ouray and at Durango are of the lower, Luciano Mesa Member of the Todilto Formation. At Durango, the Luciano Mesa Member of the Todilto Formation is about 1.5 m of dark gray, thinly laminated, kerogenic limestone (Fig. 6). It represents deposition in a vast salina lake that covered much of northern New Mexico and part of southwestern Colorado (Lucas et al., 1985; Kirkland et al., 1995; Lucas and Anderson, 1996).

In southwestern Colorado, strata of the Summerville Formation are as much as 111 m of thinly and cyclically bedded grayish red, yellowish gray, and grayish yellow green siltstone, fine-grained gypsiferous sandstone and mudstone (Figs. 5-6). Goldman and Spencer (1941) named the prominent sandstone at its base (about 5 m thick) the Bilk Creek Sandstone Member. Summerville deposition took place on a vast arid coastal plain that extended from Utah to Oklahoma (Anderson and Lucas, 1992, 1994; Lucas and Anderson, 1997). The basal contact of the Summerville Formation is where ripple-laminated, gypsiferous sandstone rests with a sharp contact on limestone of the underlying Todilto Formation. The top of the Summerville Formation is where sandstone of the Bluff Sandstone rests on siltstone or mudstone of the Summerville Formation.

Summerville strata in southwestern Colorado resemble Summerville strata elsewhere on the southern Colorado Plateau – they are a repetitively bedded succession of fine-grained gypsiferous sandstone and siltstone with some beds of mudstone. They are also in the same stratigraphic position as Summerville strata elsewhere, between the Todilto and Morrison formations. Thus, recognition of the Summerville Formation in southwestern Colorado is justified (e.g., Lucas et al., 2006).

Elsewhere on the Colorado Plateau, the Summerville Formation consists of two members, the lower, Beclabito and upper, Tidwell members (Lucas and Anderson, 1997). The Tidwell Member is mostly the lateral equivalent of the Bluff Sandstone (e.g., Anderson and Lucas, 1994, 1995; Lucas and Anderson, 1997; Lucas, 2014), so the Summerville Formation in southwestern Colorado is essentially equivalent to the Beclabito Member.

In southwestern Colorado, the Bluff Sandstone is up to 152 m thick (Figs. 5-6). As elsewhere on the southern Colorado Plateau, the Bluff Sandstone consists of two members, a lower Junction Creek Member and an upper Recapture Member (Anderson and Lucas, 1996, 1997; Lucas and Anderson, 1997, 1998; Lucas, 2014) (Fig. 5). The lower member is eolian sandstone that was the Junction Creek Sandstone of Goldman and Spencer (1941) and is here considered the Junction Creek Member of the Bluff Sandstone. About 33 m above the base of the sandstone there is a significant bedform change, from laminar/massive beds below to east-dipping foresets above. These are primarily eolian deposits well represented by the type section of the Junction Creek Member near Durango, Colorado (Fig. 6).

The Recapture Member is mostly pale brown, grayish red, and light greenish gray gypsiferous siltstone, fine-grained sandstone and mudstone. Recapture strata are less than 10 m thick in southwestern Colorado and lithologically resemble underlying Summerville strata. Their fine-grained gypsiferous lithotypes indicate that these strata do not belong to the Morrison Formation, but instead are better assigned to the Recapture Member of the Bluff Sandstone (Lucas and Anderson, 1997, 1998; Lucas, 2014).

In southwestern Colorado, the Morrison Formation consists of two members, a lower, sandstone-dominated Salt Wash Member (up to about 122 m thick) and an upper, mudstone-dominated Brushy Basin Member, also up to about 122 m thick (Craig et al., 1955; Anderson and Lucas, 1997). The Salt Wash Member is an interval of trough-crossbedded sandstone and conglomeratic sandstone, and subordinate interbedded mudstone. Brushy Basin Member strata are mostly variegated pale greenish gray, grayish yellow green, pale olive, yellowish brown, and pale reddish brown zeolitic mudstone with a few beds of trough-crossbedded pebbly sandstone.

The Salt Wash Member rests with marked unconformity on the Recapture Member of the Bluff. At Durango (Fig. 3A), the Salt Wash Member is about 82 m thick and consists of crossbedded sandstone and conglomeratic sandstone with a few interbeds of reddish-brown mudstone. The Brushy Basin Member is about 105 m thick and is mostly greenish gray zeolitic mudstone with a few interbeds of arkosic sandstone and silica-pebble conglomerate.

The upper contact of the Morrison Formation in southwestern Colorado is a sharp, unconformable surface where conglomeratic sandstone of the Lower Cretaceous Burro Canyon Formation rests directly on mudstone of the Brushy Basin Member.

Biostratigraphy and Correlation

The eolian, salina and arid coastal plain deposits of the San Rafael Group have not yielded fossils in southwestern Colorado, and yield relatively few fossils regionally. However, regional stratigraphic relationships, some biostratigraphy and radioisotopic ages indicate the Entrada and Todilto are of Middle Jurassic (Callovian) age, the Summerville encompasses the Middle-Upper Jurassic boundary (it is Callovian-Oxfordian in age) and the Bluff Sandstone is of Late Jurassic (Oxfordian) age (e.g., Anderson and Lucas, 1997; Lucas and Anderson, 1997). Regional biostratigraphy, magnetostratigraphy and radioisotopic dates from the Morrison Formation indicate it is of Late Jurassic (mostly Tithonian) age (e.g., Anderson and Lucas, 1997; Trujillo and Kowallis, 2015).

TRIASSIC-JURASSIC UNCONFORMITIES

Pipiringos and O'Sullivan (1978) posited the presence of several regional unconformities in the Triassic-Jurassic strata of the western USA. Some of these unconformities have proven to be controversial, particularly with regard to their exact stratigraphic position, regional extent and the duration of the hiatus represented by each unconformity. Other unconformities, however, are well accepted and reflect important geological events in the Triassic-Jurassic history of the western USA.

The oldest unconformity is Tr-1 at the base of the Moenkopi Group. In southwestern Colorado (Fig. 7), this is the unconformity between the Tenderfoot Formation and underlying Pennsylvanian and lower Permian strata. Locally, there is angularity at this unconformity. It represents a substantial hiatus—all of middle-late Permian time, plus parts of the early Permian and Early Triassic, at least 20 million years.

In southwestern Colorado, there is an unconformity within the Moenkopi Group, at the base of the Ali Baba Formation (Fig. 7). This unconformity appears to be relatively local, and one for which there is no temporal control of the hiatus.

The Tr-3 unconformity separates the Upper Triassic Chinle Group from underlying Lower-Middle Triassic Moenkopi Group strata. The hiatus it represents is parts of Middle Triassic and Late Triassic time, about 10 million years.

Lucas (1993) proposed two basinwide unconformities within the Chinle Group—Tr-4 at the base of the Moss Back Formation and equivalents, and Tr-5 at the base of the Rock Point Formation and equivalents. In southwestern Colorado, the lower part of the Chinle Group is not present, and the Moss Back Formation rests directly on Moenkopi Group strata (Fig. 7). This means the basal Chinle Group unconformity here is a compound unconformity of Tr-3 and Tr-4. Thus, the unconformity between the Chinle and Moenkopi groups in southwestern Colorado represents a hiatus of most or all of Anisian time, and all of Ladinian and Carnian time, or about 25 million years using current calibration of the Triassic timescale (Lucas et al., 2012; Ogg et al., 2014).

The Tr-5 unconformity of Lucas (1993) is the same as the J-0 unconformity of Pipiringos and O'Sullivan (1978). This is because Pipiringos and O'Sullivan (1978) thought the strata immediately above the unconformity are of Jurassic age, so it approximates the Triassic-Jurassic boundary. However, it was later realized that the strata immediately above the unconformity are of Late Triassic age, so "J-0" is a within Late Triassic

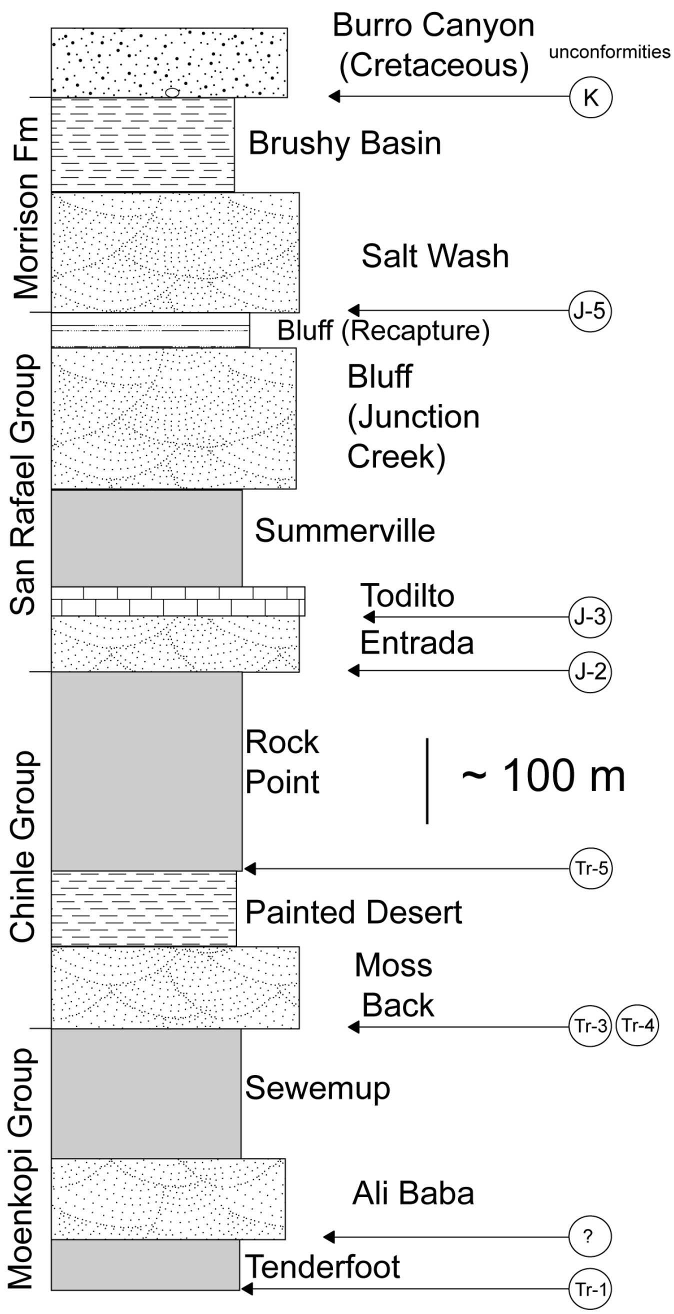

FIGURE 7. Summary of Triassic-Jurassic section in southwestern Colorado showing stratigraphic location of important unconformities (Tr-1 through K, in circles).

unconformity. It is marked by a major facies change across the Chinle Group depositional basin, and age constraints indicate the hiatus is within the Norian Stage, so it is relatively short in geologic time terms.

The J-2 unconformity is broadly recognized across southwestern Colorado and northern New Mexico where the Middle Jurassic Entrada Sandstone rests on Upper Triassic strata of the Chinle Group (Fig. 7). The hiatus is about 40 million years. During much of this hiatus, deposition of the Glen Canyon Group took place across eastern Utah and northeastern Arizona.

There is marked lithologic contrast across the Entrada-Todilto contact that suggests this surface is another regional unconformity across southwestern Colorado and northern New Mexico (Fig. 7). It may correlate to the J-3 unconformity of Pipiringos and O'Sullivan (1978).

The J-5 unconformity of Pipiringos and O'Sullivan (1978) has been the subject of much discussion. Thus, there is no consensus on its stratigraphic position, which has ranged from a bedform break within the Bluff Sandstone to the base of the Salt Wash Member of the Morrison Formation (see reviews by Anderson and Lucas, 1992, 1997). I favor the latter (Fig. 7) and recognize the J-5 unconformity as the tectonosequence boundary between the San Rafael Group depositional basin (which had a paleoslope down to the northwest) and the Morrison depositional basin (which had a paleoslope down to the east). The hiatus represented by the J-5 unconformity appears to be relatively short geologically, within the Late Jurassic.

Across the western USA, Cretaceous rocks unconformably overlie the Jurassic strata, the K unconformity of Pipiringos and O'Sullivan (1978) (Fig. 7). In southwestern Colorado this is the unconformity between the Morrison Formation and the overlying Burro Canyon Formation, a Tithonian-Barremian hiatus of at least 20 million years.

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