Triassic rocks of northwestern New Mexico and southwestern Colorado

Sherman A. Wengerd, 1950, pp. 67-75

in:

San Juan Basin (New Mexico and Colorado), Kelley, V. C.; Beaumont, E. C.; Silver, C.; [eds.], New Mexico Geological Society 1st Annual Fall Field Conference Guidebook, 152 p.

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TRIASSIC ROCKS OF NORTHWESTERN NEW MEXICO AND SOUTHWESTERN COLORADO

By Sherman A. Wengerd
University of New Mexico

Regional Setting

Triassic rocks of the "Four Corner" area thicken westward and southwestward from the Uncompahgre highland in southwestern Colorado and north-central New Mexico. No Triassic rocks are present on the higher parts of the Uncompahgre highland, and the lithology of conglomerate lentils in Chinle, Shinarump, and Dolores strata indicate that the highland area was a prominent source of sediments during most of Triassic time (See map).

In early Triassic time, the Cordilleran seaway to the west, in western Utah and Nevada, was the site of marine Moenkopi deposition comprising gray shale and limestone. Continental clastic sediments were being supplied to the Moenkopi sea from the Uncompahgre highland on the east, hence the interfingering of continental clastics and marine limestone is a common feature of Moenkopi strata in central Utah (Stokes 1949, p. 79). Toward the end of Moenkopi time, virtually the entire area was subjected to subaerial erosion which is now evident in the form of local discordance between Shinarump and Moenkopi strata, particularly in southeastern Utah and northeastern Arizona.

Lithofacies and isopachous data now indicate that the Shinarump conglomerate is an extremely widespread clastic formation lying unconformably upon the Moenkopi formation, but grading eastward and upward into Chinle shale of late Triassic age. This gradation has led to the inference that the Shinarump conglomerate is, with the Chinle shale, of late Triassic age. The widespread post-Moenkopi peneplanation, and differential erosion of the Moenkopi beds in response to variable uplift in the "Four Corner" area probably occurred in middle Triassic time (Stokes 1949, p. 79). Deposition of Shinarump pediment gravels probably began in certain areas as early as mid-Triassic time. Variations in thickness, coarseness, and sorting of Shinarump sediments are a function of differential uplift on the Uncompahgre highland, variations in rainfall, condition of the post-Moenkopi pediment slope, and durability of the supplying terranes to the east and northeast. The Shinarump conglomerate, typically a pediment gravel in a large area west of the Uncompahgre Uplift, is better developed as a poorly sorted, gritty sandstone southwest of the Uncompahgre Uplift, in northwestern New Mexico. This difference of lithology, and lack of sufficient deep drilling in the San Juan Basin, coupled with conflicting vertebrate faunal evidence from shales beneath the Agua Zarca-Poleo sandstone complex in New Mexico, have to date precluded final correlation of the basal Upper Triassic sandstone beds in New Mexico with the type Shinarump beds of Arizona and Utah.

Throughout late Triassic time, Chinle shale and sandstone were deposited over broad, westward-sloping, swampy, alluvial plains, by alluviating streams which debouched into the California sea in Nevada. Volcanic activity, probably far to the northwest, added bentonite to Chinle strata. Thickness and fineness of grain of Chinle strata, and lack of sharp local discordances (with the exception of cross bedding and channelling) indicate the gentle continuous subsidence of this subaerial alluvial plain throughout late Triassic time in the "Four Corner" area.

Formation Descriptions
(Arranged alphabetically for ease of reference)

Agua Zarca sandstone. Upper Triassic (?) reddish-buff to light-gray conglomeratic sandstone, with some siltstone and silty shale, probably equivalent to the Shinarump conglomerate. Named after Agua Zarca Creek, west of Coyote, Rio Arriba County, north-central New Mexico, by Wood and Northrop in 1946. 0-380 feet thick.

Chinle formation. Upper Triassic, red, purple, lavender, and green shale, chocolate-colored sandy shale, red shaly sandstone, and bluish-gray limestone conglomerate lenses. Contains abundant bone "scrap" and petrified wood. Named after Chinle in the Chinle Valley, Apache County, northeastern Arizona by Gregory in 1915. 0-1400 feet thick.

Correo sandstone member of the Chinle shale. Upper Triassic, dark-brown to reddish-buff, massive, cross-bedded sandstone. Named after Correo, south edge of Mesa Gigante, Valencia County, New Mexico, by Kelley and Wood in 1946. 0-120 feet thick.

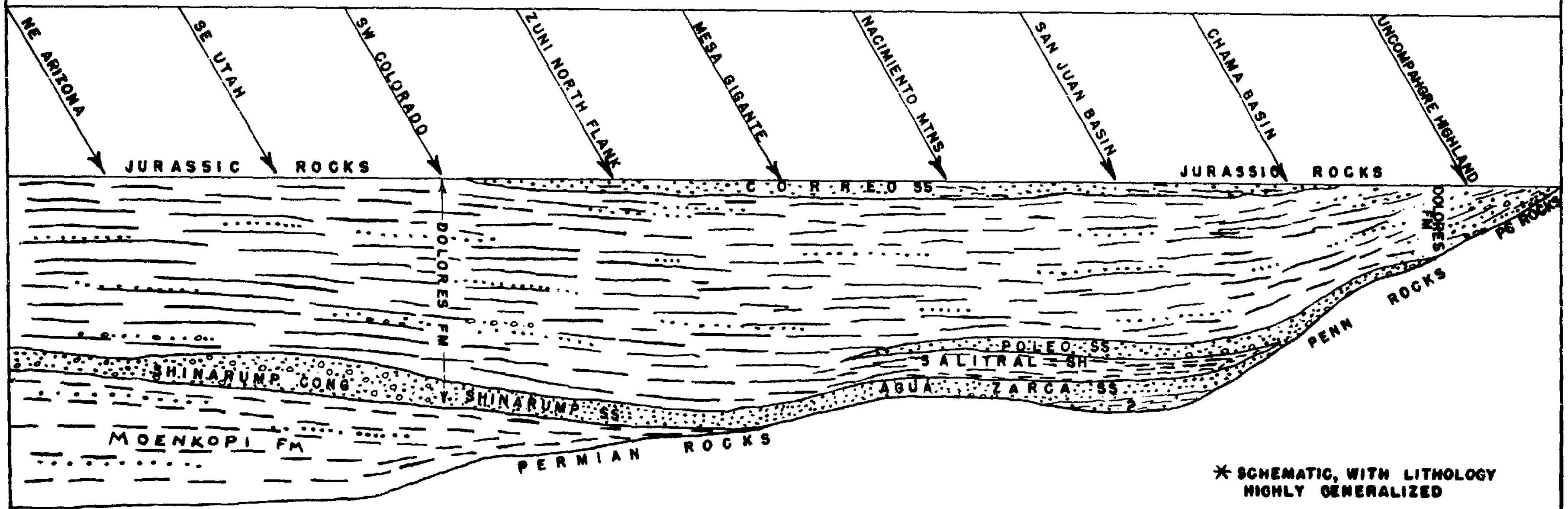
Dolores formation. Upper Triassic and possibly in part Jurassic, red to brown quartzose sandstone and conglomerate with red shale and limestone conglomerate containing abundant vertebrate bones. Named after the Dolores River, eastern San Miguel County, Colorado, by Cross in 1899. 0-600 feet thick.

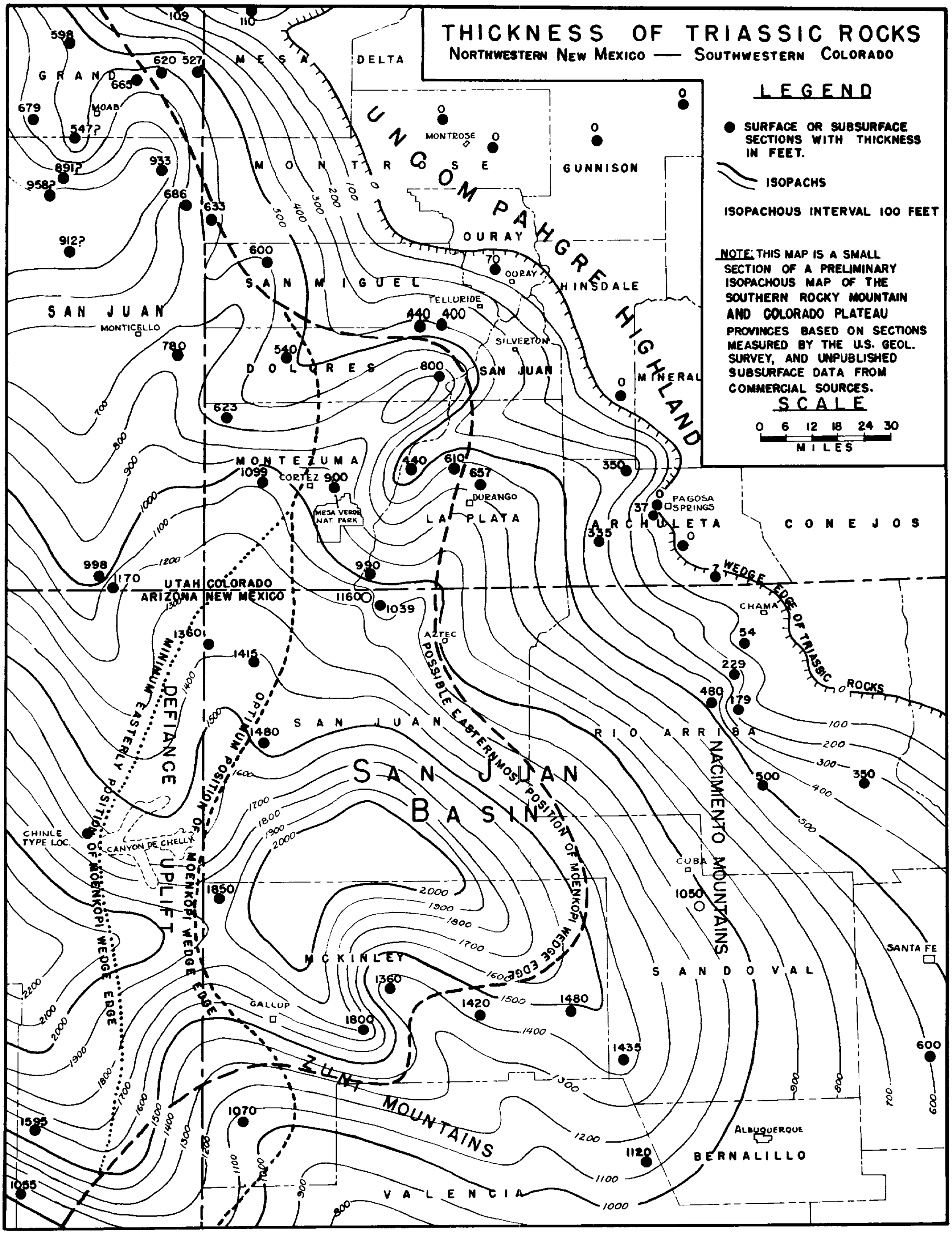
Moenkopi formation. Lower Triassic, chocolate-brown to reddish-brown sandy sandstone, shale, and sandstone. Named after Moenkopi, but for exposures in the Little Colorado Valley, Coconino County, north-central Arizona, by Ward in 1901. Redefined by Baker and Reeside in 1929. 0-500 feet thick (up to 1450 feet thick in Utah).

TRIASSIC CORRELATIONS

AGE	ARIZONA Northeast	UTAH Southeast	COLORADO Southwest	NEW MEXICO Zuni North Flank	NEW MEXICO Mesa Giganta	NEW MEXICO Nacimiento Mtns	NEW MEXICO San Juan Basin	NEW MEXICO Chama Basin	NEW MEXICO Uncompahgre Highland
UPPER TRIASSIC	CHINLE FM	CHINLE FM	DOLORES FM / CHINLE FM	CORREO SS CHINLE SH.	CORREO SS CHINLE SH.	CHINLE FM: CORREO SS CHINLE SH POLEO SS (SENORITO SS LENTIL) SALITRAL SH	CORREO SS? CHINLE SH POLEO SS? SALITRAL SH?	CHINLE SH POLEO SS	DOLORES FM / ABSENT
UPPER (?) TRIASSIC	SHINARUMP SS & CONG	SHINARUMP CONG	SHINARUMP SS	SHINARUMP SS	AGUA ZARCA SS(?)	AGUA ZARCA SS	AGUA ZARCA SS (E) OR SHINARUMP SS(W)	THIN AGUA ZARCA SS (MAY BE PRESENT)	ABSENT
LOWER TRIASSIC	MOENKOPI FM	MOENKOPI FM	MOENKOPI FM	QUESTIONABLE MOENKOPI SH	ABSENT	ABSENT	MOENKOPI SH (MAY BE PRESENT)	ABSENT	ABSENT

REGIONAL STRATIGRAPHIC SECTION




THICKNESS OF TRIASSIC ROCKS
NORTHWESTERN NEW MEXICO —— SOUTHWESTERN COLORADO
LEGEND
SURFACE OR SUBSURFACE SECTIONS WITH THICKNESS IN FEET.
ISOPACHS
ISOPACHOUS INTERVAL 100 FEET
NOTE: THIS MAP IS A SMALL SECTION OF A PRELIMINARY ISOPACHOUS MAP OF THE SOUTHERN ROCKY MOUNTAIN AND COLORADO PLATEAU PROVINCES BASED ON SECTIONS MEASURED BY THE U.S. GEOL. SURVEY, AND UNPUBLISHED SUBSURFACE DATA FROM COMMERCIAL SOURCES.
SCALE
0 6 12 18 24 30
MILES
UNCOMPAHGRE HIGHLAND
GRAND
MESA
DELTA
MONTROSE
GUNNISON
OURAY
HINSDALE
SAN MIGUEL
TELLURIDE
SILVERTON
SAN JUAN
MONTICELLO
MOAB
DOLORES
MINERAL
MONTEZUMA
CORTEZ
MESA VERDE NAT. PARK
DURANGO
LA PLATA
ARCHULETA
PAGOSA SPRINGS
CONEJOS
WEDGE EDGE OF TRIASSIC ROCKS
UTAH COLORADO
ARIZONA NEW MEXICO
CHAMA
AZTEC
POSSIBLE EASTERN POSITION OF MOENKOPI WEDGE EDGE
OPTIMUM POSITION OF MOENKOPI WEDGE EDGE
MINIMUM EASTERLY POSITION OF MOENKOPI WEDGE EDGE
DEFIANCE UPLIFT
SAN JUAN BASIN
RIO ARRIBA
NACIMIENTO MOUNTAINS
CHINLE TYPE LOC.
CANYON DE CHELLY
CUBA
McKINLEY
GALLUP
SANDOVAL
SANTA FE
ZUNI MOUNTAINS
ALBUQUERQUE
BERNALILLO
VALENCIA

Poleo sandstone member of the Chinle shale. Upper Triassic, gray to buff massive sandstone. Named for Mesa Poleo, eastern Rio Arriba County, New Mexico, by von Huene in 1911. 0-115 feet thick.

Salitral shale member of the Chinle shale. Upper Triassic, varicolored shale with limestone concretions. Named after Salitral Creek, west of Coyote, Rio Arriba County, New Mexico, by Wood and Northrop in 1946. 0-105 feet thick.

Senorito sandstone lentil of the Chinle shale. Equivalent to Agua Zarca sandstone. Named for Senorito Canyon, Nacimiento Mountains, western Sandoval County, New Mexico, by Renick in 1931.

Shinarump conglomerate. Upper Triassic (?), gray to buff coarse-grained sandstone and conglomerate containing abundant petrified wood. Named after the Shinarump Cliffs, south of the Vermilion Cliffs in southern Kane County, Utah, by Gilbert in 1875. 0-200 feet thick where identified as Shinarump.

Correlations

The Problem

Study of the Triassic rocks in the southwestern United States is complicated by the following conditions:

1. Sedimentational variations caused by continental conditions of deposition and geographic differences in the amount of rainfall during Triassic time.

2. Highly variable sources of Triassic sediments controlled in part by:
   A. Irregular uplift and differential rock terranes in the source areas (Cross 1899) (Cross and Spencer 1905) (Cross and Larsen 1913).
   B. Irregular ancient topographic spurs and reentrants on the west and southwest flank of the Uncompahgre Uplift (See Isopachous map).

3. Conflicting paleontologic evidence based on fresh water invertebrates, vertebrate bones, and plants, as well as conflicting interpretations of faunal evidence in relation to lithologic characteristics (Baker and Reeside 1929) (Bates 1942) (Colbert 1948 and 1950) (Darton 1910, 1925, and 1928) (Eckel 1949) (Fontaine and Knowlton 1890) (Gregory 1913 and 1917) (Heaton 1933 and 1939) (von Huene 1911, 1915, and 1926) (Northrop 1950) (Reeside 1929) (Renick 1931) (Stokes 1949) (Smith 1914) (Winchester 1933) (Wood, et al. 1948).

4. Geographic position of the San Juan Basin, with few deep well data in an area of critical sedimentational change in Shinarump strata, and eastward disappearance of Moenkopi strata (Kelley and Wood 1946) (Wood and Northrop 1946) (Read, et al. 1949).

In view of these difficulties, a short summary is presented for each area where Triassic rocks have been studied in some detail. Arizona and Utah Triassic stratigraphy is not discussed here owing to the relatively fewer Triassic problems where Triassic beds are thicker and more continuously exposed.

Southwestern Colorado

Cross first described Triassic rocks in the Telluride area and named the red sandstone, grit, conglomerate, and shale the Dolores formation (1899). He measured 1550+ feet of Triassic beds and noted that the coarse sediments were derived from Algonkian and Paleozoic rocks of the San Juan continental area (Cross 1899, p. 2). Later study of vertebrate and plant fossils showed the Triassic beds to be only 400 feet thick, his earlier measurements having included Permian beds (Cross and Spencer 1905). Owing to the nearness of this area to the major sources for Triassic sediments, subdivision of the Dolores section was not attempted; in fact, Jurassic sandstone beds were included. Later work on the Animas Canyon section and other nearby Triassic exposures indicated a late Triassic age for these strata.

Eckel's lithologic descriptions and stratigraphic position of the beds suggest, however, that the basal sandstone and shale section totaling 273 feet in Animas Canyon, Colorado, may be equivalent to the Poleo sandstone, Salitral shale, and Agua Zarca sandstone in the Nacimiento Mountains as described by Wood and Northrop (1946). As it will be shown later in this report that the Agua Zarca sandstone is probably equivalent to the Shinarump sandstone, it is very likely that close lithologic study will prove the existence of Shinarump equivalents in the Animas Canyon section.

Moenkopi strata were encountered in a deep well drilled on the McElmo anticline in Montezuma County and in other wells in southwestern Colorado, but correlative strata are absent east of Durango. It is possible that certain sections now called Dolores formation may contain Chinle, Shinarump, and Moenkopi equivalents.

Triassic rocks in southwestern Colorado are overlain by Jurassic sandstone beds of the Glen Canyon and San Rafael groups, and underlain by Cutler strata of Permian age.

Zuni Mountains, New Mexico

Darton's early work on the red beds of New Mexico indicated that Shinarump and Moenkopi beds were present in the Zuni Mountain area (1928). Later work by Baker and Reeside (1929) and Reiche in 1942 cast doubt on the existence of Moenkopi beds in northwestern New Mexico based on rates of thinning in eastern Arizona, and the presence of abundant silicified wood in purple shale beneath a 100-foot white sandstone at the approximate stratigraphic position of the Shinarump sandstone (Bates 1942, p. 45). Despite this meager unsupported evidence, no valid Upper Triassic fossils have been found in the purple shale beneath the white sandstone. Regional correlations, lithologic examination, and isopachous study of each formation carried into New Mexico from Arizona and Utah, suggest strongly that Shinarump and Moenkopi beds are present off the northwest plunge of the Zuni anticline, and possibly throughout a great part of the deeper San Juan Basin. Additional evidence is presented by Kelley and Wood in the discovery of a thick Shinarump section in Mesa Lucero, southeast of the Zuni Mountains (1946). The drilling of additional wells in the basin will aid in solving this problem of whether Moenkopi beds are present in the San Juan Basin and the possibility of the Shinarump sandstone being directly correlative with the Agua Zarca sandstone in the Nacimiento Mountains. Triassic rocks in the Zuni area are overlain by Wingate strata of Jurassic age, and underlain by San Andres strata of Permian age.

Archuleta Area, Colorado

The name "Dolores" as applied by Cross to Triassic beds in southwestern Colorado has been carried into Archuleta County where the classical tripartite division of the Triassic system cannot be applied. Surface sections in Piedra Canyon and subsurface sections in wells drilled in Archuleta Canyon vary greatly in thickness and lithology (Wood, Kelley, and McAlpin 1948) (Read, et al. 1949). The Dolores formation is believed to be of late Triassic age, but possibly includes some Jurassic beds. Where the formation is very thin, the lithology appears similar to that of the Poleo and basal Agua Zarca sections in the Nacimiento Mountains to the south. Typical Chinle shale is generally present in the Triassic section only where it is thicker than 200 feet. This facies change is probably controlled by nearness to the source of Triassic sediments as represented by the Triassic wedge-edge on the flank of the Uncompahgre Uplift. It is notable that the Triassic clastics in the area appear to be largely Permian debris in contrast to Triassic coarse clastics of Paleozoic and pre-Cambrian origin which are present in Utah and Arizona, great distances from the Uncompahgre highland.

Dolores beds lie on rocks ranging from Permian to pre-Cambrian age, on the southwest flank of the Uncompahgre highland. These strata are overlain by Entrada sandstone of Jurassic age which formerly extended over a great part of the nearby highland area.

Chama Basin - Nacimiento Mountains New Mexico

The Triassic system in this area is represented by the Chinle formation which has been divided as follows:

Upper shale member 235-953 feet (?)
Poleo sandstone lentil 0-115 feet
Salitral shale tongue 0-105 feet
Agua Zarca sandstone member 90-400 feet (?)
(Wood and Northrop 1946)

The Poleo sandstone thins from Mesa Poleo southward, whereas the Agua Zarca sandstone thins northward from its thickest development near San Ysidro. What is now named Agua Zarca sandstone was called the Poleo sandstone by Renick (1931), but surface tracing of the beds proved the existence of a shale now known as the Salitral tongue. Where the Poleo sandstone is absent, the Salitral tongue cannot be differentiated from the main body of the Chinle shale (Wood and Northrop 1946).

The conglomeratic sandstone at the base of the Chinle shale in the Chama Basin is probably the Poleo sandstone as defined by von Huene in 1911, although the Salitral shale may be absent and both the Agua Zarca and Poleo sandstone may be present (See Regional Stratigraphic Section). This conclusion is based on thickness, and the presence of abundant basal conglomerate lentils in the Poleo sandstone in the Chama Basin.

In 1922, Darton stated that the Poleo sandstone was equivalent to the Shinarump conglomerate and further, that the shale beneath the sandstone was probably Lower Triassic Moenkopi (quoted by Northrop 1950). Baker and Reeside later showed that the shale beneath the Poleo sandstone was late Triassic in age, based on vertebrate fossils (1929). This discovery led to their suggestion that the Poleo sandstone is younger than the Shinarump conglomerate of Arizona. It may be inferred that these Upper Triassic fossils came from the shale called the Salitral by Wood and Northrop; which does not disprove the suggestion that the Agua Zarca sandstone (formerly called Poleo through miscorrelation by Renick in 1931) is possibly a direct time and lithologic equivalent of the Shinarump beds present at Mesa Lucero, north flank of the Zuni Uplift, and near Chinle, west of Canyon de Chelly, Arizona.

The Chinle shale of the Ghost Ranch country (Chama Basin) contains at least six fossil zones, yielding bones of amphibians, phytosaurs, small dinosaurs, and fresh water clams (Colbert 1950). The Chinle section represents two phases of sedimentation comprising a basal massive sandstone, which Colbert also suggests may be the Shinarump equivalent (1950, p. 60), and the soft varicolored shale above. Lower Triassic Moenkopi strata are absent on the outcrops along the east side of the San Juan Basin and in the Chama Basin.

Triassic rocks overlie Cutler, Yeso, and San Andres strata, and are overlain by the Wingate (Entrada) sandstone of Jurassic age, in the east and northeast sectors of the San Juan Basin.

The Triassic correlations of the "Four Corner" area, based on a survey of the literature, subsurface and surface work, and certain as yet unvalidated inferences, are shown on the correlation chart and the regional stratigraphic section.

Oil and Gas Possibilities

Triassic rocks of the San Juan Basin are entirely of non-marine origin and only slight shows of petroleum have been found.

The Byrd-Frost et al. MacIntosh No. 1 in Section 25, T 36 N, R 18 W, Montezuma County, Colorado, was completed in August, 1948, as a carbon dioxide well making between 150,000 and 500,000 cubic feet of gas per day from the Shinarump conglomerate. A dry-ice plant will shortly be in operation.

The nature of the Triassic sediments and lack of thick marine, source beds subjacent or superjacent to excellent reservoir rocks such as the Shinarump conglomerate, Agua Zarca sandstone, Poleo sandstone, and the Correo sandstone, appear to preclude Triassic oil and gas production in the San Juan Basin. Under certain special conditions of timing, fracturing, and sealing, small quantities of oil and gas may move into Triassic rocks from Pennsylvanian rocks below. In the northeastern part of the San Juan Basin, Dolores sandstone beds probably overlap Pennsylvanian marine source beds, but the timing of oil origin and migration, in relation to deposition of the potential reservoir sandstone beds appears incorrect for the formation of oil and gas pools.

Selected References

Baker, C. L. (1920) Contributions to the stratigraphy of eastern New Mexico: Am. Jour. Sci. 4th Ser., vol. 49, pp. 99-126.

Baker, A. A., and Reeside, J. B., Jr. (1929) Correlation of the Permian of southern Utah, northern Arizona, northwestern New Mexico, and southwestern Colorado: Bull. Am. Assoc. Petrol. Geol., vol. 13, p. 1413.

Baker, A. A. (1936) Geology of the Monument Valley-Navajo Mountain region, San Juan County, Utah: U. S. Geol. Survey Bull. 865, 105 pp.

Baker, A. A., Dane, C. H., and Reeside, J. B., Jr. (1936) Correlation of the Jurassic formations of parts of Utah, Arizona, New Mexico, and Colorado: U. S. Geol. Survey Prof. Paper 183.

Barb, C. F. (1946) Selected well logs of Colorado: Colo. Sch. of Mines Quart., vol. 41, No. 1, 435 pp.

Bartram, J. G. (1939) Summary of Rocky Mountain geology: Bull. Am. Assoc. Petrol. Geol., vol. 23, p. 479.

Bates, R. L. (1942) The oil and gas resources of New Mexico: N. Mex. Bur. Mines and Min. Res. Bull. 18, 320 pp.

Bryan, Kirk (1938) Geology and ground-water conditions of the Rio Grande depression in Colorado and New Mexico: Part 4, Rio Grande Joint Investigation, Nat. Res. Comm. vol. 1.

Camp, C. L., Colbert, E. H., McKee, E. D., and Wells, S. P. (1947) A guide to the continental Triassic of northern Arizona: Plateau, vol. 20, No. 1, pp. 1-8.

Colbert, E. H. (1947) The little dinosaurs of Ghost ranch: Nat. Hist. vol. 61, pp. 392-399, 427-428.

Colbert, E. H. (1948) Triassic life in the southwestern United States: Trans. N. Y. Acad. Sci., Ser. 2, vol. 10, No. 7, pp. 229-235.

Colbert, E. H. (1950) Mesozoic vertebrate faunas and formations of northern New Mexico: Soc. Vert. Paleont. Guidebook of 4th Ann. Field Conf., pp. 57-72.

Cope, E. D. (1875) The geology of New Mexico: Acad. Nat. Sci. Philadelphia Proc.

Cross, Whitman (1899): U. S. Geol. Survey Geol. Atlas, La Plata Folio 60, 14 pp.

Cross, Whitman (1899): U. S. Geol. Survey Geol. Atlas, Telluride Folio 57, 17 pp.

Cross, Whitman and Spencer, A. C. (1905): U. S. Geol. Survey Geol. Atlas, Rico Folio 130, 20 pp.

Cross, Whitman and Larsen, E. S. (1913) Contributions to the stratigraphy of southwestern Colorado: U. S. Geol. Survey Prof. Paper 90e, pp. 35-50.

Cross, Whitman and Larsen, E. S. (1935) A brief review of the geology of the San Juan region of southwestern Colorado: U. S. Geol. Survey Bull. 843, pp. 48-49, 113-114.

Darton, N. H. (1910) A reconnaissance of northwestern New Mexico and northern Arizona: U. S. Geol. Survey Bull. 435, 88 pp.

Darton, N. H. (1925) A resume of Arizona geology: Univ. Ariz., Ariz. Bur. Mines Bull. 119, Geol. Series 3, 298 pp.

Darton, N. H. (1928) "Red Beds" and associated formations in New Mexico: U. S. Geol. Survey Bull. 794, 356 pp.

Daugherty, L. H. (1941) The Upper Triassic flora of Arizona: Carnegie Inst. Wash. Publ. 526.

Eckel, E. B. (1949) Geology and ore deposits of the La Plata district, Colorado: U. S. Geol. Survey Prof. Paper 219, 179 pp.

Fontaine, W. M., and Knowlton, F. H. (1890) Notes on the Triassic plants from New Mexico: U. S. Nat. Mus. Proc., vol. 13, pp. 281-285.

Gregory, H. E. (1913) The Shinarump conglomerate: Am. Jour. Sci. (4) vol. 35, pp. 424-438.

Gregory, H. E. (1916) The Navajo country: A geographic and hydrographic reconnaissance of parts of Arizona, New Mexico, and Utah: U. S. Geol. Survey Water-Supply Paper 380, 219 pp.

Gregory, H. E. (1917) Geology of the Navajo country: U. S. Geol. Survey Prof. Paper 93, 161 pp.

Hager, Dorsey (1948) Gas and oil possibilities of northeast Arizona: State Land Department of Arizona, 19 pp.

Harrell, M. A. and Eckel, E. B. (1939) Ground-water resources of the Holbrook region, Arizona: U. S. Geol. Survey Water-Supply Paper 836b, pp. 19-105.

Heaton, R. L. (1933) The Ancestral Rockies and Mesozoic and late Paleozoic stratigraphy of the Rocky Mountain region: Bull. Am. Assoc. Petrol. Geol., vol. 17, p. 109-168.

Heaton, R. L. (1939) Contribution to Jurassic stratigraphy of Rocky Mountain region: Bull. Am. Assoc. Petrol. Geol., vol. 23, p. 1140.

Huddle, J. W., and Dobrovolny, E. (1945) Late Paleozoic stratigraphy and oil and gas possibilities of central and northeastern Arizona: U. S. Geol. Survey Oil and Gas Invest. Prelim. Chart 10.

Huene, F. von (1911) Kurze Mitteilung uber Perm, Trias, and Jura in New Mexico: Neues Jahr, Beilage Band 32, pp. 330-39.

Huene, F. von (1915) On the reptiles of the New Mexico Trias in the Cope Collection: Bull. Am. Mus. Nat. Hist., vol. 34, Art. 15, pp. 485-507.

Huene, F. von (1926) Notes on the age of the continental Triassic beds in North America, with remarks on some fossil vertebrates: Proc. U. S. Nat. Mus., vol. 49, Art. 18, p. 1010.

Irving, J. D., and Cross, Whitman (1907): U. S. Geol. Survey Geol. Atlas Ouray Folio 153.

Kelley, V. C., and Wood, G. H. (1946) Lucero Uplift, Valencia, Socorro, and Bernalillo Counties, New Mexico: U. S. Geol. Survey Oil and Gas Invest. Prelim. Map 47.

Longwell, et al. (1923) Rock formations in the Colorado Plateau of southeastern Utah and northern Arizona: U. S. Geol. Survey Prof. Paper 132a, pp. 1-23.

McKnight, E. T. (1940) Geology of the area between Green and Colorado Rivers, Grand and San Juan Counties, Utah: U. S. Geol. Survey Bull. 908, 147 pp.

Needham, C. E., and Thompson, M. L. (1941) Panhandle Geological Society Field Conference Guidebook, June 14-15, 15 pp., 1 map.

Newberry, J. S. (1876) Descriptions of Carboniferous and Triassic fossils collected... in, J. N. Macomb, Report of the Exploring Expedition from Santa Fe... in 1859. U. S. Army Eng. Dept., pp. 135-148.

Northrop, S. A. (1950) General geology of northern New Mexico: Soc. Vert. Paleont. Guidebook 4th Ann. Field Conf., pp. 26-47.

Read, C. B., Wood, G. H., Wanek, A. A., and Mackee, P. V. (1949) Stratigraphy and geologic structure in the Piedra River Canyon, Archuleta County, Colorado: U. S. Geol. Survey Oil and Gas Invest. Prelim. Map 96.

Reeside, J. B., Jr. (1929) Triassic-Jurassic 'Red Beds' of the Rocky Mountain region: Jour Geol., vol. 37, No. 1.

Renick, B. C. (1931) Geology and ground-water resources of western Sandoval County, New Mexico: U. S. Geol. Survey Water-Supply Paper 620, 117 pp.

Schuchert, C., and Dunbar, C. O. (1941) A textbook of geology: Part II, Historical Geology, pp. 301-321, John Wiley and Sons, Inc., New York.

Society of Vertebrate Paleontology (1950) Guidebook for the Fourth Field Conference in northwestern New Mexico: Am. Mus. Nat. Hist. and Univ. of New Mexico, 91 pp.

Smith, J. P. (1914) The Middle Triassic marine invertebrate faunas of North America: U. S. Geol. Survey Prof. Paper 83, 254 pp.

Stokes, W. L., and Phoenix, D. A. (1948) Geology of the Egnar-Gypsum Valley area, San Miguel and Montrose Counties, Colorado: U. S. Geol. Survey Oil and Gas Invest. Prelim. Map 93.

Stokes, W. L. (1949) Triassic and Jurassic rocks of Utah: The Oil and Gas Possibilities of Utah, Utah Geological and Mineralogical Survey, pp. 79-89.

Vorbe, G., Wilport, R. H., and Bates, R. L. (1946) Fall field trip to San Juan Basin - Guidebook: Sept. 20-22, 14 pp., 2 cross sections, 1 map.

Wilmarth, M. G. (1938) Lexicon of geologic names of the United States: U. S. Geol. Survey Bull. 896, Part I (A-L), pp. 1-1244, Part II (M-Z), pp. 1245-2396.

Winchester, D. E. (1933) The oil and gas resources of New Mexico: New Mex. Bur. Mines and Min. Res. Bull. 9, 233 pp.

Wood, G. H., Kelley, V. C., and MacAlpin, A. J. (1948) Geology of southern part of Archuleta County, Colorado: U. S. Geol. Survey Oil and Gas Invest. Prelim. Map 81.

Wood, G. H. and Northrop, S. A. (1946) Geology of Nacimiento Mountains, San Pedro Mountain, and adjacent plateaus in parts of Sandoval and Rio Arriba Counties, New Mexico: U. S. Geol. Survey Oil and Gas Invest. Prelim. Map 57.

Zapp, A. D. (1949) Geology and coal resources of the Durango area, La Plata and Montezuma Counties, Colorado: U. S. Geol. Survey Oil and Gas Invest. Prelim. Map 109, 2 sheets.

NOTES