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TRIASSIC AND JURASSIC ROCKS OF THE ALBUQUERQUE AREA

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The Albuquerque area may be defined as the Albuquerque-Belen basin of the Rio Grande depression (Kelley, 1952) and the adjacent associated platforms, uplifts, channels, and constrictions (see Fig. 1). The present configuration is chiefly the result of Tertiary and Quaternary diastrophism and bears little relation to the distribution of Triassic and Jurassic rocks except as it controls the outcrops of these beds.

Many of the units so well known in the classical sections of the Colorado Plateau region are either missing or have merged with other members until all become unrecognizable. The areas in which outcrops occur are widely scattered, commonly confined to the mountain blocks, or to isolated structural basins and complexly faulted zones along the margins of the Rio Grande depression.

TRIASSIC ROCKS

Traditionally, the Triassic system has been subdivided into tripartite units usually labeled lower, middle, and upper. As additional information has been collected it is obvious that such a separation is not everywhere applicable. McKee and others (1959) utilized three intervals, A, B, C, in ascending order, in their treatment of the Triassic rocks of the United States, although recognizing that interval B has a very restricted distribution. The intervals A, B, and C of their paper are correlative with the German tripartite division of the Triassic, as well as with accepted groupings of the Alpine European stages.

The classic Colorado Plateau section consisting of the Moenkopi, Shinarump, and Chinle formations is assigned to intervals A and C by McKee and others (1959) and has been enlarged through inclusion of the Wingate formation of the Glen Canyon group in the C interval by Harshbarger, Repenning, and Irwin (1957). The Dockum group of eastern New Mexico, West Texas, Oklahoma, and southwestern Colorado is apparently confined to the C interval and has not been as extensively subdivided as has the Colorado Plateau section.

In the Albuquerque area only rocks of the C interval are present, corresponding to the German Keuper or the combined Karnian, Norian, and Rhaetian stages of the European marine sequence. The Albuquerque area lay on a shelf between a western basin containing more than 2,000 feet of Chinle sediments in the Zuni Mountains-St. Johns area, and an eastern basin containing more than 2,000 feet of Dockum sediments in and near Lea County, New Mexico, and Yoakum County, Texas. Correlation between Chinle-type sediments west and north of Albuquerque, and Dockum-type sediments east and south of Albuquerque has been difficult because of the intervening present-day Rio Grande structural trough. The southerly depositional margin of the Triassic rocks induced facies changes that are rapid and unpredictable owing to local variations in tectonic activity. Local names have been introduced in several areas, including some originating in the Albuquerque area, and the relationships between such local units are not always clear (see Table 1).

The Triassic sediments of the Albuquerque area are predominantly fine-grained sandstone, siltstone, and mudstone with intercalated lenticular conglomerate and coarse-grained sandstone beds. In most places the lower part of the section contains more sandstone and is coarser grained than the upper part, although this is not the case in exposures in parts of the Lucero Mesa area (Kelley and Wood, 1946). Maroon, reddish purple, and brown colors are prominently developed and often serve as identifying features for this rock sequence. Locally the sandstones and conglomerates may be buff to nearly white in color and stand out sharply against the bright-red mudstone slopes. Bentonitic clays are abundant in the mudstone units and the alternate shrinking and swelling of the soil in the semi-arid southwestern climate results in characteristic "crazed" exposures. In the upper part of the lower sandy facies, petrified wood and chert pebbles are locally abundant.

The Chinle formation was named by Gregory (1917) from exposures in Chinle Valley, Arizona; Gregory's original description of the formation did not include the Shinarump conglomerate, which he considered a separate formation. McKee and others (1959) included the Shinarump as a lower member of the Chinle formation and indicated that it extends little if any distance east of the New Mexico-Arizona stateline. Other local members of the Chinle formation have been described in Arizona, such as the Petrified Forest member, Owl Rock member, and Sonsela sandstone member, but these cannot be extended very far to the east or north (Stewart, 1957). Wood and Northrop (1946) subdivided the Chinle formation in the Nacimiento uplift into four units, in ascending order: Agua Zarca sandstone, Salitral shale, Poleo sandstone, and the upper Chinle beds. These units are not readily recognizable away from the type localities northwest of the Jemez Mountains and were not individually delineated on the Nacimiento uplift map. Along the north flank of the Zuni Mountains, Smith (1954) mapped a lower member, a middle sandstone member, and an upper member of the Chinle formation; these beds had originally been erroneously described by Darton (1928) as Moenkopi, Shinarump, and Chinle formations. The lower and middle members in the Zuni Mountains suggest correlation with the lower Petrified Forest and the Sonsela sandstone members of the Arizona section while the upper member contains limestone layers and lenses similar to the Owl Rock member. In the Lucero Mesa area Kelley and Wood (1946) divided the Chinle formation into two units: a lower red shale member and the overlying Correo sandstone member; they also recognized a thick unit between the Chinle formation and the underlying Paleozoic limestones which they referred to the Shinarump conglomerate; however, it seems likely that these beds are merely the lower sandy facies of the Chinle formation and may correlate much more closely with the Santa Rosa sandstone member of the Dockum group to the east, or with the Agua Zarca, Salitral, and Poleo members farther north. The Correo sandstone member has a very local distribution and is not recognized away from Mesa Gigante in the northern part of the Lucero Mesa area.

West of the Albuquerque area, the Chinle formation is a thick mass of red mudstone, siltstone, and sandstone with marly beds and intercalated conglomerate lenses. A sandy facies occupies the lower one-third to one-half of the formation while mudstone and shale are predominant in the upper portion. The lower sandy facies averages 300 to 500 feet thick from the Lucero Mesa area to the New Mexico-Arizona stateline, whereas the upper shaly portion ranges

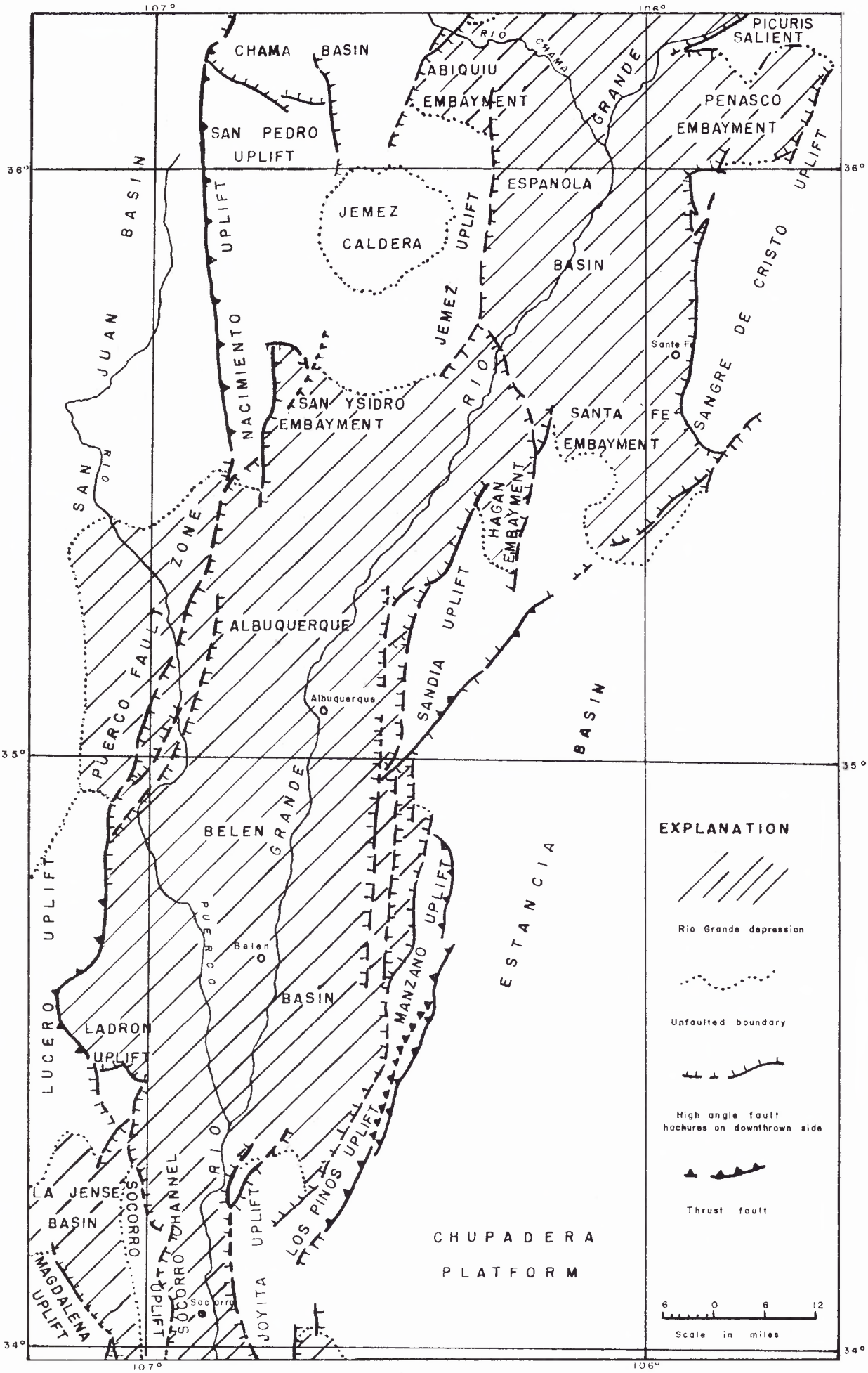

Figure 1. ALBUQUERQUE AREA (after Kelley, 1954)

from a few hundred feet to more than 1,500 feet in thickness. At least part of the variation in thickness of the upper member may be due to pre-Jurassic erosion. The appearance of coarser grained units in the upper parts of the formation to the south suggests also some depositional variation. A thickening of nearly 20 feet per mile occurs between the east end of Mesa Gigante and Ramah on the south side of the Zuni Mountains.

The Dockum beds were described by Cummins in 1890 as conglomerate, sandstone, and red clay, 150 feet thick, near Dockum, Texas (Wilmarth, 1938, p. 616). McKee and others (1959) showed thicknesses in excess of 2,000 feet along the southern part of the Texas-New Mexico stateline and thicknesses of 1,000 to 1,500 feet in east-central New Mexico. Southeast of the Albuquerque area considerable thicknesses of Triassic rocks have been removed by erosion. Locally, near Cerrito del Lobo, the Dockum rests upon Precambrian metamorphic rocks as a result of pre-Triassic erosion. Lithologically, the Dockum beds are similar to the Chinle units, although the bentonitic layers so common in the Arizona section are subordinate or lacking in the Texas and eastern New Mexico exposures. Several members, principally of local significance, were described east of the Albuquerque area. A lower sandy facies similar to the lower unit in the Nacimiento and Zuni Mountains sections is called the Santa Rosa sandstone member and an upper mudstone facies, the Redonda member. In Texas, the Camp Springs conglomerate, the Tecovas and Trujillo formations, and the Sloan Canyon formation have been assigned to the Dockum beds. McKee and others (1959) placed the Pierce Canyon red beds, which underlie the Santa Rosa sandstone in southeast New Mexico, in the Triassic (?) as the lowest unit in the Dockum group, although there is some evidences suggesting a Permian age for these rocks.

McKee and others (1959) estimated that the Triassic rocks in the Albuquerque area had an original thickness between 500 and 1,000 feet.[1] These thicknesses do not include any rocks correlated with the Wingate or Kayenta formations since these beds do not extend this far east. Outcrops to the north and south of the Albuquerque area show some thinning; north of the Jemez uplift Triassic rocks wedge out against the Precambrian core of the Brazos uplift. In the latitude of Socorro more than 400 feet of Triassic rocks are present with less than 100 feet of this thickness assignable to a lower sandy (Santa Rosa?) facies. Kelley and Silver (1952, p. 108) stated that Triassic rocks are absent in the Caballo Mountains 75 miles south of Socorro; it is not clear whether pre-Cretaceous erosion or Triassic non-deposition is indicated by such absence. The thinning of the lower sandy facies as compared with areas to the north, west, and east is suggestive of non-deposition.

Originally the Wingate sandstone was considered the lower member of the Glen Canyon group and placed in the Jurassic. However, Harshbarger, Repenning, and Irwin (1957) restricted the Wingate sandstone of Dutton (1885) to the lower half of the type section at Fort Wingate, New Mexico; they recognized two members, a lower Rock Point member and an upper Lukachukai member within the restricted Wingate over much of the Navajo Reservation of New Mexico and Arizona. Fossil evidence coupled with intertonguing between the underlying Chinle formation and the Rock Point member places all of the restricted Wingate sandstone in the Triassic. Although the Lukachukai member extends considerably farther east than the Rock Point member, neither of these units is present in the Albuquerque area; the Lukachukai member is reported to pinch out a few miles south and east of Laguna, New Mexico.

Faunal evidence suggests that deposition of Dockum beds began prior to the deposition of the Chinle formation. In Arizona and southern Utah no hiatus is present between the latest stages of Triassic deposition and the overlying Jurassic deposits. During Triassic time the locus of deposition appears to have shifted westward and sedimentation continued after deposition in eastern New Mexico and west Texas had ceased. Correlation is difficult because of the variable lithologies and the fact that fossils are scarce and poorly preserved. A continuous evolution from primitive phytosaurs in the Tecovas beds of west Texas through more advanced forms in the Petrified Forest member of the Arizona section to highly advanced types in the Redonda member of the Dockum group and the Rock Point member of the Wingate sandstone provides the framework on which Table 1 is based. The lower sandy facies in the Albuquerque area is represented by the Agua Zarca, Salitral, and Poleo members to the west, or the Santa Rosa sandstone to the east. It contains no diagnostic fossils and correlations within this part of the section are extremely tenuous. The large collections of vertebrate fossils described from the Ghost Ranch area north of the Albuquerque area are confined to the upper shaly member of the Chinle formation and merely provide an upper limit to the age of the lower sandy facies; the Ghost Ranch fauna is correlated with forms from the upper part of the Petrified Forest member and from shale units below the Redonda and Sloan Canyon members.

JURASSIC ROCKS

The Jurassic rocks of the Albuquerque area represent a complex series of marine (?) and non-marine units which, as they are traced toward the southern edge of the Albuquerque area, coalesce into a single inseparable mass of sandstone and finally wedge out by intraformational and interformational unconformities. The classic Jurassic section of the Colorado Plateau region contained the Glen Canyon group, the San Rafael group, and the Morrison formation. Local member and formational names have been applied and extended without benefit of faunal control and considerable nomenclatural confusion has resulted. McKee and others (1956) subdivided the Jurassic system into four units, in ascending order, A, B, C, and D. The unit boundaries do not necessarily coincide with time or formational planes but in a general way the four intervals can be correlated with the European stages. Rocks from the uppermost portion of interval B, most of interval C, and a part of interval D are exposed in the Albuquerque area. Table 2 illustrates the relationships between the units of the Albuquerque area and adjoining regions. Three units of the San Rafael group plus the Morrison formation have been recognized to the west and north of the Albuquerque area. Similar units also extend eastward at least to the Texas-New Mexico stateline, but all strata pinch out southward in response to a combination of pre-Cretaceous erosion and non-deposition.

The oldest Jurassic beds in the Albuquerque area are massive alternating evenly bedded and cross-bedded sand-

[1]This maximum appears to be low. In an unpublished thesis, Harrison (1949) reported about 2,100 feet in the Hagan basin—a figure generally believed to be excessive. —Ed.

Table I – Proposed Correlation of Triassic Rocks between the Albuquerque and adjacent Areas

U.S. Geol. Survey Poleotectonic Map Intervals	Eastern Arizona			North Flank, Zuni Mtns., N. Mexico	Albuquerque Area West	Albuquerque Area East	Eastern New Mexico	N.E. New Mexico & Western Texas	European Stages Alpine	European Stages German
			Gregory Units							
Interval C	Wingate sandstone	Moenave formation		Wingate sandstone					Rhaetian	Keuper
		Lukachukai member		Lukachukai member				Sheep Pen sandstone		
		Rock Point member	A	Chinle formation			"Chinle" formation: Redondo member	Sloan Canyon formation		
	Chinle formation	Owl Rock member	B	Upper member		Dockum group: Upper member	Dockum group: Shale member	Dockum group: Trujillo formation	Norian	
		Upper Part Petrified Forest member	C		Chinle formation: Correo member; Red Shale member					
		Sonsela member		Middle member				Tecovas formation		
		Lower Part Petrified Forest member	-?-		Poleo ss.; Salitral sh.	Santa Rosa sandstone	Santa Rosa sandstone			
		Lower Sandstone member	D	Lower member	Agua Zarca sandstone	?—	-?-			
		Shinarump member		?—	?—			Camp Springs conglomerate	Karnian	
		?—						Basal Dockum beds		
							Pierce Canyon redbeds			
Interval B	?— ?— Moenkopi formation								Ladinian / Anisian	Muschelkalk
Interval A	?— ?—								Scythian	Bunter

stone layers assigned to the Entrada formation. The Entrada formation disconformably overlies the Chinle or Dockum beds, although no angularity can be measured in individual outcrops. The Entrada formation was named by Gilluly and Reeside in joint conference with Moore and Gregory (Wilmarth, 1938) from exposures on Entrada Point in the San Rafael Swell, Utah. At the type locality the formation is alternating thin- and thick-bedded, red sandstone and siltstone grading upward into massive red-brown earthy sandstone. Traced eastward from the type locality, the Entrada sandstone develops an upper clean buff-white sandy facies often referred to as the slick-rim Entrada, and the red silty facies of the type locality becomes very thin. Harshbarger, Repenning, and Irwin (1957) describe a third facies that underlies the other two facies and is a clean sandy facies; its distribution is restricted to the northwestern part of the Navajo Reservation in Arizona. Harshbarger, Repenning, and Irwin's (1957) terminology is adopted for this paper: the lowest unit is the lower sandy facies; the typical unit of Entrada Point is the medial silty facies; and the slick-rim unit is the upper sandy facies. Only the medial silty facies and the upper sandy facies are present in the Albuquerque area. The medial silty facies is recognized only in the western portion, where it is 10 to 50 feet of even-bedded fine-grained buff to white sandstone in 1- to 2-foot layers interbedded with platy red mudstone and siltstone ranging from a few inches to 2 feet in thickness. The sandstone is stained red from the interbedded mudstone and the whole weathers to a steep slope or cliff. The medial silty member is overlain by the upper sandy facies which consists of buff to brown sandstone, predominantly evenly bedded at the base and grading upward into a mixture of small-scale, simple, and planar cross-stratification; the uppermost parts of the upper sandy facies are yellowish to white in color and contain even-bedded layers. Locally, the upper sandy facies intertongues with the overlying Todilto limestone, whereas a short distance away angularity of 10 to 15 degrees may be measured.

The Todilto limestone was originally described by Gregory (1917) from exposures at Todilto Park, New Mexico. Todilto Park is near the western margin of deposition of the Todilto limestone and the type section contains much clastic material which is not present in the Albuquerque area. The lower part of the formation is sandy, particularly in those areas where the formation intertongues with the underlying Entrada. Elsewhere the base of the unit is thin-bedded, platy, fetid gray limestone with intercalated layers of black or greenish mudstone and shale; limestone beds are from 2 to 12 inches in thickness and the shaly layers 4 inches or less. The basal limestone is usually from 12 to 15 feet thick, although extremes of less than 5 feet and more than 25 feet are known. The limestone grades upward into lenticular massive gypsum, locally very pure, that may reach thicknesses of more than 100 feet. The northern part of the Albuquerque area appears to have been the center of an evaporite basin during Todilto time because the gypsum deposits decrease in thickness and uniformity away from it.

The upper contact of the Todilto limestone exhibits considerable change from west to east across the Albuquerque area. On the eastern side the gypsum layers are overlain disconformably by sandstone and mudstone assigned to the lower part of the Morrison formation. On the western side several sandstone, siltstone, and mudstone facies intertongue and grade upward into recognizable Morrison beds. Farther west and to the south Harshbarger, Repenning, and Irwin (1957) have recognized the Cow Springs sandstone as a thick eolian sandstone unit which is equivalent to parts of the Entrada, Todilto, upper San Rafael group, and Morrison beds. Pre-Upper Cretaceous erosion has destroyed most of the evidence for such a unit in the Albuquerque area, but a southerly increase in sandstone in the Morrison formation as well as in the Todilto limestone and overlying upper San Rafael units along the western side of the Albuquerque area is very suggestive (Silver, 1948).

In the San Rafael Swell two formations comprise the upper part of the San Rafael group: the marine limestones and shales of the Curtis and the overlying Summerville siltstones, sandstones, and mudstones. The Curtis formation extends only a few miles south and east of the San Rafael Swell, but Harshbarger, Repenning, and Irwin (1957) recognize the Summerville formation as far south and east as Ft. Wingate, New Mexico, and correlate it with the "buff shale and brown-buff sandstone members of the Morrison formation" (Kelley and Wood, 1946) in the Lucero Mesa area. The Summerville formation was named by Gilluly and Reeside (1928) from exposures on Summerville Point in the San Rafael Swell. At the type locality the boundary between the underlying Curtis formation and the Summerville is arbitrary, but to the south and east Harshbarger, Repenning and Irwin (1957) recognize a lower silty facies and an upper sandy facies in the Summerville which they believe correspond to the Curtis and Summerville formations of the type localities. In the western part of the Albuquerque area the upper sandy facies of the Summerville is thought to be present, associated with tongues of the Cow Springs sandstone. The Summerville beds are distinguished from adjacent rocks by good sorting, fineness of grain, and even, thin bedding. Intraformational crumpling and slump structures are common, often bounded by undisturbed layers of essentially identical material. The layers are red to reddish brown and seldom vary in color throughout the entire range in grain size from sandstone to claystone. Some representatives of the Summerville formation may be present on the east side of the Albuquerque area, but they cannot be easily distinguished from the lower part of the Morrison formation.

The Morrison formation includes the youngest Jurassic rocks in the Albuquerque area. The name Morrison formation was first published by Cross (1894) for the exposures near the town of Morrison, Colorado. The formation has subsequently been extended over most of the Western Interior of the United States. Local facies names have been used extensively but McKee and others (1956) restricted these to seven fairly widespread units (see Table 2). In the Albuquerque area the principal unit is the Brushy Basin member, although a lower sandy facies in the Brushy Basin member to the east and north may represent equivalents of the Recapture, Westwater Canyon, or Salt Wash members. The white sandstone member in the Lucero Mesa area (Kelley and Wood, 1946) is interpreted as a tongue of the Cow Springs sandstone by Harshbarger, Repenning, and Irwin (1957). The Brushy Basin member of the Morrison formation is the most extensive unit as well as the most uniform. It consists of variegated, green, gray, buff, and pink mudstone and siltstone interbedded with buff to white, lenticular sandstone beds. The sandstone layers are

Table 2—Proposed Correlation of Jurassic Rocks between the Albuquerque and adjacent Areas

U.S. Geol. Survey Paleotectonic Map Intervals	Eastern Utah			Northeastern Arizona			North Flank, Zuni Mtns, New Mexico			Albuquerque Area West			Albuquerque Area East	Eastern New Mexico	European Stages
Interval D	Morrison formation	Brushy Basin member	Morrison formation	Brushy Basin member	Cow Springs sandstone	Morrison formation	Cow Springs ss.	Brushy Basin member	Brushy Basin member / Prewitt member	Cow Springs ss.	Brushy Basin member	Morrison formation	Morrison formation	Morrison formation	Portlandian
			Westwater member	Westwater member				Westwater member					Brushy Basin member	Brushy Basin member	
			Recapture member	Recapture member				Recapture member							Kimmeridgian
			Salt Wash member	Salt Wash member							White Sandstone member				
		Lower sandy member	Bluff sandstone	Bluff sandstone	San Rafael group								Lower member	Lower member	
Interval C	Curtis formation		Summerville formation	Upper sandy member	Summerville form.		San Rafael group	Upper member	Thoreau form.	San Rafael group	Brown buff sandstone member	Summerville form.			Oxfordian
			Curtis formation	Lower silty member				Lower member			Buff shale member				
Interval B	Preuss sandstone		Entrada / Upper sandy mem.	Entrada / Upper sandy member			Entrada	Upper sandy member		Entrada	Upper sandy member		Entrada Sandstone	Entrada sandstone (Ocate ss., Exeter ss.)	Callovian
	Twin Creek formation		Carmel formation	Medial silty member / Carmel formation				Medial silty member			Medial silty m.				Bathonian
															Bajocian
Interval A	Nugget sandstone	Glen Canyon group	Navajo sandstone	Navajo sandstone	Glen Canyon group										Toarcian
															Pliensbachian
			Kayenta formation	Kayenta formation											Sinemurian
															Hettangian

often coarse grained and conglomeratic and some of the finer grained layers are marly. North of the Albuquerque area the Brushy Basin member contains bentonitic layers and glass shards indicative of volcanic activity during latest Jurassic time. To the south and west the sand content of the Brushy Basin member increases and the member cannot be distinguished from the upper part of the Cow Springs formation. Similar difficulties may arise to the west where the Westwater Canyon member can be separated from the upper part of the Cow Springs. Facies changes are very rapid in the Albuquerque area because of proximity to the southern depositional margin of the Jurassic rocks. Likewise, thicknesses vary greatly in relatively short distances because of pre-Upper Cretaceous erosion.

Correlation and relative ages of the Jurassic rocks are less certain than for the Triassic beds. Fossils have not been found in the Entrada sandstone, Summerville formation, or Cow Springs formation in this area. The Morrison formation has yielded fragmentary dinosaur remains. According to S. A. Northrop (personal communication, July 23, 1961), a few pieces of bone, some of which were radioactive, were collected by W. L. Chenoweth from the variegated member of the Morrison formation at several localities in Valencia County during the summer of 1952, notably in the Mesa Gigante-Suwanee Peak area. In his unpublished master's thesis, Chenoweth (1953) noted that although the variegated member of Kelley and Wood had been correlated by several workers with the Brushy Basin member, he believed it to be older and probably equivalent to the Chaves or Recapture member. Dinosaur bones collected by Chenoweth and a bone collected by J. E. Self during the summer of 1953 from the Morrison formation near Grants were submitted by Northrop to E. H. Colbert, of the American Museum of Natural History, who reported that three well-known dinosaur genera are represented, as follows:

Brontosaurus: near Grants
Allosaurus: near Acoma and also near Suwanee Peak
Stegosaurus: west side of Mesa Gigante

The Todilto limestone has yielded fresh- or brackish-water ostracods and a few fish with marine affinities, but none of the forms is particularly diagnostic. The Curtis formation in the San Rafael Swell has a characteristic marine fauna as does the Carmel formation immediately below the Entrada sandstone in the same locality. Practically all the dinosaur fauna reported from the Morrison formation comes from areas far to the north so that age assignments and correlations must rest largely upon lithologic grounds. Except for parts of the Todilto-Summerville sequence all the Jurassic rocks in the Albuquerque area are eolian or fluviatile floodplain deposits; the Todilto-Summerville sequence is thought to represent rather abnormal marine or tidal-flat [possibly lacustrine? Ed.] conditions. The uppermost parts of the Brushy Basin member may also contain units that may be Lower Cretaceous (Burro Canyon, Stokes and Phoenix, 1948) in age, although in the Albuquerque area evidence for this has been removed by pre-Upper Cretaceous erosion.

SEDIMENTATIONAL HISTORY

The early Mesozoic was an interval during which epeirogenic forces were active, but no major orogenies took place in the southwestern region. The extensive continental seas which had flooded the area during the Pennsylvanian and Permian periods did not reappear until the Cretaceous period. The Albuquerque area was a nearly flat, featureless plain which was bounded to the south by a gentle rise to a broad belt of low hills which extended across the southern part of New Mexico and Arizona (Mogollon Highlands of Harshbarger, Repenning, and Irwin, 1957); to the north, parts of the old Uncompahgre positive area were uplifted and intermittently shed sediment southward. Westward, the plain sloped very gently toward a marine shelf whose maximum eastward extent was in central Arizona and which in turn extended westward into a miogeosyncline whose trough occupied most of Nevada and western Utah. Deposition began in early Triassic time in the Nevada miogeosyncline and in the Arizona shelf area with limestone and fine-grained clastics. The older Defiance and Zuni positive areas, although greatly reduced, apparently marked the eastern limit of deposition of the early Triassic beds. The red mudstones and siltstones of the Moenkopi formation do not extend east of this area. In the Albuquerque area erosion was leveling the region, exhuming ancient positive elements (Pedernal high) to the southeast.

Erosion continued throughout early and middle Triassic time, but by the beginning of the late Triassic, gentle, irregular warping began to deform the region into local basins and uplifts. Deposition of Dockum beds began in central West Texas with a relatively fine-grained siltstone and mudstone but as warping continued conglomerate and sandstone were deposited particularly near the margins of the basins. The Albuquerque area developed as a low shelf separating basins to the southeast and west where more than 2,000 feet of terrestrial mudstone, siltstone, and sandstone accumulated. The late Triassic terrane was traversed by sluggish streams meandering generally westward and eventually reaching the marine waters in Arizona. The late Triassic deposits are all continental and contain some marl and limestone. Exterior drainage was maintained across the basins and evaporite sequences are lacking. By late Triassic time the Defiance and Zuni positive areas had disappeared, but the Uncompahgre uplift was still weakly active. Uplift of the Mogollon Highlands to the south of the Albuquerque area apparently kept pace with the sinking of the depositional area, because little change in the type sedimentation is visible throughout the Chinle and Dockum beds. Locally, conglomerate and sandstone layers suggest minor variations in uplift and erosion of the source areas.

By the end of the Triassic the source areas of sediment for the Albuquerque area had been leveled and deposition ceased. Orogenic movements were not a factor because farther west no hiatus occurs between Triassic and Jurassic sediments. However, the climate did become more arid and some erosion undoubtedly occurred during early Jurassic time in the Albuquerque area. Farther west the Lukachukai member of the Wingate sandstone was accumulating as extensive sand dunes, and broad upwarping to the north and east brought about changes in the drainage patterns. The Rock Point member of the Wingate sandstone accumulated in a basin whose axis trended northeast-southwest.

During early Jurassic time a gradual realignment of the depositional areas took place and marine waters invaded the Western Interior region from the north. The earliest Jurassic beds were the fluviatile and eolian deposits of the Kayenta, Navajo, and Nugget formations of Arizona and Utah, but in early middle Jurassic time abundant marine faunas in the Twin Creek formation of Utah, Idaho, and

Wyoming attest to the invasion of the boreal seas. During middle Jurassic time the seaway extended southward beyond the Arizona-Utah stateline, and tidal-flat and floodplain deposition extended considerably farther south and east. Rejuvenation of the low-lying Mogollon Highlands in southern Arizona and New Mexico blocked deposition to the south and provided a source of abundant sand from the earlier Navajo and Wingate accumulations. Harshbarger, Repenning, and Irwin (1957, p. 44) pointed out that an uplift to the southwest at the close of Kayenta time eliminated the gap between the old Cordilleran geanticline to the west and the Mogollon Highlands to the south and also provided much of the source area for the upper Jurassic sediments in the southern Cordilleran region. In the Albuquerque area deposition did not begin until late in middle Jurassic time. The medial silty member of the Entrada sandstone marked the easterly edge of tidal-flat and floodplain deposition. Above these layers was spread the fluviatile and eolian blanket of the upper sandy facies of the Entrada sandstone. The upper sandy facies of the Entrada sandstone was the first Mesozoic unit to spread eastward over the old Uncompahgre positive area and it had multiple sources. In the Albuquerque area most of the Entrada sandstone was derived from sources to the south and east.

Continued uplift of the Mogollon Highlands resulted in a restriction of the Entrada depositional basin and the limestone and evaporite deposits of the Todilto limestone began to form. The environment of deposition of the Todilto limestone is uncertain (Anderson and Kirkland, 1960). The scarcity of fossils and the fetid nature of the beds suggest an abnormal condition and yet desiccation was never complete enough to result in saline deposits. Harshbarger, Repenning, and Irwin (1957) postulated a gulf with a restricted channel which allowed alternating desiccation and renewal of marine waters. They proposed a connection just southwest of the Four Corners area. However, a northeasterly connection to the eastern Colorado evaporite basin, which in turn was connected to the Sundance sea to the north, is also a possibility. The thick gypsum deposits indicate that the central part of an essentially land-locked basin lay in the Albuquerque area. Following the withdrawal of the Todilto sea, erosion removed portions of the evaporite deposits, although deposition was still continuing farther west in the old marine basin.

Jurassic deposition in the Albuquerque area closed with the Morrison formation. The exact nature of the hiatus between the Todilto and Morrison is not known, because correlatives of the intervening units in the more complete plateau section cannot be recognized in the sandy facies below the typical Brushy Basin member. Relief on the contact between the units rarely exceeds a few tens of feet and is often less than one foot; layers above and below the boundary are essentially parallel. It seems likely that the Albuquerque area remained close to base level during the time represented by the Curtis, Summerville, Salt Wash, Recapture, and Westwater deposition farther west; certainly deposition and erosion were at a minimum.

The Brushy Basin member of the Morrison formation was a floodplain deposit of mudstone and siltstone with occasional channel-sandstone and conglomerate lenses. Petrified wood and bone fragments are common in the coarser grained portions of the member. It spread over the entire Rocky Mountain region grading abruptly into eolian sandstone along the southern margin of the depositional area. In the Albuquerque area the Mogollon Highland provided a local source for the eolian sands but most of the material was derived from far to the east and west of the area. Pre-Upper Cretaceous erosion has removed any very late Jurassic beds as well as Lower Cretaceous rocks that might have accumulated in the Albuquerque area, but the proximity of the Jurassic depositional margin to the south would seem to have precluded extensive deposition.

In summary, the Albuquerque area was a stable platform during most of Triassic and Jurassic time. A total of less than 2,000 feet of sediment was deposited and much of the material is fine-grained siltstone, sandstone, or mudstone. Minor downwarping and uplift are reflected in local sandstone and conglomerate layers, but no orogenic movements of any magnitude disturbed the stability of the platform. Subsequent structural complexity and extensive erosion hamper detailed correlation between various facies, but the stable nature of the area throughout the entire Mesozoic is unquestioned.

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