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JURASSIC STRATA IN NORTHEASTERN NEW MEXICO

by

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INTRODUCTION

The Jurassic System in northeastern New Mexico is represented by a rock sequence consisting predominantly of sandstone, siltstone, mudstone, and shale with a few thin, discontinuous layers of impure limestone. This sequence is divided into the Exeter Sandstone at the base, overlain by the Morrison Formation. Locally, an algal limestone is present between the Exeter and Morrison (see fig. 1).

The name "Bell Ranch Formation" as defined by Griggs and Read (1959, p. 2006) for a thin-bedded sequence of gray sandstone and brownish red siltstone at the top of the Exeter in the Tucumcari-Sabinoso area has not been used in this paper. The writer concurs with Trauger's observations (Groundwater, this guidebook) questioning the need for this separation. The sequence may be locally distinctive but it is doubtfully a lithosome continuous enough to deserve formational rank.

A thin, widespread red chert layer in the lower part of the Morrison Formation serves as an important stratigraphic marker in this region. At a few localities gypsum beds are also present in the lower part of the Morrison. At most places the rock record appears to represent a time of continuous continental sedimentation; no evidence has been presented to suggest a widespread hiatus.

The Jurassic strata overlie rocks of Triassic age, separated by a regional disconformity with local angular discordance. These strata are in turn overlain in most places by rocks assigned to the Cretaceous System. The Jurassic-Cretaceous boundary is interpreted as a regional disconformity, but in several localities the evidence supporting the discontinuity is tenuous.

Although paleontological evidence to support a Jurassic age assignment for these strata is sparse and the precise age correlation is still open to question, some vertebrate (dinosaur) remains have been found in a few scattered localities supporting a general Jurassic age assignment. Some palynological evidence from the upper part of the rock sequence suggests a very late Jurassic or even an Early Cretaceous age (L. R. Wilson, University of Oklahoma, personal communication, 1972).

EXETER SANDSTONE

The lower part of the Jurassic rock sequence is characterized by white to pale-reddish-brown, massive to randomly crossbedded, friable, fine-grained, well-sorted sandstone (fig. 2). The unit's lower contact is disconformable with the underlying rocks of the Triassic System (primarily the Dockum Group), and the upper boundary appears to be conformable with the overlying mudstone and shale of the Morrison Formation. Evidence for intertonguing of Exeter and Morrison lithologies exists at several places.

The name "Exeter" was first applied by Lee (1902, p. 45) to a sandstone exposed in the Dry Cimarron Valley. The specific type locality is near the now-abandoned Exter Post Office. Lee erred in his use of the original name "Exter," and Stanton (1905) and DeFord (1927) later attempted to correct this error by using the original spelling. But because of widespread use of the spelling "Exeter," and because the Exter Post Office is no longer in existence, Lee's spelling has been accepted.

Dobrovolny and Summerson (1946) used the term "Wingate(?) sandstone" for this rock unit in describing the surface geology and Mesozoic stratigraphy of a part of northwestern Quay County, New Mexico.

Bachman (1953), in a report on the geology of a portion of northwestern Mora County, New Mexico, applied the name "Ocate sandstone" to this rock unit.

In a subsequent study of the distribution of this sandstone unit in northeastern New Mexico the writer (Mankin, 1958) concluded that the "Wingate(?) sandstone" of Dobrovolny and Summerson and the "Ocate sandstone" of Bachman were all a part of the same lithosome. The term "Exeter" was applied to this unit throughout its aereal extent in northeastern New Mexico in recognition of the nomenclatural priority established by Lee (1902).

In an earlier study Heaton (1939) correlated the Exeter Sandstone with the Entrada Formation of the Four Corners area (Gilluly & Reeside, 1927, p. 76) and used the latter name for the Exeter. Griggs and Read (1959), in a review of the stratigraphic nomenclature of the Tucumcari-Sabinoso area of northeastern New Mexico, used the term "Entrada sandstone" without reference to the term "Exeter" or its priority in this region. Subsequent workers have used the term "Entrada" (e.g., Trauger and Bushman, 1964) without further comment.

The writer has used the term "Exeter" in preference to the more widely accepted usage of "Entrada" to emphasize the fact that no strong correlation of this sandstone unit in northeastern New Mexico has yet been made with the Entrada of the Four Corners area. The present correlation is established solely on the basis of similarity of stratigraphic sequences in the two regions. Until a more definitive correlation is established, the term "Exeter" should be retained for this rock unit in northeastern New Mexico.

The Exeter Sandstone crops out in the valley of the Dry Cimarron, along the Canadian Escarpment, along the north-facing escarpment of Llano Estacado south of the Canadian River, and in buttes, mesas, and other isolated exposures in this region. The distribution of these exposures suggests that the sandstone was an essentially continuous rock unit prior to its partial removal in the present erosion cycle.

A typical stratigraphic section of the Exeter Sandstone is characterized by a lower portion with large-scale crossbedding. This crossbedded portion commonly constitutes approximately the lower two-thirds of the section. This is in turn overlain in apparent conformity by thick-bedded sandstone layers that display crossbedding in some places, but on a small scale. The exact boundary between these apparently different sedimentation units is difficult to define at all localities, but where the boundary is discernible the thickness ratio of the two units is not a constant.

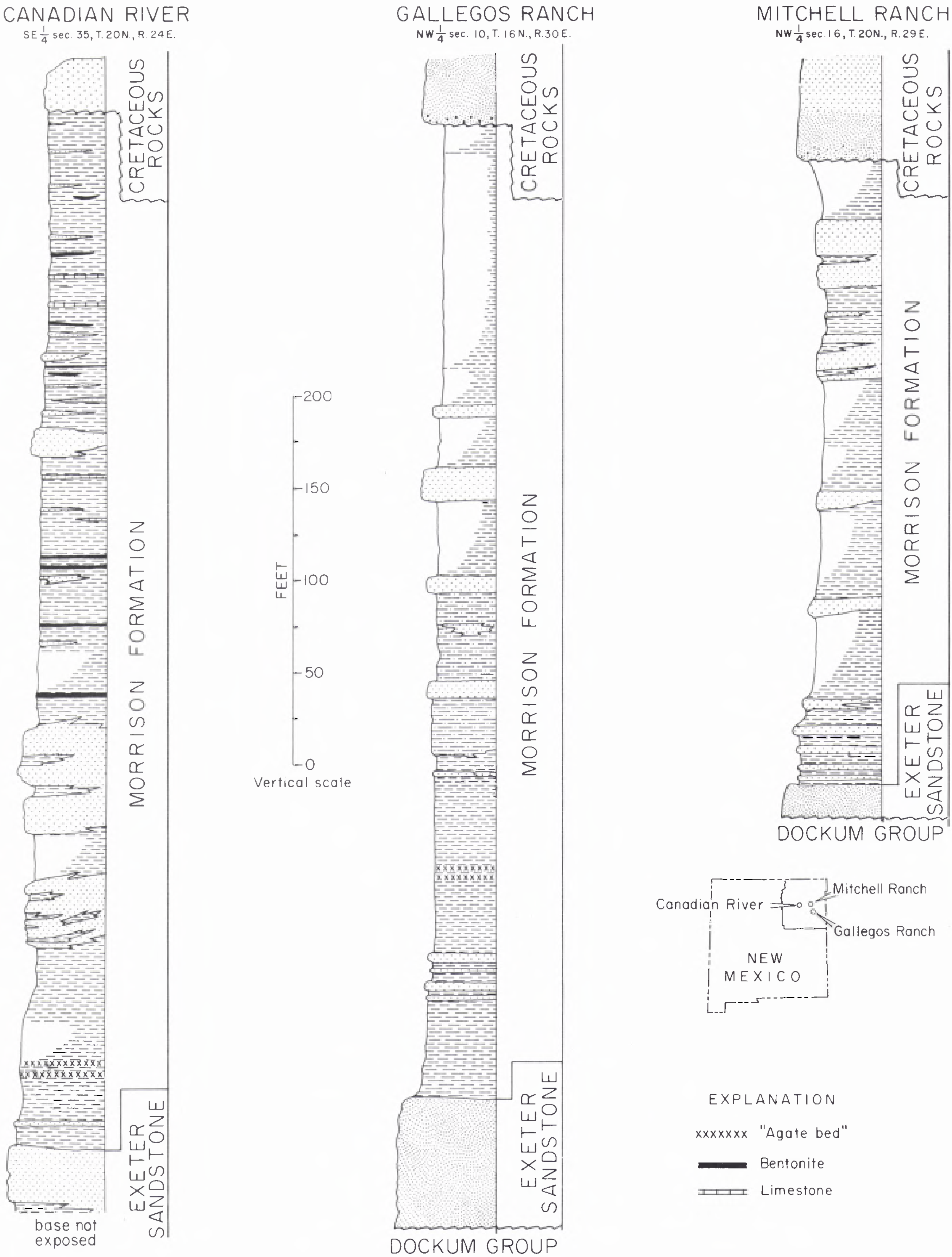

Figure 1. Selected stratigraphic sections of Jurassic rocks in northeastern New Mexico.

Figure 2. View of Exeter Sandstone butte, looking north, on east side of Ute Creek west of dry-ice plant at Bueyeros (center sec. 28, T. 21 N., R. 30 E., Harding County). Contact with underlying Dockum Group of Triassic age at base of massive sandstone. Exeter at this locality is about 50 feet thick.

The boundary of the upper sedimentation unit must be arbitrarily defined, because the sandstone layers are interbedded with silty shale units that have lithic affinities with the overlying Morrison Formation. This lithologic transition is characteristic of most localities and is particularly prominent along the Canadian Escarpment (see Road Log p. 27).

The thickness of the Exeter Sandstone ranges from a few feet at Gallegos Point to more than 220 feet in Metropolitan Park in the Tucumcari basin. Trauger and Bushman (1964) reported the 220-foot figure from the latter locality and interpreted the sandstone accumulations to be a result of contemporaneous basin subsidence. Elsewhere the Exeter Sandstone displays thickness variations of a smaller magnitude; about 60 feet would be a representative thickness for much of northeastern New Mexico.

One exception to the evidence for a continuous lithosome is seen at Gallegos Point (see Road Log, p. 30). Here, the lower, crossbedded portion is missing, and the upper, even-bedded portion rests directly upon strata believed to be a part of the Dockum Group (Redonda Formation?) of Triassic age. From 2 miles north to several miles south of this exposure the normal sequence of Exeter Sandstone is present. This suggests the presence of a pre-Exeter topographic high. Unfortunately, landslide debris of the Morrison and overlying Cretaceous strata covers the Exeter Sandstone directly north and south of Gallegos Point. Thus the exact stratigraphic relations are obscured.

The apparent topographic high at Gallegos Point together with the thick sandstone accumulation in the Tucumcari basin suggests either pre-Exeter tectonism and/or contemporaneous tectonism in northeastern New Mexico. Other evidence for this gentle anticlinal and synclinal folding may be seen in an examination of the attitude and distribution of the Triassic strata.

The Exeter may be typically characterized as a sparsely cemented, very well-sorted, fine-grained sandstone. In an earlier study by the writer (Mankin, 1958) 18 samples were statistically analyzed for vertical and lateral variations. Sixteen of the samples were classified as fine sand and the remaining two as coarse silt. Although the number of samples analyzed is not an adequate representation of the population, a consistent decrease in the mean grain size from northwest to southeast for samples from the upper part of the Exeter was noted.

Most of the samples displayed sorting values which place them in the well-sorted class. No consistent variation in sorting values, either vertically or laterally, was noted, but the small variation in numerical values could obscure any such trend. Thin-section examination reveals that a minor bimodal development in some samples is a result of microlenses of a finer, well-sorted mixture of fine sand to coarse silt.

A striking feature of the Exeter Sandstone is the high degree of rounding displayed by the sand grains. A visual examination of disaggregated samples, using a standard comparison chart, reveals that the roundness values follow a normal Gaussian distribution. The mode of the distribution varies between subrounded and rounded for different samples. This high degree of roundness is unusual for quartz grains in the fine sand class and implies a high energy environment for transportation and/or deposition.

Many of the larger quartz grains display an apparent surface frosting. This surface texture has been attributed to pitting from wind abrasion by other workers. A study of individual sand grains under high power (100X) magnification using a water immersion technique reveals that many of the apparent pits are in fact incipient quartz overgrowths. These overgrowths do not imply that the quartz grains have not been pitted. Rather, the overgrowths would merely conceal the evidence for such abrasion. A study with the SEM would probably provide important information on the surface of these sand grains.

The sand grains are composed predominantly of quartz. Feldspar is the only other important mineral constituent; most samples contain 5-9 percent feldspar, with orthoclase, microcline, and plagioclase occurring in subequal amounts. Accessory minerals constitute only a trace amount of any sample. The nonopaque fraction consists predominantly of tourmaline and garnet; some samples also contain staurolite, rutile, and zircon.

Morrison Formation

A sequence of variegated greenish-gray and reddish-brown silty shale and mudstone with some layers and lenticular masses of coarser grained terrigenous material overlies the Exeter Sandstone throughout northeastern New Mexico. This sequence of strata is assigned to the Morrison Formation.

The term "Morrison" was first used by Eldridge (1896) for typical exposures near the town of Morrison, Colorado. In this area Eldridge defined the boundaries as follows (1896, p. 60):

> Its upper limit is sharply defined by the Dakota Sandstone, while the brown and pink sandstone closing the Trias as clearly marks its lower limit.

In 1902 Lee traced the Morrison Formation into northeastern New Mexico and described the general stratigraphic relationships of these strata in exposures in the Dry Cimarron Valley. Stanton (1905), Rothrock (1925), DeFord (1927), and others have contributed to an understanding of the stratigraphic distribution and age assignment of these strata in northeastern New Mexico.

In this region the Morrison Formation conformably overlies the Exeter Sandstone. In most places the boundary is arbitrarily defined because of alternating Exeter and Morrison lithologies in a transitional interval.

In the southwesternmost exposures of these rock units (in the vicinity of Las Vegas) the strata are conformably separated by a dark-gray, irregularly bedded, fetid, shaly limestone. This unit has been correlated with the Todilto Limestone of northwestern New Mexico by Darton (1928), later corroborated by Heaton (1939). Exposures of this limestone are restricted to the Las Vegas area, and no positive correlation of these exposures with those in northwestern New Mexico has been established. Because of the uncertainty of the correlation with the Todilto of northwestern New Mexico, and because this unit may represent only a local lacustrine deposit within thy Morrison Formation, it is considered in this report a facies of the Morrison.

The upper boundary of the Morrison Formation is disconformable with the overlying sandstones and shales of the Cretaceous System. Outcrop evidence for the unconformity is not apparent at most localities because slumping has obscured the relationships of these strata (figs. 3, 4).

At most exposures of the Morrison Formation in northeastern New Mexico slumping obscures not only the upper and lower contacts but also destroys the intraformational stratigraphic relationships. The writer believes, in concurrence with Trauger (U.S. Geological Survey, Albuquerque, New Mexico, personal communication, 1972), that this slumping occurred during the last major wet cycle of the Pleistocene glacial epoch.

At some places where essentially undisturbed exposures of the Morrison Formation can be found, the strata may be divided into three units. In the Tucumcari region the subdivision is represented by a lower variegated shale; a middle

Figure 3. View of Morrison Formation capped by Cretaceous strata, looking northeast. Locality is 24 miles south-southeast of Mosquero on the Mosquero-Campana road. (Mile 51 of first day log.) Morrison is poorly exposed owing to extensive slumping. Note erratic distribution of large Cretaceous sandstone blocks on slumped surface.

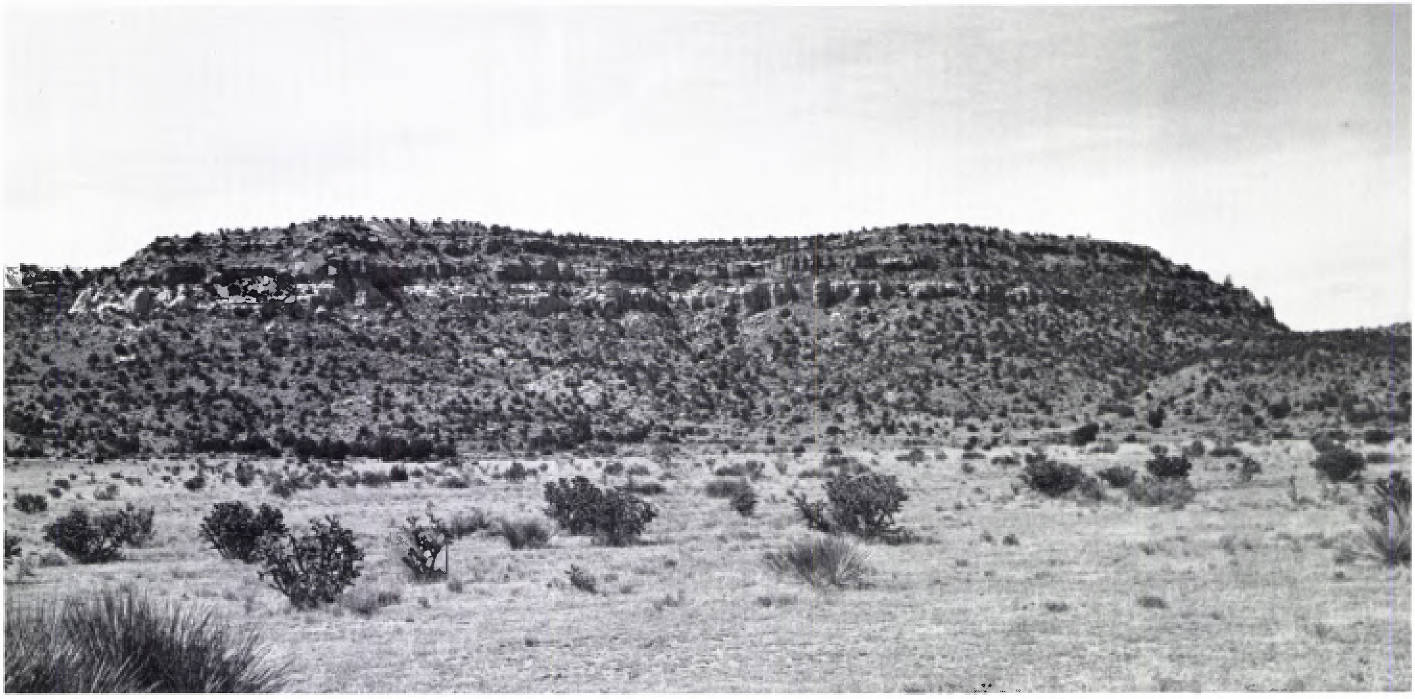

Figure 4. View of Morrison Formation capped by Cretaceous strata, looking northwest. Locality is at Padilla Gap (NE¼ sec. 12, T. 21 N., R. 31 E., Harding County). Morrison-Cretaceous contact is placed at base of massive white sandstone. Note extensive slumping of Morrison.

unit composed of mudstone with some soft, lenticular sandstone; and an upper unit composed of shale with some thick-bedded, silica-cemented sandstone layers. The boundaries of these units are not well defined and are not everywhere applicable. At some localities the entire sequence is composed of mudstone and shale, whereas at other places sandstone is the predominant lithology. Therefore, no attempt has been made in this paper to formally divide the Morrison into members.

Other lithologies in the Morrison Formation include gypsum beds, impure limestone layers, volcanic ash and bentonite beds, and nodular chert zones.

The Morrison in this region is sparsely fossiliferous. Fragments of bone and wood are present in a few localities. Where present these materials are locally abundant and seem to be restricted to a narrow stratigraphic interval. Although bone and wood fragments seem to be more abundant in the middle part of the section, their distribution is not confined to a specific stratigraphic zone within the formation. Both the bone and wood fragments are silicified, and many samples are moderately to highly radioactive.

The bone fragments are considered to be dinosaur remains based largely on the size and bone structure displayed by individual specimens. No further delineation of the bone fragments has been attempted, and the writer is unaware of any study of these collections from northeastern New Mexico. Similarly, no information is available on the specific identity of the fossil wood.

The gypsum beds seem to be primarily confined to the lower part of the formation; normally, the beds range from 1 to 3 feet in thickness and are associated with that interval displaying the transitional Exeter and Morrison lithologies. Exposures of these gypsum beds are also confined primarily to the Dry Cimarron Valley.

The thin, impure limestone layers are present in many exposures of the Morrison Formation. No pattern of stratigraphic distribution has been ascertained, and continuity of individual layers cannot be established between adjacent exposures with more than 1 mile of separation. The limestone layers are commonly 1 to 6 inches thick and contain admixtures of fine sand, silt, and clay in varying proportions. Some limestones also display minor silicification. Although no pattern of stratigraphic distribution for these layers has been determined, there seems to be a greater concentration of these beds in the eastern and northeastern parts of the region.

A few volcanic-ash and bentonite layers are present in the Morrison Formation. The ash beds range from 2-3 inches to almost 1 foot in thickness. They seem to be more abundant in the upper portion of the formation and in the northwestern part of the region. The beds are white to light gray and display irregular upper surfaces. Bentonite layers are particularly abundant in exposures along the valley of the Dry Cimarron (Cooley, 1955). These layers range in thickness from a few inches to almost 1 foot. Although the volcanic-ash and bentonite beds are more abundant in the occurrences described above, at no place do these lithologies make up more than a minor portion of the rock sequence.

Exposures of nodular chert zones are visible i the Morrison Formation at many places. Although nodular chert has been observed at several stratigraphic positions within the formation, most zones have a minor geographic distribution. An exception is the distinctive nodular red-chert zone present at most exposures in the lower few feet of the formation. Because of its narrowly defined stratigraphic distribution, distinctive appearance, and widespread occurrence, this layer has been called the "agate bed." A detailed study of this interval by the writer has revealed that the "agate bed" is not a single layer but rather a narrow zone in which nodules of red silica may be found. The textural varieties of silica associated with the "agate bed" include flint, chert, chalcedony, and quartz.

Whereas the lithologies described above are distinctive but minor features of the Morrison Formation, the essential lithic characteristics of the formation may be described as a framework of silty and sandy mudstone and shale with discontinuous beds and lenticular masses of sandstone occurring at different stratigraphic positions at different localities. These sandstone bodies, some of which are noticeably conglomeratic, display many distinctive channel characteristics. Among these features are lenticular cross sections, cut-and-fill structures, shale-pebble conglomerates, and small-scale festoon cross-bedding.

The sandstone units of the Morrison Formation are commonly fine grained, but coarse grains and even granules and pebbles are present in some layers (see discussion in Road Log of Stop 2, p. 18). The sorting is variable, ranging from very well to very poorly sorted. Most samples examined have values in the moderately sorted class.

The composition of the sandstone units ranges from subarkose to arkose; the feldspar- and igneous-rock-fragment content ranges from 10 to 40 percent. Orthoclase and microcline are present in subequal amounts, but the plagioclase content is variable.

The feldspar content displays a consistent stratigraphic and geographic variation. Samples from the base of the formation contain only small amounts of feldspar, similar to the underlying Exeter Sandstone (± 10 percent). In the lower half of the formation the feldspar content increases markedly to as much as two or three times that at the base. In the upper half the feldspar content gradually decreases to values approaching those found at the base of the unit. Additionally, the feldspar content displays a gradual decrease to the southeast from maximum values approaching 40 percent in the west-central and northwestern parts of northeastern New Mexico.

The accessory-mineral content of the sandstone comprises both stable and metastable minerals. The nonopaque fraction is dominated by tourmaline and zircon, with garnet and apatite common constituents in many samples. In a few samples staurolite is present in moderate amounts; rutile, epidote, kyanite, sphene, and chlorite are rare. The metastable minerals display erratic distributions, apparently reflecting intrastratal solution. Many garnet and staurolite grains are extensively pitted, and skeletal crystals are common in some samples.

The principal clay-mineral content of the mudstone and shale units of the Morrison Formation is illite, montmorillonite, and an interstratified montmorillonite-illite. Additionally, kaolinite is present in many samples, particularly those containing an admixture of sand. Chlorite is present in some samples, but volumetrically it and kaolinite are only minor constituents of the clay-mineral fraction.

The lower portion of the Morrison Formation is characterized by a mechanical mixture of illite and montmorillonite. The illite displays an X-ray-diffraction pattern indicating a partial expansion of the three-sheet structure. This probably results from a partial removal of potassium from its interlayer position.

The montmorillonite from the lower portion of the section displays the normal expansion characteristics. No effort has been made to characterize the chemical composition or structural characteristics of this montmorillonite, but an examination of the data available suggests a similarity with the montmorillonite from the bentonite layers within the formation.

The mixed-layer montmorillonite may represent either an advanced stage of weathering of illite or alteration of volcanic ash to bentonite in the presence of a potassium-ion concentration sufficient to produce some nonexpandable layers in the clay structure. Additional mineral studies are needed to further evaluate this aspect of the clay-mineral content of the Morrison Formation.

The thickness of the Morrison is difficult to assess, owing to the extensive slumping. Consequently, only a limited number of reliable outcrop measurements are available; a few logs from water wells provide some additional datum points. Where measurements are available the thickness values range from less than 100 feet southeast of Tucumcari to more than 500 feet at several places along the Canadian Escarpment. Most of the values obtained from outcrop measurements are between 300 and 400 feet.

No major thickness trends have been ascertained for this region except for a general thinning across the Sierra Grande Arch. Minor thickness variations in the Tucumcari area may be due to contemporaneous subsidence (Trauger, U.S. Geological Survey, Albuquerque, New Mexico, personal communication, 1972) of the basins described earlier in the section on the Exeter Sandstone.

INFERRED DEPOSITIONAL HISTORY

The strata assigned to the Jurassic System in northeastern New Mexico seem to reflect a long period of essentially continuous continental sedimentation. The stratigraphic sequence is bounded by regional disconformities, but no evidence has been found to support the presence of unconformities with more than a local extent within these strata. However, in continental beds, and in the absence of paleontological information, such inferences are tenuous at best.

The Exeter Sandstone was deposited on an erosion surface underlain by Triassic strata. The local relief on the surface was low, but regional variations in elevation probably exceeded 100 feet. Based upon field and laboratory observations, the lower part of the Exeter Sandstone seems to represent an interior-basin, dune-sand deposit. Locally, the upper part exhibits features that are more characteristic of a lacustrine or playa-lake environment. Mineralogical and textural analyses, together with some crossbedding measurements, suggest a northwestern source for the sand. The ancestral Rocky Mountains—composed of igneous and metamorphic rocks, together with a minor sedimentary component—are considered to have been the probable source area.

The presence of metastable accessory minerals and fresh feldspar in the well-cemented portions of the Exeter suggests that the climate of both the source area and the environment of deposition was arid. The presence of these minerals also implies that the cementation occurred soon after deposition of the sand.

It has been suggested that the fetid, algal limestone near Las Vegas, New Mexico, at the top of the Exeter Sandstone may reflect the development of a large lake in response to a gradual change in the climate. However, gypsum beds along the Dry Cimarron Valley at the same stratigraphic position suggest a continuation of an arid climate. The fact that these beds occupy the same stratigraphic position does not necessarily demonstrate a similarity of age. However, because of the short geographic separation, and in the absence of major tectonic complications, these two lithologies are probably contemporaneous. Under these conditions it is conceivable that the climate could have remained arid while the lacustrine environment inferred from the algal limestone could have been maintained by ground-water control.

The Exeter therefore seems to reflect an environment in which southeasterly-migrating dunes were interspersed with playa lakes. The playas may have become more extensive toward the upper part of the section, suggesting an increase in rainfall. The climate remained sufficiently arid, however, to develop thick gypsum beds at the top of the sandstone sequence.

The Exeter-Morrison boundary reflects a change in depositional conditions from an eolian and playa-lake complex to an environment where mudstone and shale were the principal lithologies. The interfingering of the Exeter and Morrison lithologies indicates that the change was gradual and deposition essentially continuous.

The mudstone and shale of the Morrison indicate that water was the principal mode of sediment transport in contrast to the presumed eolian deposition of the Exeter. These strata were apparently deposited on a broad mudflat environment with a few major stream channels transporting coarser clastic materials. These channels must have migrated across the mudflat, because the channel-mudstone deposits are not confined to a specific stratigraphic interval within the Morrison. The large variation in particle size of sediments making up the channel-sandstone deposits probably reflects fluctuations in the discharge of the stream channels. In some channel deposits individual particles are as large as coarse pebbles, indicating a moderate discharge and corresponding velocity for the stream.

The thin, impure limestone layers at many localities also occur in different parts of the stratigraphic section, indicating the presence of lacustrine conditions. The fact that these layers are relatively thin (normally several inches thick) implies that these conditions were of short duration at any one locality.

The volcanic-ash and bentonite beds in the upper part of the Morrison, the abundant plagioclase feldspar, and the euhedral zircon, apatite, and hexagonal biotite in the accessory-mineral suite of the sandstone units indicate the presence of volcanic activity in the region. Based on the distribution of these indicators, the probable source of volcanic activity was to the northwest.

A zone of red-chert layers (the "agate bed") in the lower part of the Morrison may represent an altered volcanic ash. The evidence to support such an interpretation is tenuous, but no other suitable explanation comes to mind.

The climate during the deposition of the Morrison gradually changed from the arid conditions that prevailed during the deposition of the Exeter to a humid, temperate, or even subtropical, climate toward the top of the formation. The evidence for this change includes the dinosaur bones and wood fragments, the alteration of mineral constituents such as feldspar and the metastable accessory minerals in the mudstone and shale units, and the abundance of channels near the top of the formation. The distribution of the "degraded" illite also indicates extensive leaching characteristic of warm, humid conditions.

In summary, the Jurassic strata of northeastern New Mexico were deposited as a sequence of interior-basin continental sediments. The climate gradually changed from the arid conditions prevailing during the eolian and playa-lake deposition of the Exeter to the humid, temperate, or even subtropical, conditions of the upper part of the Morrison. Volcanic activity increased in intensity, resulting in ash accumulations in the upper part of the Morrison.

The deposition of these strata is considered to have occurred during Late Jurassic and perhaps even Early Cretaceous time, but paleontological evidence to support this age assignment is meager. Palynological investigations seem to offer the best promise of establishing a more precise age for this sequence of strata.

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