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STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS OF JURASSIC-CRETACEOUS SEDIMENTARY ROCKS IN THE SOUTHWEST PART OF THE CHAMA BASIN, NEW MEXICO

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INTRODUCTION

The Chama basin is located on the eastern margin of the Colorado Plateau structural province. It is bounded on the north by the San Juan sag, on the east by the Brazos uplift, on the south by the Rio Grande rift and Jemez volcanic field, and on the west is separated from the San Juan Basin by the Nacimiento uplift and Archuleta anticlinorium (Kelley, 1955).

Although the general stratigraphy of the Chama basin is fairly well known, problems concerning stratigraphic relations between members of the Morrison Formation and between Jurassic and Cretaceous sedimentary rocks still exist. These problems include: (1) determination of stratigraphic boundaries between members of the Morrison Formation, (2) resolution of nomenclature for the various members of the Morrison Formation, (3) definition of the contact between the Burro Canyon(?) Formation and the Morrison Formation, and (4) definition of the contact between the Dakota Sandstone and the Burro Canyon(?) Formation. Many workers (Smith and others, 1961; Muehlberger, 1967; Bingler, 1968; Doney, 1968; Grant and Owen, 1974; and Saucier, 1974) have recognized these problems, but the detailed study necessary to resolve them has not been done. Swift (1956) attempted to resolve the stratigraphic problems within the Morrison Formation and between the Morrison and overlying Cretaceous sedimentary rocks, but his study contains some errors in correlation of the Jurassic and Cretaceous sedimentary rocks of the Chama basin with those of the eastern San Juan Basin.

A four year study was begun in 1976 to resolve these four problems. The area selected for initial examination lies in the southwest part of the Chama basin. It includes the southern mesas known collectively as Mesa Alta and land northward from them to the Rio Chama (fig. 1). Discussed briefly are the stratigraphic relationships and environments of deposition of the Jurassic and Cretaceous sedimentary rocks present in the area. Previous work in this area was by Swift (1956) and Fitter (1958). [**Editor's note: see also the paper by Owen and Siemers elsewhere in this volume.**]

STRATIGRAPHY

Jurassic sedimentary rocks in the area include in ascending order, the Entrada Sandstone, Todilto Limestone and Morrison Formation. Cretaceous sedimentary rocks are represented by the Burro Canyon(?) Formation and the overlying Dakota Sandstone.

A fence diagram (fig. 2) shows stratigraphic relationships between members of the Morrison Formation as well as between the Todilto Limestone, Morrison Formation and Burro Canyon(?) Formation.

Entrada Sandstone

The Entrada Sandstone in the southwest part of the Chama basin consists of 84-103 meters of medium to fine-grained, moderately well sorted, calcareous sandstones. It is separated from the underlying Upper Triassic Chinle Formation by a regional unconformity.

The sandstones are composed of subrounded to well-rounded quartz grains with minor amounts of black accessory minerals. Throughout the southern part of the basin, the Entrada generally exhibits a three-fold color banding of varying thicknesses. The basal part is usually light reddish orange, the middle part grayish white, and the upper part yellow tan. The changes in color are due to varying amounts and changes in oxidation state of iron.

The lower part of the formation is characterized by large-scale, sweeping wedge and trough cross-stratification. The middle of the formation contains medium-angle wedge cross-stratification, ripples, iron concretions and wavy laminations, which were produced by masses of adhesion ripples. The upper

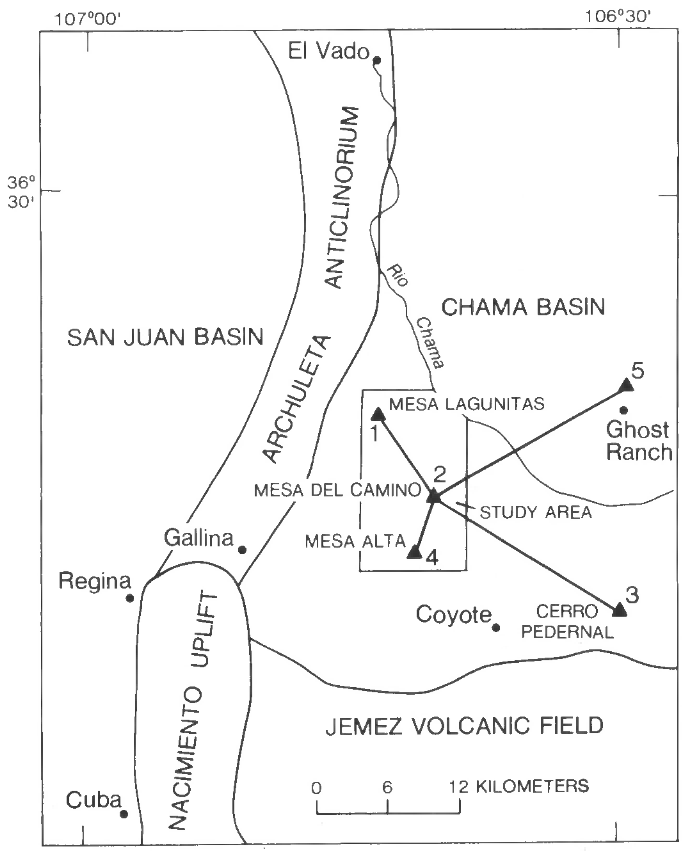

Figure 1. Index map showing location of the southwest portion of the Chama basin (after Doney, 1968, fig. 15); the study area; and locality numbers of measured sections used in Figure 3.

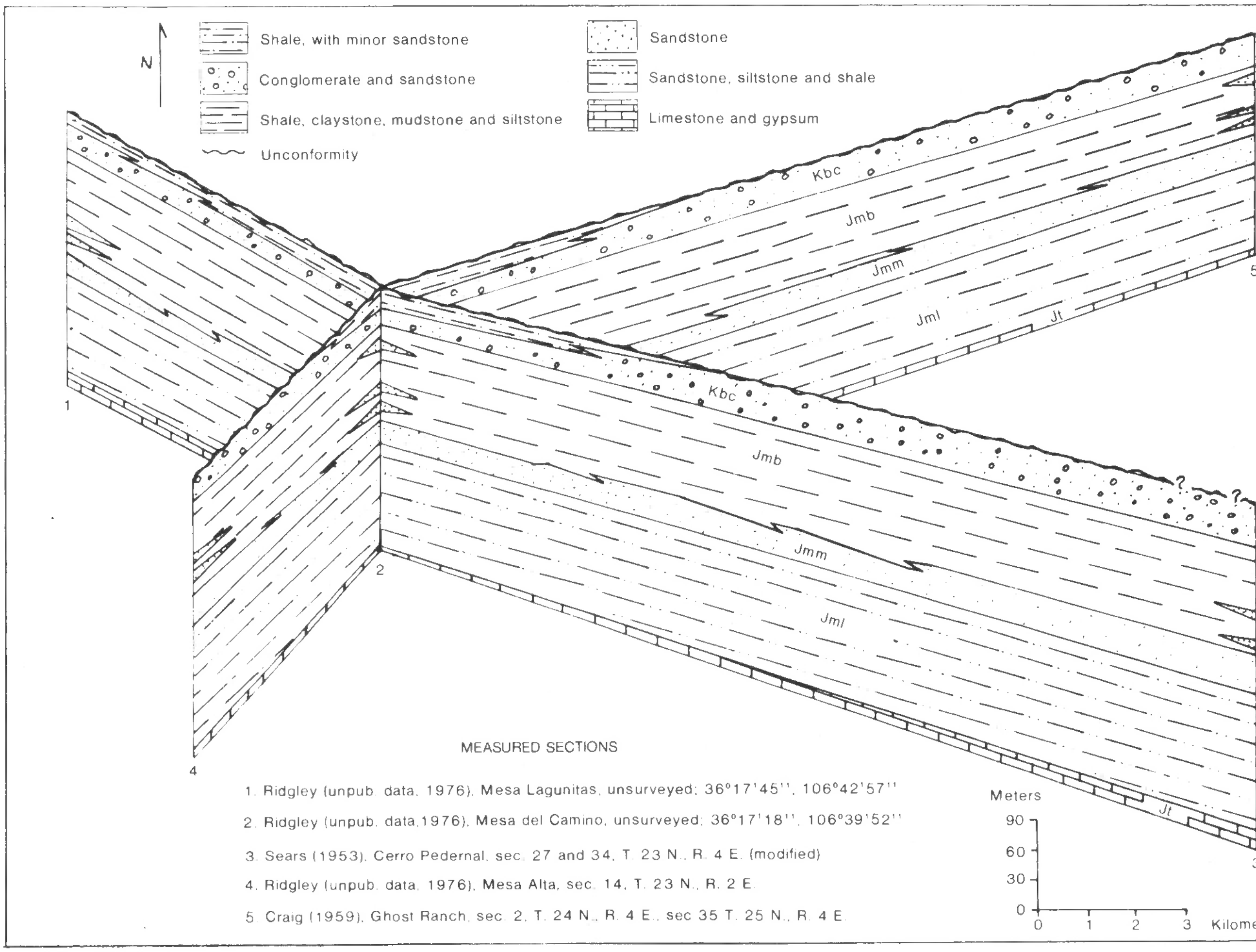

Figure 2. Diagrammatic fence diagram of sections of Jurassic and Cretaceous rocks in the southwest part of the Chama basin. Lines of sections are shown in Figure 1. Stratigraphic symbols are: Burro Canyon (?) Formation (Kbc); Brushy Basin Shale Member (Jmb), middle sandstone member (Jmm), and lower member (Jml) of the Morrison Formation; and Todilto Limestone (Jt). The contact between the Burro Canyon(?) Formation and overlying Dakota Sandstone at locality 3 could not be picked with certainty, as indicated by queries, from the description.

part of the formation is massive, with only minor low-angle cross-beds and parallel laminations present.

Todilto Limestone

The Todilto Limestone, used as a datum for correlation purposes, is composed of thin-bedded limestone and shale, massive limestone, and gypsum. Its thickness is variable, but in general, it ranges from 3 to 30 meters thick in the southwest part of the basin. Contact with the underlying Entrada is conformable.

The lower part of the Todilto consists of interbedded gray to brownish-gray calcareous shale and limestone. The limestone is thin bedded and arenaceous, and gives off a fetid odor when broken. Load deformation, caused by pressure from the overlying limestone or gypsum prior to complete consolidation, is common.

The lower part grades upward into massive limestone or gypsum. The limestone is gray and arenaceous, and contains thin shale partings. The gypsum is white and massive, and contains shale partings or stringers of limestone.

Morrison Formation

The Morrison Formation consists of three lithologically distinct and mappable members. The lower member, composed of fine-grained sandstone, claystone and shale, has been known by various names. Craig (1959), using the stratigraphic nomenclature from the San Juan Basin, called it the Recapture Shale Member; however, most workers in the Chama basin have referred to it as the lower member of the Morrison Formation. Until the stratigraphic relationships have been clarified, the author will refer to it as the lower member.

The middle member, composed of sandstone and shale, has been called the Westwater Canyon Sandstone Member (Craig, 1959) or has been mapped with the lower member. For the purpose of this report, this unit is herein referred to informally as the middle sandstone member.

The upper member, composed of claystone and shale with minor sandstone, is the Brushy Basin Shale Member.

Lower Member

The lower member of the Morrison Formation may be divided into two somewhat distinct lithologic sequences, consisting of a basal sequence of sandstone, shale and limestone, and a thicker overlying upper sequence of sandstone and claystone.

The basal sequence, which ranges from 3 to 18 meters thick, is composed of fine- to very fine-grained sandstones, shales and limestones. This sequence thickens as the underlying Todilto Limestone thins.

The sandstones are light yellow to grayish white near the base of the unit and become buff to reddish brown in the upper portion. They are composed of subrounded quartz grains, minor amounts of chert, and black accessory minerals; are well sorted; and are cemented with calcite. The sandstones show no obvious bedding structures in the lower part of the sequence, but in the upper part they are dominantly parallel bedded and ripple marked. In the lower part of the sequence the sandstones are interbedded with gray to black shales. In the upper part the shales are reddish brown or green. Two thin (<16cm) arenaceous gray limestone beds are present in the upper meter. Contact with the underlying Todilto Limestone is conformable. The basal sandstone contains limestone nodules reworked from the Todilto Limestone. The upper contact is gradational with the upper sequence of the lower member.

Craig (1959) has indicated that the basal sequence may be a correlative of the Summerville Formation. However, no detailed mapping has been done to support this idea; the sequence is generally mapped with the lower member.

The upper sequence of the lower member consists of 60-120 meters of sandstone and claystone. The sandstones are mostly light reddish brown, calcareous, fine- to very fine grained, and moderately well sorted. They are composed of subrounded quartz grains and black and orange accessory minerals. The claystone beds are calcareous, arenaceous and are generally a dark cocoa brown. Locally the claystones near the top of the beds are altered to greenish gray. Many claystone beds contain numerous limestone nodules that are interpreted to be post-depositional features.

Vertically, the sandstones and claystones are interbedded, forming repetitious intervals, 1.2-4.6 meters thick, of sandstone capped with claystone. Many of these sandstone-claystone intervals may be traced laterally for several hundred meters; others thicken and thin over shorter distances. Sedimentary structures observed consist primarily of scattered medium- to low-angle cross-stratification, parallel bedding and ripples. Some of the low-angle cross-stratification consists of well-developed foresets in which sandstone and clay alternate. Flaser bedding, in which clay drapes cover ripple crests, was also observed. The sandstones are quite friable, weathering into rounded slopes similar to badland topography.

In general, the lower member is of constant thickness in the southwest part of the basin. However, based on the measured section at Ghost Ranch and on cross-sections of Smith and others (1961), it appears to thin to the northeast (fig. 2).

Middle Sandstone Member

The middle sandstone member is composed of two sandstone beds separated by shale layers and is from 18 to 36 meters thick. Contact with the underlying lower member is conformable and is marked by a change in mineral composition and grain size. Interfingering of the two members was not observed. The sandstones are dark olive tan to light yellowish gray, are medium to fine grained and are fair to moderately well sorted. They are composed of subangular to subrounded quartz grains, microcline, plagioclase, chert fragments and black accessory minerals. The sandstones are cemented with calcite.

The lower sandstone, which is thicker, generally forms a steep cliff and weathers into badland topography. It is parallel laminated to cross bedded, except in the upper portion, which is massive. The upper sandstone, which forms a small ledge, is generally massive with only minor cross-stratification and parallel bedding. Sedimentary structures are not often observed, owing to the friable nature of the sandstones. The shales are reddish brown and greenish gray, calcareous and arenaceous. They form a steep slope between the two sandstone beds.

Brushy Basin Shale Member

In the area examined, the Brushy Basin Shale Member averages 84 meters in thickness and is composed of claystone and shale with minor amounts of sandstone and dense siltstone. Contact with the underlying middle sandstone member has been picked at the base of a lower red-orange claystone bed and at the top of the upper sandstone bed of the middle sandstone member.

The lower part of the member (40-49 meters thick) is characterized by pale-red-orange and greenish-gray claystone and several channel sandstones. The claystones are calcareous, arenaceous, and contain minerals of the smectite group (also known as the montmorillonite group). The sandstones are light buff to rusty tan, are medium to fine grained, and are moderately well sorted. They are composed of quartz, feldspar, minor amounts of rock fragments and black accessory minerals. The sandstones are lenticular and discontinuous. Sedimentary structures consist of low-angle wedge, planar and trough cross-stratification. Although the sandstone units are friable, they form thin ledges between claystone slopes.

The middle part of the Brushy Basin is dominantly red-brown and greenish gray claystone and shales and is from 13 to 26 meters thick. The claystones and shales are calcareous and arenaceous. Smectites are present in all but the uppermost part of the sequence. At various horizons, the shale intervals contain dense, siliceous, limy concretions, which range in width from 2 cm to 0.9 m. These are interpreted to be post-depositional features. This middle interval forms fairly gentle, rubble-covered slopes.

The upper part of the member (12-18 meters thick) is composed of an alternating sequence of gray shales and claystones and gray, dense, siliceous siltstones. The shales and claystones are the dominant lithology. They are arenaceous, slightly calcareous and contain kaolinite and mixed-layer illite.

The siltstones form laterally persistent beds 10-46 cm thick. They are conformable with the underlying and overlying shales and claystones. The siltstones are composed of subangular to subrounded quartz grains, feldspar, rock fragments and minor amounts of black minerals. They are cemented by a mosaic of fine-grained quartz and chert. On the outcrop sedimentary structures were not apparent, however in thin section thin subparallel laminae were observed.

Although channel-type sandstones are not common in the upper part of the Brushy Basin Member, one is present at Mesa del Camino (fig. 2, section 2). Craig (1959) also described several thin channel-type sandstones in the upper part of the Brushy Basin at Ghost Ranch (fig. 2, section 5). These sandstones are similar in composition, texture and sedimentary structures to the sandstones near the base of the member.

Burro Canyon(?) Formation

The presence of the Burro Canyon Formation in the Chama basin has been postulated by many workers (Craig, 1959; Smith and others, 1961; Muelhberger, 1967; Grant and Owen, 1974; and Saucier, 1974). Saucier (1974) presented an excellent discussion supporting the presence of the Burro Canyon Formation in the central part of the Chama basin and described its stratigraphic relationship to overlying and underlying formations. Swift (1956) indicated that this unit was probably an equivalent of the Burro Canyon Formation. However, because no direct correlation has been made between this unit and the Burro Canyon in Colorado; in his unpublished thesis, he called it the Dead Mans Peak Formation (Saucier, 1974), for exposures found near Dead Mans Peak. McPeek (1965) in two stratigraphic cross-sections extended correlation of the Burro Canyon Formation to the El Vado area on the western side of the Chama basin (fig. 2). However, he indicated that the Burro Canyon there was not a mappable unit and therefore mapped it with the Dakota Sandstone.

In areas examined by the author, this unit is in the same stratigraphic position as the Burro Canyon Formation and has lithologies similar to those of the Burro Canyon (McPeek, 1965; Saucier, 1974). The unit is lithologically distinct from the formations above and below, is widespread, and ranges in thickness from 21 to 61 meters. It is the author's opinion that this is a mappable unit and should not be mapped with the Dakota Sandstone or Morrison Formation as has been done previously.

Contact between the Burro Canyon(?) Formation and the Brushy Basin Member of the Morrison Formation is usually covered with talus. However, in places where it is exposed it is picked where a basal conglomerate rests on gray shales or claystones of the Brushy Basin (fig. 3). The Burro Canyon is separated from the overlying Dakota Sandstone by a regional unconformity. The contact is one of sandstone on sandstone, mudstone, or shale (fig. 4). Thinning of the formation to the south is a result of pre-Dakota erosion and is not depositional thinning (fig. 2).

The Burro Canyon(?) Formation in the southwest part of the Chama basin is similar to that reported by Saucier (1974) for the central part of the basin. It consists primarily of conglomerate and sandstone with thin red and green shale and mudstone lenses. Mudstones and shales are sparse in the lower two-thirds of the formation, but are dominant in the upper third. The sandstones and conglomerates are buff to tan and locally pink or white. Pebbles in the conglomerate range from 1 to 6 cm in diameter and consist of chert and cherty limestone; sedimentary rock fragments up to 10 cm long are also present. Many limestone pebbles contain crinoid stems of probable Paleozoic age. The white chert pebbles are considered by Saucier (1974) to be one of the most diagnostic features of the Burro Canyon Formation in north-central New Mexico.

The basal sandstones of the Burro Canyon(?) are medium to fine grained and are poor to well sorted. They are composed of quartz with minor amounts of feldspar, chert and black accessory minerals. White kaolinite is present throughout the unit.

The shales and mudstones are red or green, siliceous and contain kaolinite and illite. At Mesa del Camino and Mesa Lagunitas a thin (0.3-0.6m thick) siliceous tuff occurs approximately 2 meters below the Dakota Sandstone. Thin sections from samples at both localities contain angular volcanic fragments. The volcanic fragments, which have a pumiceous texture, are composed of glass that is partly devitrified to manganese oxide and fine grained mosaics of quartz and feldspar. Glass shards were not observed in the pumice. The tuff is cemented by very fine-grained mosaics of quartz and chert. The sandstone in the upper third of the formation is fine-grained and is composed of subangular to subrounded quartz. It is friable and contains abundant white patches of kaolinite.

Figure 3. Contact between the Burro Canyon(?) Formation (Kbc) and the Brushy Basin Shale Member (Jmb) at Mesa del Camino.

Sedimentary structures in the Burro Canyon Formation include trough and wedge cross-stratification, parallel laminations and ripple laminations. The ratio of conglomerate to sandstone is low and decreases from the base to the top of the formation. In addition there is an overall fining upward sequence. Contacts between sandstone and overlying conglomerate are sharp and may be parallel or scoured. Clay galls are often present at these interfaces. The basal sandstone and conglomerate form a prominent cliff (figs. 3 and 4) whereas the upper shale, mudstone and thin sandstones form gentle slopes (fig. 4).

Figure 4. Contact between the Dakota Sandstone (Kd) and the Burro Canyon(?) Formation (Kbc) at Mesa Lagunitas.

Dakota Sandstone

The Dakota Sandstone in the southwest part of the Chama basin varies in thickness, owing to differential erosion. It caps many of the mesas around the southern margin of the basin. In the areas examined, the Dakota may be divided into three lithologic units. The basal unit consists predominantly of conglomerate and sandstone. The middle unit is characterized by sandstone and carbonaceous shales and siltstones. The upper unit is composed of fine-grained sandstone.

The basal unit is characterized by 9 to 18 meters of channel-type conglomerate and medium- to fine-grained sandstone. Minor lateral gray kaolinitic clay and slightly carbonaceous mudstone lenses are also present. The conglomerates are buff to rusty tan and contain pebbles of chert (1-4 cm in diameter) and sandstone clasts (1-6 cm in diameter). The sandstones are buff to tan, moderately well sorted and are composed of subrounded quartz grains, feldspar and minor black accessory minerals. Carbonized fragments of leaves and stems are common in the sandstones at Mesa Alta, but are scarce at Mesa Lagunitas and Mesa del Camino. At the latter localities the basal sandstone is thinner (-12 m). Kaolinitic clay patches are present in the lower portion of this unit and probably represent reworked material from the Burro Canyon(?) Formation.

The middle unit is characterized by thin, yellowish-tan sandstones with trace fossils and by black carbonaceous shales and siltstones. The sandstones are fine to very fine grained and are moderately well sorted. They are composed primarily of subrounded to well-rounded quartz grains with minor amounts of feldspar and black accessory minerals. These sandstones are laminated to slightly crossbedded and contain numerous burrows of a trace fossil parallel to bedding surfaces. This trace fossil is similar to the trace fossil Planolites illustrated by Grant and Owen (1974, fig. 11). The sandstones are from 0.6 to 1.2 meters thick and are interbedded with gray shales or thin, light-gray shaly sandstones. Laterally these sandstones and shaly sandstones grade into dark-gray to black carbonaceous siltstones and shales. Several of the carbonaceous shales contain thin, poorly developed coal horizons.

The middle unit forms a slope between more resistant sandstones of the upper and lower units. Exposures are generally poor because this unit is often covered with talus.

The upper unit, where present, consists of yellow-tan well-sorted sandstones, which are fine grained and are composed of subrounded to well-rounded quartz grains. The sandstones are parallel bedded and crossbedded with thin sets of planar tabular cross-stratification. Burrow casts of a trace fossil are common parallel to bedding planes of the lower sandstones. The trace fossil is similar to the trace fossil Thalassinoides illustrated by Grant and Owen (1974, fig. 7).

ENVIRONMENTS OF DEPOSITION

Most workers in the Chama basin have commented briefly on the environments of deposition of the Jurassic and Cretaceous sediments; the author is in general agreement with their interpretations. A brief discussion of the environments of deposition of the previously discussed formation follows.

Entrada Sandstone

The Entrada Sandstone was deposited in an eolian environment. Both dune and interdune areas have been recognized. The dune sands are characterized by high-angle foresets (20°-30°) and lag concentrations on former deflation surfaces. Interdune areas, composed of fine-grained sand with minor amounts of silt, are characterized by ripples, polygonal mud cracks and parallel and wavy laminations. The wavy laminations appear to be adhesion ripples. Glennie (1970, p. 71-73) considered that adhesion ripples form where the ground surface is damp. This condition is generally found in interdune and sabkha environments.

Todilto Limestone

The Todilto Limestone in the southwest part of the Chama basin was deposited in a lacustrine environment. This interpretation is based on the presence of limestone, interbedded limestone and shale, and gypsum.

Morrison Formation

The Morrison Formation was deposited in a variety of continental fluvial and lacustrine environments. The basal sequence of the lower member was deposited in an environment transitional between fluvial and lacustrine. The thin laterally persistent limestone beds suggest a lacustrine environment. In addition, the lower gray to black shales reflect deposition under mildly reducing conditions similar to those that prevailed in the lake in which the Todilto Limestone was deposited. These conditions are in contrast to the oxidizing conditions under which the upper sequence of the lower member was deposited. This basal sequence, in general, represents a time in which clastic deposition in the lake exceeded chemical precipitation.

Geometry of the sandstones and claystones in the upper sequence of the lower member indicate that it was deposited under fluvial conditions. Sedimentary structures, grain size and clay content suggest deposition on a vast flood plain by low-energy streams. Thin, well-cemented, laterally continuous, slightly crossbedded sandstone lenses are interpreted as stream-channel fillings, whereas the more friable, parallel-bedded sandstones and claystones represent flood plain deposits.

The middle sandstone member was also deposited under fluvial conditions. Streams which deposited the middle sandstone member were of higher energy, as is shown by the greater proportion of channel-type sandstones to flood plain deposits. The increase in grain size and angularity and a corresponding decrease in sorting also reflects renewed uplift in the source area.

The relationships of the various lithologies and sedimentary structures in the Brushy Basin Member indicate deposition by meandering streams over vast flood plains. Grain size and composition of sediments suggest deposition under low to moderate energy levels. The occurrence of smectites may reflect the presence of distant volcanic activity during deposition of the Brushy Basin Member (Grim, 1968, p. 501-503).

Burro Canyon(?) Formation

The Burro Canyon(?) Formation is interpreted to have been deposited by a series of high-energy braided to meandering streams. This interpretation is based on observed sedimentary structures and on geometric relationships between sandstone and conglomerate intervals that indicate the development of point bars, channel bars and channel-fill deposits. Measurements of cross-beds indicate the streams flowed in directions ranging from NNW to NNE. The source of the sediment was to the southwest. These observations are in agreement with those reported by Saucier (1974) and Grant and Owen (1974).

The upper part of the Burro Canyon(?) Formation reflects deposition by meandering streams under lower energy fluvial conditions. Lower energy conditions are reflected by less extensive, finer grained sandstones and by a greater abundance of shales and mudstones.

Dakota Sandstone

The Dakota Sandstone was deposited in three somewhat different but transitional environments. The basal unit was deposited under dominantly fluvial conditions. This interpretation is based on the observed sedimentary structures and the channeling nature of the basal conglomerates and sandstones.

The middle unit, represented by thin, burrowed sandstones and by carbonaceous siltstones and shales, was deposited in fluvial and shallow marine environments. Deposition probably took place under a variety of flood plain, paludal and paralic conditions (Grant and Owen, 1974).

The upper unit was deposited in a variety of near-shore littoral environments. Grant and Owen (1974) believed that the trace fossil Thalassinoides indicates marine conditions of deposition. In addition, measurements of cross-beds indicate deposition in a south-southwest direction. This is in agreement with a southward transgressing Cretaceous sea.

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