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Lacustrine sediments of Baca Formation (Eocene), western Socorro County, New Mexico

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This article is a summary of a portion of a master's thesis (Cather, 1980) and describes the lithologic and sedimentologic characteristics of the lacustrine rocks of the Baca Formation in western Socorro County, New Mexico. It deals primarily with the Baca exposures in the area adjacent to the Gallinas Mountains (fig. 1), although some features of the lacustrine-system rocks exposed in the Bear Mountains vicinity also are discussed.

Introduction

The Eocene Baca Formation of western New Mexico (fig. 1) and correlative Eagar Formation and Mogollon Rim gravels of Arizona comprise a sequence of conglomerate, sandstone, mudstone, and claystone that crops out in discontinuous exposures along a west-trending belt from near Socorro, New Mexico, to the Mogollon Rim of Arizona. These sediments represent the basin-fill deposits of a large intermontane basin present in western New Mexico and eastern Arizona during late Laramide time. The Baca Basin is bounded on the north by the Lucero, Zuni, and Defiance uplifts; on the southwest by the Mogollon Highland; on the southeast by the Morenci uplift; and on the east by the Sierra uplift (fig. 2). These Laramide uplifts, particularly the Mogollon Highland, were the dominant contributors of detritus to the basin.

FIGURE 1—LOCATION OF BACA FORMATION OUTCROPS IN WESTERN SOCORRO COUNTY. Stippled areas indicate outcrops that contain significant exposures of lacustrine-system rocks; base map from Dane and Bachman (1965).

Stratigraphy and informal units

In the Gallinas Mountains vicinity, the Baca Formation is approximately 290 m thick and consists of a red-bed sequence of sandstone, mudstone, and minor conglomerate. The Baca disconformably overlies the Crevasse Canyon Formation (Late Cretaceous) and, in turn, is overlain by the volcaniclastic rocks of the Spears Formation (Oligocene). The Baca–Spears contact is generally conformable and gradational over a few meters.

In the Bear Mountains area, Potter (1970) divided the Baca into three informal members which he termed, in ascending order, the lower red, middle sandstone, and upper red units. Cather (1980) extended this terminology to the Gallinas Mountains vicinity but emphasized that these informal units are genetically related to lake-level fluctuations in a large Eocene lacustrine system in the Bear–Gallinas Mountains area; however, the terminology is not applicable to either the predominantly fluvial Baca–Eagar rocks to the west or to the Baca exposed east of the Rio Grande.

Depositional systems

A depositional system is a genetically defined, three-dimensional physical stratigraphic unit composed of a contiguous set of process-related sedimentary facies (Fisher and Brown, 1972; Galloway, 1977). Depositional systems are the stratigraphic manifestation of major ancient geomorphic features, such as barrier islands, lakes, and eolian dune fields. Criteria utilized in the discrimination of paleoenvironments include lithofacies geometry, lateral and vertical variation in grain size and sedimentary structures, nature of contacts between lithofacies, petrographic data, and fossils.

Sediments deposited within the Baca Basin represent a broad spectrum of depositional environments, including braided-alluvial-plain, meanderbelt, and lacustrine systems and their component facies (Johnson, 1978). Based on the facies distribution of Johnson (1978), the paleocurrent data of Snyder (1971), Johnson (1978), Pierce and others (1979), and Cather (1980), and the tectonic framework proposed by Cather (1980), a model for the basin-wide distribution of facies and paleoflow is presented in fig. 2. Two ancient depositional systems are present in the Baca Formation in the Bear–Gallinas Mountains area, the lacustrine and the braided-alluvial-plain systems.

The importance of braided-stream depositional processes within the Baca Basin has been demonstrated by Johnson (1978). An extensive braided alluvial plain dominated the western portion of the basin. Johnson (1978) delineated proximal, medial, and distal facies within the braided-alluvial-plain system based on conglomerate/sandstone ratios. In the Gallinas Mountains area, only the distal facies is present and comprises the lowermost 13 m of the lower red unit and the entire middle sandstone unit. The distal facies is characterized by high sandstone/conglomerate and sandstone/mudstone ratios, the dominance of horizontal laminations and trough crossbedding, and the general lack of well-developed, large-scale vertical textural trends. Deposition is interpreted to have taken place in intrachannel and overbank areas by flashy-discharge, possibly ephemeral, braided streams. The reader is referred to Johnson (1978) and Cather (1980) for more detailed discussions of the Baca braided-alluvial-plain system. Only the lacustrine system is discussed in this article.

LACUSTRINE SYSTEM—The lacustrine system is widespread throughout the Baca Basin. Lacustrine sedimentation took place in two general settings (Johnson, 1978): small, impermanent lakes situated on fluvial-system floodplains; and a large, shallow, persistent lake located in the Bear–Gallinas Mountains area.

Johnson (1978) recognized fan-delta, fine-grained-delta, and basin facies within the Baca–Eagar lacustrine system. Only the fine-grained-delta and basin facies are present in the Gallinas Mountains area. The lacustrine system comprises the entire upper red member and all of the lower red unit except the basal 13 m.

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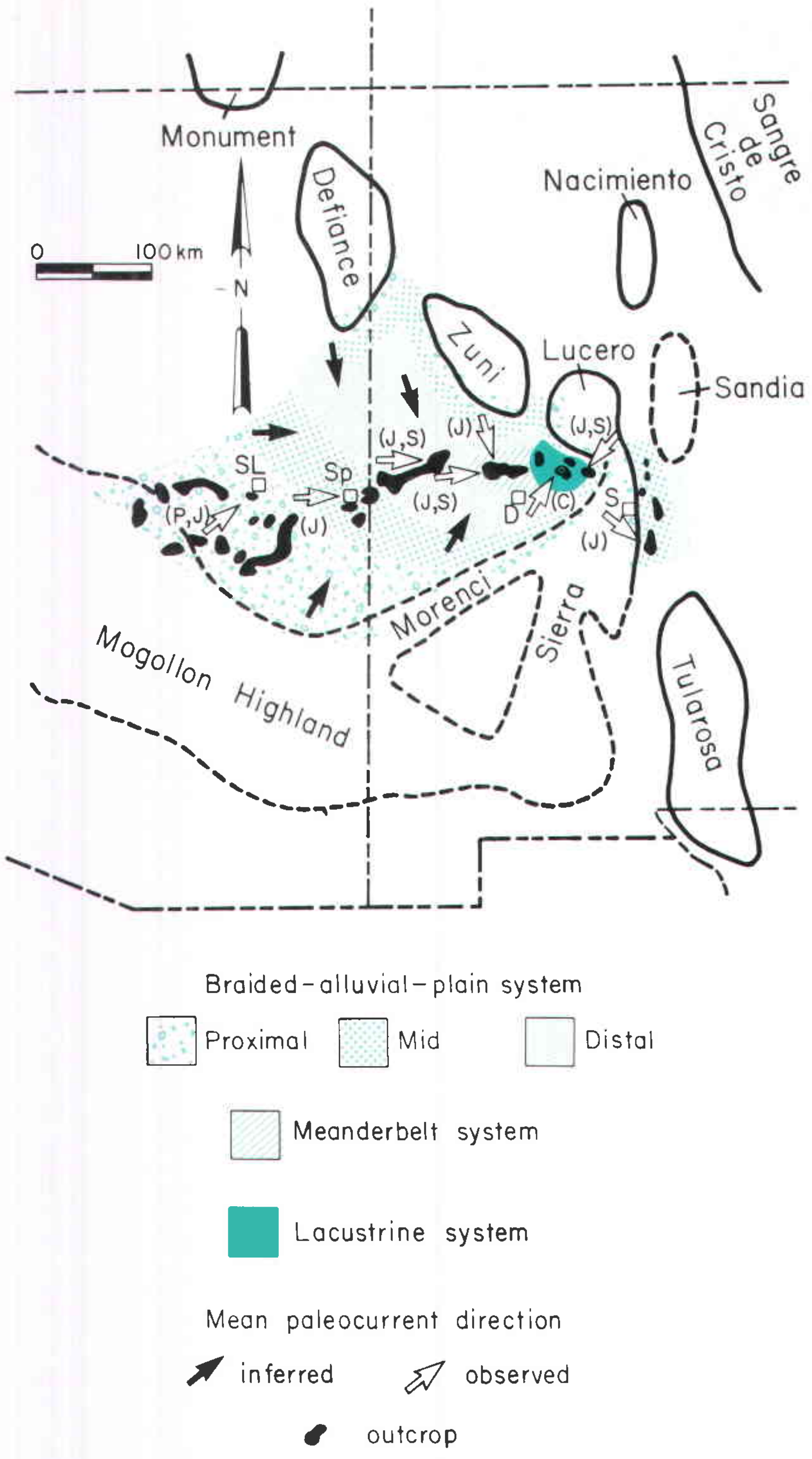

FIGURE 2—MODEL FOR DISTRIBUTION OF FACIES AND PALEOCURRENTS IN THE BACA BASIN DURING EARLY BACA TIME (HIGH LAKE STAND). Reference points: **S** = Socorro, **D** = Datil, **Sp** = Springerville, **SL** = Show Low. Paleocurrent data sources (in parentheses): **J** = Johnson (1978), **P** = Pierce and others (1979), **S** = Snyder (1971), **C** = Cather (1980).

Fine-grained delta facies (*characteristics*)—Cyclical upward-coarsening sequences characterize this facies (fig. 3). Individual cycles range in thickness from approximately 6 to 35 m and average about 9 m thick. In contrast to the braided-alluvial-plain sediments, mudstone is a volumetrically important constituent of the lacustrine system; sandstone/mudstone ratios are about 1:1.

The basal portion of an idealized cycle consists of a laterally persistent calcareous mudstone or claystone intercalated with thinly bedded (generally less than 25 cm thick) very fine- to medium-grained sandstone. Carbonate content of mudstones, determined by weighing samples before and after acidization with cold, dilute hydrochloric acid, generally ranges between 10 and 15 percent by weight. Mudstones rarely exhibit laminations and are usually structureless and homogeneous, with the exception of burrows. Burrowing in the mudstones is pervasive. In contrast to sandstones in the lower portions of deltaic cycles, mudstones do not exhibit well-defined burrows, but rather show a churned, curdled texture both megascopically and microscopically, which gives rise to the homogeneous nature of the mudstones. Rare horizons of mudcracks and pedogenic calcite nodules were also observed.

Structures present within the thinly bedded sandstones intercalated with the above-described mudstones include horizontal laminations, current-ripple laminations, parting-step lineation, occasional normal-graded beds, and burrows. Burrows are vertical, horizontal, and oblique; range in diameter from 1 to 5 cm; and sometimes exhibit knobby surface ornamentation and scoop-shaped backfill laminae (Johnson, 1978, p. 77). According to Johnson these burrows are similar to *Scoyena* sp., which are common in nonmarine red beds (Hantzschel, 1975) and are believed to have been formed by polychaete worms. The thin-bedded sandstones in the lower portions of cycles are often inclined (fig. 4), forming large-scale foresets with dip angles ranging up to 15 degrees in rare instances. Dip angles are more commonly only a few degrees (fig. 5) and are often so gently inclined that the angularity is not readily apparent in a solitary exposure.

The above-described units are transitionally overlain by a horizontal- and current-ripple-laminated, laterally continuous, fine- to coarse-grained sandstone that averages about

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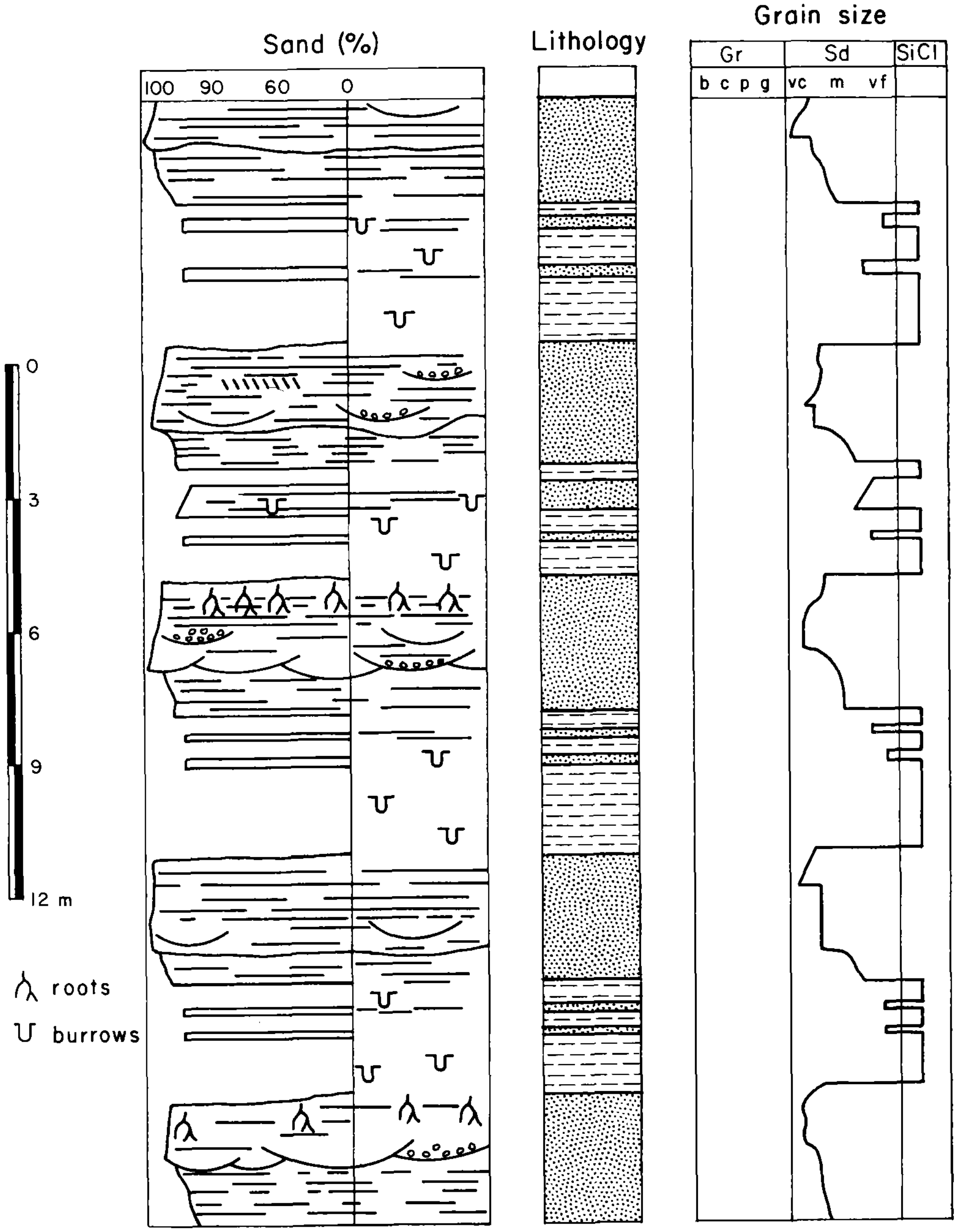

FIGURE 3—Typical vertical section of lacustrine fine-grained delta facies, showing upward-coarsening cycles; modified from Johnson (1978).

1.5 m in thickness. Orientation of current-ripple cross laminations usually indicates a direction of flow at high angles to that shown by other paleocurrent indicators within the same deltaic cycle. The well-sorted, nearly homogeneous nature of these sandstones gives rise to a quasi-spheroidal weathering habit (fig. 5). Coloration of this and superjacent sandstones within a given cycle may be red or yellowish gray, whereas previously described subjacent intercalated mudstones and sandstones are almost always red.

Upsection, the next part of an ideal cycle will sometimes exhibit large, symmetrical, channel-shaped sandstone units that have erosional bases. Channels may be as much as 15 m wide and 5 m deep but are generally much smaller. Intrachannel sedimentary structures include medium-scale trough crossbedding and plane beds. Where symmetrical channel-shaped units are not present, the base of the upper part of each cycle is represented by an irregular, low-relief, erosional surface. The remainder of the upper portion of the cycle is composed of fine- to coarse-grained sandstone with minor conglomerate and mudstone identical to the rocks of the distal braided-alluvial-plain facies.

Fine-grained delta facies (depositional processes)—The cyclical sediments of the fine-grained delta facies are interpreted to record alternate deltaic progradation and abandonment in a shallow lake. Geometry of lithofacies and vertical and lateral sequences of textures and sedimentary structures are similar to those found in lobate high-constructive marine deltas (Fisher and others, 1969). Depositional processes are inferred to be the same as in these marine deltas (Johnson, 1978).

The lower intercalated mudstones and thin-bedded sandstones were deposited in a prodelta and distal delta-front environment. Silt and clay were deposited by settling from suspension. The thin sandstone beds are frontal-splay deposits, probably representing prodelta turbidites. Normal-graded beds, a typical feature of turbidites, are occasionally seen in these sandstones. Turbidites in lacustrine environments have been described by many workers, including Normark and Dickson (1976), Theakstone (1976), and Grover and Howard (1938). Mudcracks and caliches in the lower portion of deltaic cycles are interpreted to represent lake-level low stands.

The laterally continuous, quasi-spheroidally weathering, and horizontally laminated and rippled sandstones are delta-front deposits. These sandstones were deposited in channel-mouth bars or in longshore-current-redistributed bars. The primary processes on the delta front were plane-bed aggradation and ripple migration. The large divergence between paleocurrent directions shown by delta-front ripples and that of other indicators within a given deltaic cycle suggests that ripple migration direction was predominantly controlled by longshore currents.

The large, symmetrical, channel-shaped sandstones sometimes present in the upper part of deltaic cycles are distributary-channel deposits. Sedimentary structures indicate that plane beds and subaqueous dunes were the dominant bedforms within distributary channels. Vegetative stabilization of delta-platform braided-stream channels near the lake allowed for the development of large, symmetrical, relatively low width-to-depth-ratio distributary channels. Deltaic deposits that lack distributary channels indicate nonstabilization of delta-platform stream channels, as is common in classic "Gilbert-type" delta or fan-delta deposits (Gilbert, 1885; Theakstone, 1976). The remainder of the upper portion of the deltaic cycle is composed of delta-platform sandstones and minor conglomerates deposited by braided-stream processes identical to those of the distal braided-alluvial-plain facies. These sediments represent the braided-stream-dominated, subaerial portion of the delta and are analogous to the topset beds of classic Gilbert-type deltas.

Basin facies (characteristics)—When present, the lacustrine basin facies occurs directly beneath the delta facies and consists of generally structureless mudstone and claystone with sparse, thin interbeds of very fine sandstone and siltstone. Evidence of burrowing is abundant. The basin facies is identical to the lower, prodeltaic portion of the fine-grained delta facies, with the exception that the sand and silt interbeds of the basin facies are never inclined and are generally thinner and less abundant than those of the delta facies. The boundary between the two facies is arbitrary.

Basin facies (depositional processes)—Basin depositional processes are exactly the same as those of the lower prodeltaic portion of the

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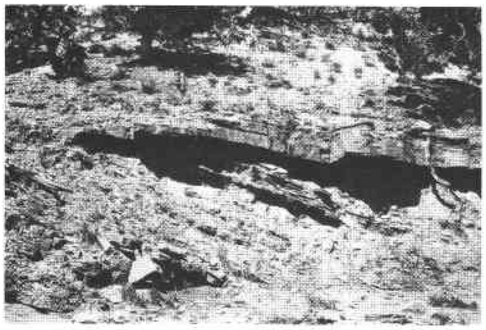

FIGURE 4—BACA FINE-GRAINED DELTA DEPOSIT EXHIBITING UNUSUALLY STEEPLY INCLINED FORESET BEDS. Hammer in center for scale.

FIGURE 5—GENTLY INCLINED PRODELTA FORESET BEDS OVERLAIN BY QUASI-SPHEROIDALLY WEATHERING DELTA-FRONT DEPOSITS. Hammer handle points in direction of delta progradation.

fine-grained delta facies and include settling of silt and clay from suspension, deposition of silt and sand by turbidity currents, and homogenization of mudstones and claystones by burrowing. The thin, sparse nature of the sand and silt interbeds indicates deposition far from nearshore sources of coarse sediments.

CHARACTERISTICS OF LACUSTRINE SYSTEM—The laterally persistent nature of the delta front and delta platform sandstones and the general lack of destructional-phase features indicate that Baca fine-grained deltas were mainly high-constructive lobate (Fisher and others, 1969), which suggests progradation into relatively shallow water. Water depth, as indicated by the thickness of prodelta mudstones and prodelta foreset beds, was generally less than 6 m. During deposition of the upper red unit, however, water depth may have been considerably deeper, as attested by the increased thicknesses of mudstones in that unit.

Baca deltaic and basin sediments in the Gallinas Mountains area show evidence of deposition in a closed lacustrine basin. High concentrations of early authigenic (precompaction) phreatic calcite in basinal and lower-delta sandstones and mudstones suggest evaporative concentration of solutes in a closed-lake environment. The restricted megafaunal assemblage in the Baca lacustrine system also favors a closed-lake system. Only a few scattered ostracods were observed. Langbein (1961) notes that closed lakes usually exhibit widely fluctuating water levels and are found exclusively in arid and semiarid regions. The climate in west-central New Mexico during the Eocene was probably semiarid, as indicated by the paleocaliches and diagenetic reddening in the Baca Formation (Cather, 1980). Rare caliches and mudcracked horizons in Baca prodelta and basin sediments are indicative of fluctuating lake levels. The presence of the fluvially dominated middle sandstone unit between the predominately lacustrine lower and upper red units indicates a large-scale regression that was probably caused by a drastic drop in lake level because of climatic change.

Steeply inclined Gilbert-type foresets are rare in the fine-grained delta facies. Factors contributing to the development of foresets include: a) homopycnal flow (inflow density approximately equal to lake-water density), which causes three-dimensional mixing and an abrupt decrease in current velocity, resulting in rapid deposition of sediment (Bates, 1953); b) deltaic progradation into deep water (McGowen, 1970; Axelsson, 1967; Hjulstrom, 1952); and c) transport of coarse bedload sediments, of which Gilbert-type foresets are composed, to the distributary mouth (Smith, 1975; Axelsson, 1967). The conditions listed above were rarely present during deposition of the Baca deltas in the Gallinas Mountains area. Water depths were shallow and Baca sediments in the study area were rarely coarser than coarse sand. The probable closed nature of the lake implies that lake waters were more dense (because of salinity) than inflowing river water, producing hypopycnal flow and plane-jet formation (Bates, 1953). Lack of three-dimensional mixing causes the plane jet to maintain its velocity over a relatively long distance basinward, resulting in deposition of sediments over a considerable distance from the distributary mouth. This process leads to the development of a gently sloping prodelta surface, which produces the typical shallowly inclined prodelta foresets seen in the fine-grained delta facies. The Gilbert-type deltas in the Baca Canyon area (Johnson, 1978) probably formed in response to possible deeper-water conditions and the input of coarse, conglomeratic sediments derived from the nearby Sierra uplift.

Thin, destructional-phase shoreface sequences produced by reworking of upper-delta sediments by waves and longshore currents following deltaic abandonment and subsidence (Fisher and others, 1969) are rarely seen. The paucity of destructional-phase shoreface sequences suggests relatively low-energy conditions within the lake basin. Attenuation of wave energy resulting from shallow water depths may explain the rarity of destructional-phase features.

The large, shallow lake system present during Baca time in the Bear–Gallinas Mountains area would have tended to be polymictic (frequent overturn) since surface mixing because of eddy diffusion would be expected to penetrate at least several tens of feet (Johnson, 1978). Evidence of abundant burrowing of basin and prodelta sediments indicates that lake-bottom sediments were oxygenated, supporting a polymictic regime. Preservation of laminations in lake-bottom sediments is usually restricted to oligomictic and meromictic (permanently stratified) lakes, in which lack of oxygen inhibits the activities of burrowing organisms.

The majority of the red coloration of the Baca sediments (in both lacustrine and fluvial facies) appears to be due to intrastratal solution of iron-bearing minerals, precipitation of hydrated iron oxides, and subsequent dehydration of these oxides resulting in the development of hematite pigment (Cather, 1980). The diagenetic reddening of Baca lacustrine sediments was initiated by dissolution of unstable, iron-bearing minerals in a positive-Eh setting. This may have taken place in the oxygenated, lake-bottom environment (Johnson, 1978) or via subaerial exposure during periods of lake-level low stands.

Other lines of evidence support a lacustrine interpretation for large parts of the Baca Formation in the Bear–Gallinas Mountains area: a) the presence of rare oolites and ostracods and common intraclasts that were observed in thin sections from the Gallinas Mountains area (Cather, 1980); b) the occurrence of limestone beds in the lower red unit of the Baca in the Bear Mountains area, which are interpreted by Massingill (1979) to be of lacustrine origin; and c) in his work on the palynology of the Baca Formation in the Bear Mountains vicinity, Chaiffetz (1979) stated that the predominantly pink-gray Baca sediments (that is, the lower and upper red units, which I interpret to be dominantly lacustrine) yielded only a few poorly preserved pollen grains and the fresh-water alga, *Pediastrum*. However, a greenish-gray shale sample from a thin mudstone in the fluvially dominated middle sandstone unit (I was present during sampling) produced spores and pollen from a wide variety of upland flora, including conifers. Chaiffetz (1979) further states that the presence of *Pediastrum* ". . . perhaps requires some standing fresh-water bodies in the region at that time."

LACUSTRINE MODEL—The limited exposures of the Baca lacustrine system make comparison to modern and ancient analogues difficult. Exposures in the Bear–Gallinas Mountains area consist only of marginal lacustrine deposits. Paleoflow in the Gallinas Mountains area is generally northeast directed (Cather, 1980), indicating that the location of the basin center was in that direction. The nature of the basin-center deposits is not known because of erosional stripping following late Tertiary uplift of the Colorado Plateau and development of the Mogollon slope (Fitzsimmons, 1959). However, any model of the Baca lacustrine system must take into account the following characteristics: a) shallow water depth, b) fluctuating lake levels, c) rarity of lacustrine megafauna, and d) high concentrations of early authigenic calcite cements in marginal lacustrine sediments.

Eugster and Surdam (1973), Eugster and Hardie (1975), and Surdam and Wolfbauer (1975) have proposed a closed-basin, playa-lake model for Eocene Lake Gosiute in Wyoming that adequately fits many of the characteristics of the Baca lacustrine system.

Lake Gosiute was a large, shallow, closed lake that exhibited widely fluctuating lake levels. With the exception of periods of lake-level low stands during which large volumes of trona were deposited, chemical sedimentation within Lake Gosiute was dominated by precipitation of calcite and dolomite. Megafaunal diversity in Lake Gosiute was greater than that of the Baca Formation lacustrine system and included ostracods, mollusks, algal reefs, and fish. The more restricted assemblage of the Baca lacustrine system may be a result of lack of exposure of potentially more fossiliferous basin-center deposits and/or higher salinity resulting from higher evaporation rates in the more southerly Baca lacustrine system. Surdam and Wolfbauer (1975) suggest that modern Deep Springs Lake in Inyo County, California, may be a modern (although much smaller) analogue of Lake Gosiute.

Lake Chad, Africa (Mothersill, 1975), exhibits some characteristics similar to those inferred for the Baca lacustrine system, including a polymictic regime, the closed nature of the lake, and shallow water depth (less than 5 m).

Depositional history

The rocks of the Baca Formation in the Gallinas Mountains area record the alternate prevalence of distal braided-alluvial-plain and lacustrine environments of deposition. The alternation of these two environments reflect large-scale fluctuations of water level in a large, shallow lake present during Baca time in the Bear–Gallinas Mountains vicinity.

Baca sedimentation in the Gallinas Mountains area began with braided-stream deposition of sands and minor gravels predominantly derived from the southwest on a low-relief erosional surface developed on the Crevasse Canyon Formation (Late Cretaceous). Braided-stream sedimentation in the lower Baca is represented by the distal braided-alluvial-plain facies that comprises the basal 13 m of the lower red unit (fig. 6).

The initial interval of braided-stream sedimentation was followed by a prolonged period of marginal lacustrine sedimentation, as is represented by the cyclical deposits of the fine-grained delta and lacustrine basin facies, which comprise the remaining 86 m of the lower red unit. These lacustrine deposits indicate a large-scale southwestward transgression of the shoreline of a lake whose center was to the northeast (as suggested by paleocurrent data), resulting in onlap of lacustrine sediments over older braided-stream deposits. Local, small-scale regressive-transgressive sequences within this initial transgressive phase of Baca sedimentation reflect cyclical deltaic progradation, abandonment, and subsidence.

The initial period of lacustrine sedimentation was followed by a return to a braided-stream-dominated regime represented by the sediments of the distal braided-alluvial-plain facies that comprise the entire middle sandstone unit. The return to fluvially dominated processes indicates a large-scale regression of the lake shoreline to the northeast.

The final phase of Baca sedimentation in the Gallinas Mountains area is represented by the dominantly lacustrine sediments of the upper red unit. These sediments indicate a second major, widespread shoreline transgression coupled with minor deltaic regressive sequences, similar to those of the first transgressive phase. Water depths during the second transgressive phase may have been deeper than those of the first, as shown by the increased thicknesses of prodelta and basin mudstones in the upper red unit. Lacustrine conditions continued to prevail during deposition of the lowermost Spears Formation, as attested by the occurrence of deltaic deposits in the basal portion of that unit in some areas.

Examination of Baca stratigraphic sections in the Bear Mountains area revealed a similar, although coarser grained, vertical sequence of facies than that in the Gallinas Mountains area, indicating that the transgressions and regressions recorded near the Gallinas Mountains were not just local features but were manifested throughout the lake basin. The Eocene lacustrine system in the Bear–Gallinas Mountains vicinity may have been initiated in response to creation of the wrench-related Sierra uplift, which acted as a damming element across the generally eastward-dipping regional paleoslope (Chapin and Cather, 1981).

Three possible explanations exist for the large-scale transgressions and regressions recorded in the Baca sediments in the Bear–Gallinas Mountains area: a) shifting of the locus of lacustrine sedimentation due to tectonism within the basin; b) increased erosion caused by tectonic activity in the source area, with resultant large-scale regression because of progradation of alluvial aprons basinward; and c) climatic fluctuations with resultant large-scale transgressive and regressive phases. The relative importance of each of the above-listed hypotheses is difficult to evaluate. However, one line of evidence suggests that climatic changes were a major cause of the lake-level fluctuations. The lacustrine mudstones in the Gallinas Mountains area, with the exception of the prodelta mudstone of the basal deltaic cycle in the upper red unit, are highly calcareous and indicative of probable saline, closed-lake conditions. The essentially noncalcareous nature of the basal mudstone of the upper red unit (2 percent calcite by weight as compared with 10–15 percent in other mudstones) implies a temporary change to more fresh-water conditions during the beginning of the second transgressive phase. If the transgression were due to a change to a wetter climate, the low-saline characteristics could be easily explained by the introduction of large amounts of fresh water to the lake. Neither of the tectonic alternatives can explain the noncalcareous nature of the basal mudstone of the upper red unit. Large-scale fluctuations in the level of the contemporaneous Eocene Lake Gosiute, Wyoming, have been attributed to climatic changes by Surdam and Wolfbauer (1975). Interestingly, the relative thicknesses, sequence of occurrence, and number of major transgressive and regressive phases in Eocene Lake Gosiute (Surdam and Wolfbauer, 1975, fig. 1) are similar to those in the lacustrine system present during Baca time in the Bear–Gallinas Mountains vicinity. Although major climatic fluctuations are generally regional in extent, not enough data are available to determine possible relationships between the transgressive and regressive phases of Lake Gosiute and the Baca lacustrine system.

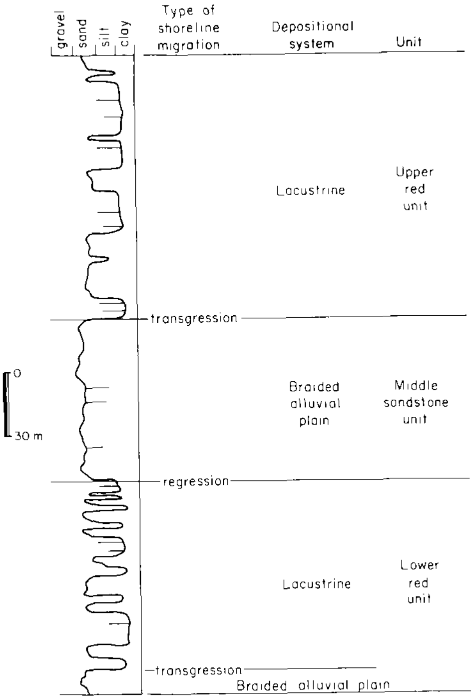

FIGURE 6—GENERALIZED BACA STRATIGRAPHIC SECTION IN THE GALLINAS MOUNTAINS AREA showing relationships between shoreline migrations, depositional systems, and informal units.

The existence of deltaic deposits in the basal Spears Formation indicates that the lake persisted for a short time during the beginning of Oligocene volcanism. The cause of the final demise of the lake is not known. Likely possibilities include climatic change and rapid infilling of the lake with volcaniclastic sediments.

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Palomas volcanic field, southern New Mexico and northern Chihuahua, Mexico

by

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Introduction

The Palomas volcanic field (late Cenozoic) sets astride the international border in south-central Luna County, New Mexico, and northern Chihuahua, Mexico, approximately 80 mi west of El Paso, Texas (fig. 1). The field covers approximately 380 mi² and is bounded on the east and west by longitudes 107°35′ W. and 107°55′ W., respectively.

Lowman and Tiedemann (1968) named the volcanic rocks the Palomas volcanic field after a brief reconnaissance of the area. Balk (1962) mapped several outcrops of the volcanic rocks north of the international border. However, to date, no published data exist on the distribution and occurrence of volcanic features within the volcanic field.

Volcanic features

Rocks in the Palomas volcanic field consist primarily of olivine basalt and associated differentiates of andesite and trachyte. The field is located on the western flank of the Rio Grande rift and displays a number of differences when compared to olivine basalt occurrences previously investigated within the rift in southern New Mexico. These differences include: 1) an older age compared to the rift basalts, 2) the occurrence of more highly differentiated members, and 3) the occurrence of a number of interesting volcanic features, including "pillow" basalt structures, basalt dikes, and lava-capped cinder cones (fig. 2).

LAVA FLOWS—Olivine-rich basalt flows are the most dominant features in the field. They are moderate to highly weathered and have a partial mantle of eolian sand. The flows range in thickness from 1 to 40 ft, but average approximately 10 ft. They range from highly vesicular to extremely dense.

The olivine basalt displays typical vertical joints whereas the more highly differentiated members of andesite to trachyte composition are characterized by well-developed closely spaced platy joints (fig. 3).

Locally abundant are xenoliths of feldspar, quartz, peridotite, and orthopyroxene; these range in size from 2 mm to 4 cm.

CINDER CONES—Over 30 cinder cones have been mapped in the volcanic field (Frantes, 1981, fig. 4). The cones, ranging from 100 to 350 ft in height, show single or multiple vents. The cones are composite and consist of interbedded cinder, agglomerate, dense lava, and agglutinated spatter. They have steep slopes and the rim is typicaly breached on one or more sides where lava appears to have been extruded. Fusiform, almond-shaped, cylindrical ribbon, and cow-dung bombs are locally abundant around the base of many of the cinder cones.

A number of cinder cones display a basal section of pyroclastic materials capped by dense flow rock. These cones are interpreted as the result of lava welling up through a cinder-spatter cone and ponding in the central vent. Subsequent erosion has removed the encircling pyroclastic materials while removing very little of the more resistant dense flow rock (fig. 5). In addition, several cinder cones have been mapped that contain concentrically oriented dikes at the top of the cone.

DIKES—A number of basaltic dikes are exposed in the Palomas field. The dikes are of olivine basalt and are primarily associated with cinder cones. The dikes dip nearly vertical, are several feet in width, and average 400 ft in length (figs. 6 and 7). Several of the cinder cones are located at the intersection of two or more dike trends.

The dikes display two different orientations. One group are linear and strike in a generally north direction. These dikes are 1-15 ft wide and extend for distances of up to a maximum of 2,000 ft. Approximately 80% of the mapped dikes are linear. The second group occur as curving ring dikes near the top of several of the cinder cones; these dikes dip

FIGURE 1—INDEX MAP SHOWING PALOMAS VOLCANIC FIELD.