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BIOSTRATIGRAPHY AND PALEOECOLOGY OF THE MISSISSIPPIAN SYSTEM, WEST-CENTRAL NEW MEXICO

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INTRODUCTION

This description of the Mississippian strata of west-central New Mexico is a brief and incomplete synopsis of various papers of the writer (Armstrong, 1955, 1958a, b, 1962). Documentation of faunal lists and of statements will be found in these publications, particularly in the last two.

Sediments of Mississippian age are exposed in the Coyote Hills, Magdalena, Lemitar, and Ladron mountains (see plate 1). These strata are from 0 to 150 feet thick. The variation in thickness is the result of early Pennsylvanian and later erosion. The Mississippian rocks are essentially carbonate deposits and are divided into two formations, the Caloso and the Kelly. The oldest, the Caloso Formation of lower Osage age, 0 to 40 feet thick, rests upon a peneplained surface of Precambrian rock. The Caloso Formation is separated from the overlying encrinites of the Kelly Formation by a paraconformity. The Kelly Formation, 0 to 75 feet thick, carries a large fauna of upper Osage age. The Kelly Formation is overlain unconformably by clastic rocks of Pennsylvanian age. Northward in the south-central Ladron Mountains, the Pennsylvanian clastics progressively truncate older Mississippian carbonates and north of Ladron Peak, Pennsylvanian strata rest directly on Precambrian rocks (figures 1 and 2).

PREVIOUS WORK

The Mississippian section in the Magdalena Mountains originally was named the *Graphic—Kelly limestone* by Herrick (1904, p. 311), after the two leading mines of the district. The rocks later were renamed the *Kelly Limestone* by Gordon (1907, p. 62-63), after the town of Kelly. In 1905, Lee collected Mississippian fossils on the south side of the Ladron Mountains; Girty identified these fossils as "Lower Mississippian" (Gordon, 1907, p. 58). Darton (1917, p. 50) believed the rocks exposed in the southern Ladron Mountains to be the most northern occurrence of the Mississippian in New Mexico. His list (p. 52) of Mississippian fossils identified by Girty from the southern Ladron Mountains included such typical Keokuk brachiopods as *Spirifer* aff. *S. logani* Hall, *Spirifer* aff. *S. tenuicostatus* Hall, and *Dimegalasma* aff. *D. neglectum* (Hall).

Loughlin and Koschman (1942), in their study of the ore deposits of the Magdalena Mountains, collected a small lot of fossils at the base of the Mississippian section, near the contact with the Precambrian, and another at the top of the limestone. They gave two lists (p. 16) of fossils identified by Girty, who noted that "the two collections are markedly unlike, thus suggesting a marked difference in age." Girty went on to say that "the fauna of the Kelly Limestone is rather strikingly different from the fauna of the (lower Osagian) Lake Valley Limestone."

Laudon and Bowsher (1949, p. 15), after examining the Kelly Formation in the Magdalena and Lemitar mountains, reported fossils to be so scarce that they were unable to collect any for laboratory study. They tentatively considered some poorly preserved fragmental material to be of late Osage age. They did not examine the Mississippian rocks of the Ladron Mountains because of the difficulty of access. Noble (1950, p. 38; Kelley and Silver, 1952, p. 86-87) proposed the name *Caloso Formation* for the entire Mississippian section in the Ladron Mountains. Noble found a fauna near the base of his Caloso Formation. The fossils were identified by S. A. Northrop (Kelley and Silver, p. 86), who ventured the opinion that the fauna of the Caloso Formation is more closely related to that of the Escabrosa Formation of southeastern Arizona than to the fauna of either the Caballero or Lake Valley Formations of southern New Mexico.

Armstrong (1955, p. 30-33) divided the Mississippian rocks of the Ladron Mountains into two formations: the Caloso Formation, which was limited to the lower 30 or 40 feet of sandstones, shales, and fine-grained limestones, and the Kelly Formation, which is the upper 0 to 60 feet. Armstrong (1958b) published a study on the Mississippian stratigraphy and paleontology in the Ladron, Lemitar, and Magdalena mountains giving detailed descriptions and illustrations of the megafaunas and their stratigraphic significance. A stratigraphic and paleontologic study of the Mississippian strata of southwestern New Mexico by Armstrong (1962) describes in some detail the regional stratigraphic, facies, and paleontologic relationship of the Kelly and Caloso Formations to the Lake Valley Formation and Escabrosa Group to the south (figure 3).

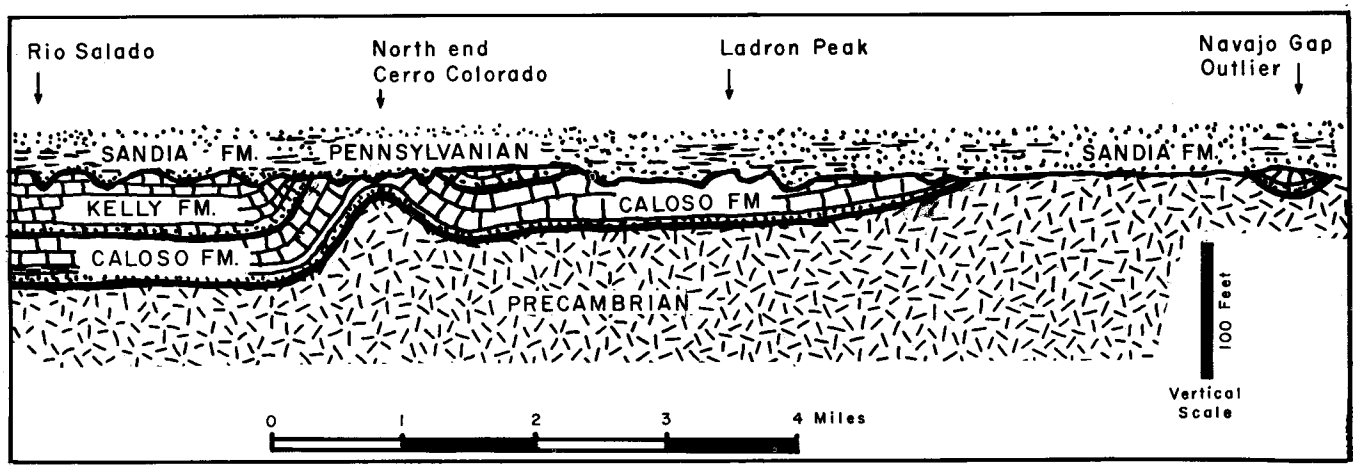

FIGURE 1

Erosional pinchout of Mississippian strata northward from the Rio Salado to Navajo Gap.

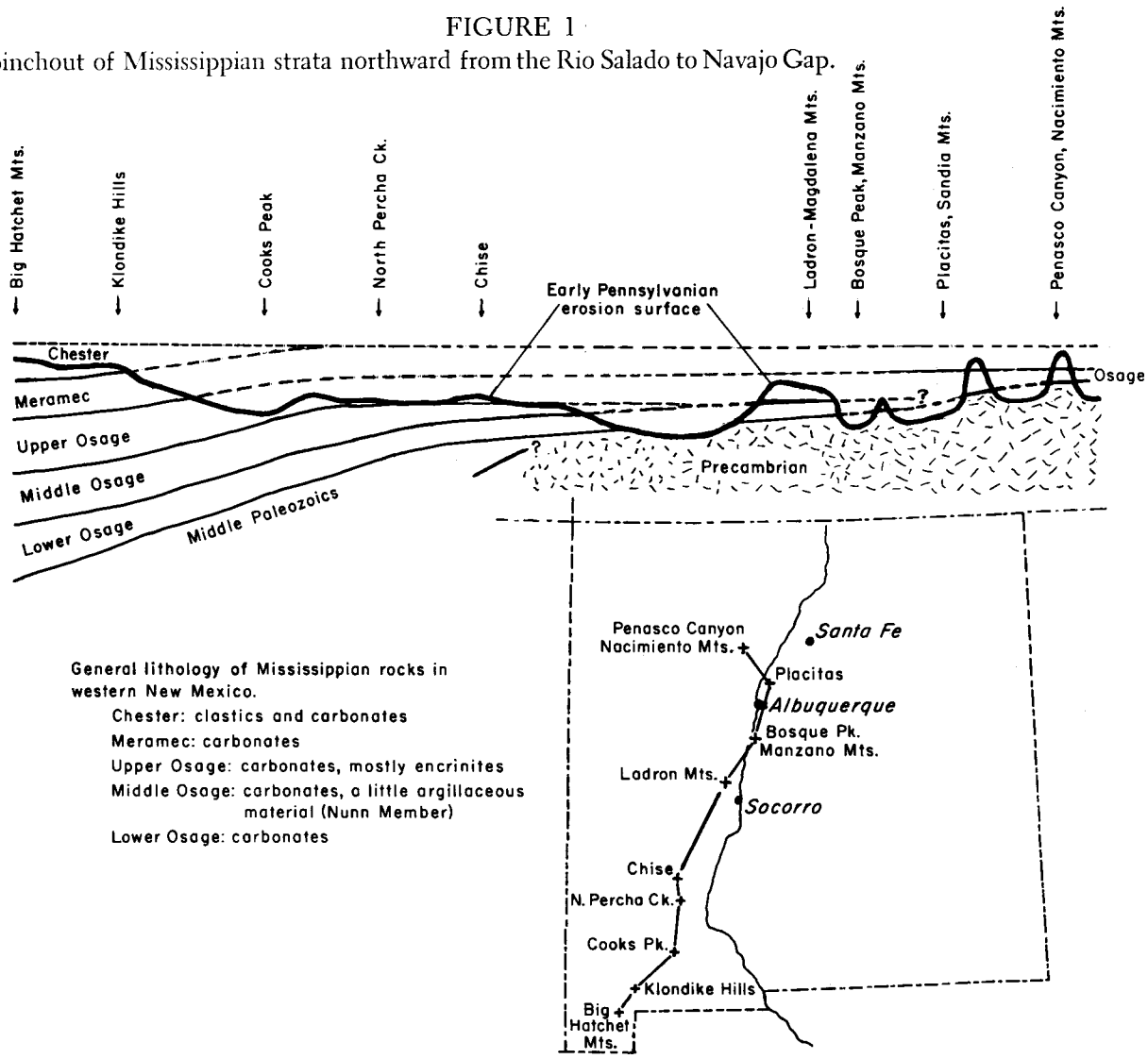

FIGURE 2

Diagrammatic section of Mississippian strata, illustrating its probable extent before and after Pennsylvanian erosion.

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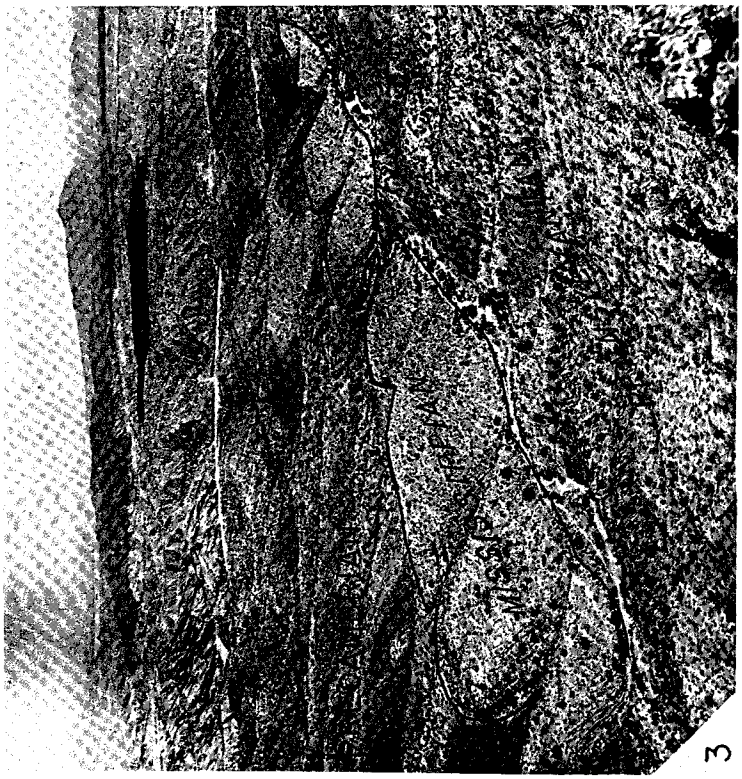

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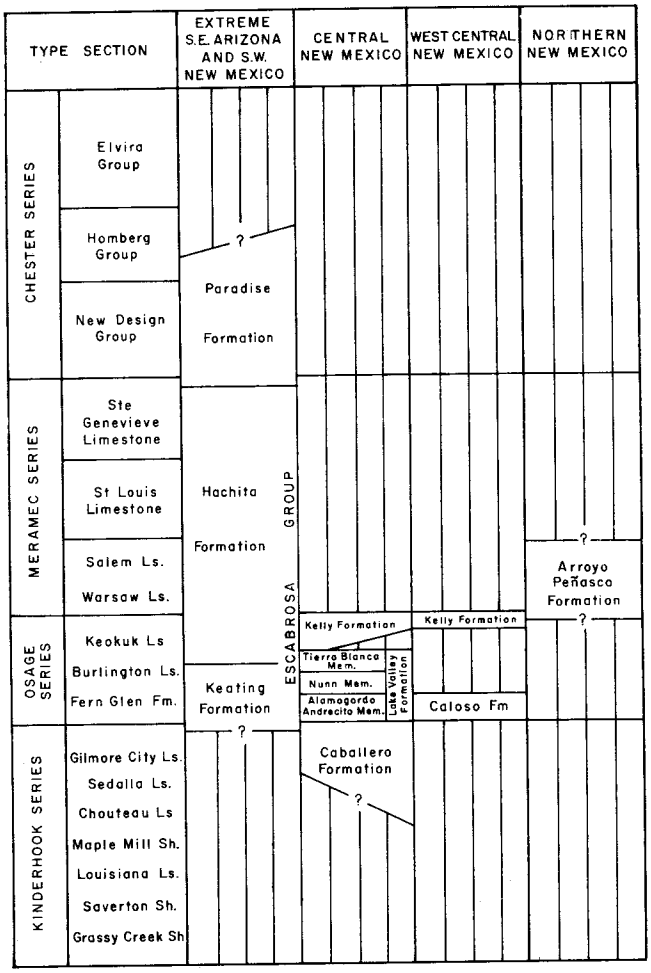


FIGURE 3

Correlation diagram of the Mississippian strata of west-central New Mexico, modified from Armstrong (1958b).

CALOSO FORMATION

LITHOLOGY

The Caloso Formation, when not affected by early Pennsylvanian or younger cycles of erosion, is from 30 to 40 feet thick. It rests on a wave cut, peneplained surface of Precambrian metamorphic and igneous rocks. The basal 1 to 15 feet of the Caloso Formation is a typical cratonic transgressive sequence of subgraywackes, orthoquartzites, and shales, which mineralogically reflect the adjacent underlying Precambrian. The basal bed may be a subrounded pebble conglomerate but grades upward rapidly to finer-grained sandstone, shales, calcareous shales, and ultimately a massive olive-gray to gray, dolomitic limestone and limestone. Nodular brown to black chert is commonly present.

The carbonate rocks of the Caloso Formation are relatively poor in fossils and bioclastic fragments. In thinsections, the rock is typically a fine-grained microcrystalline calcite. Numerous stromatolites are commonly observed within the massive carbonate unit (see plate 2, figs. 1 and 2; plate 3, fig. 3).

The majority of the Caloso carbonates are of such fine-grained and uniform texture that polished surfaces, which were etched in acid and from which acetate peels were made, revealed no relief which could be photographed. Examination of polished slabs indicates the matrix was originally soft pellet lime ooze in which there are some bioclasts, principally of the calcium-secreting green algae family Codiaceae. Occasional rare bioclasts of thinwall brachiopods and very small echinoderm plates are also found.

PLATE 1

Figures

1. Outcrops of the Mississippian Caloso and Kelly formations on the south side of Corkscrew Canyon, Lemitar Mountains. The Caloso and Kelly formations dip steeply to the west.

2. View northward toward Ladron Peak, illustrating (between inked lines) the Mississippian system (mostly the Caloso formation) at the base of the Paleozoic section. Beneath, and to the east of, the Mississippian strata is the Precambrian massif of the Ladron Mountains. Above the Mississippian strata, the Paleozoic hogback is composed of Pennsylvanian marine strata.

3. View from the crest of the Paleozoic hogback, Ladron Mountains, looking southward. Large river bed, which trends west to east, in upper third of the photograph is the Rio Salado. Outcrop patterns of the Precambrian complex and the Mississippian and Pennsylvanian systems are shown in the lower half of the photograph.

4. Type section of the Caloso formation, due east of Cerro Colorado, southern Ladron Mountains. Contacts of Precambrian complex, Mississippian Caloso and Kelly formations, and Pennsylvanian Sandia formation are inked in. Note sudden lithologic, and particularly color, break at the contact of the Caloso and Kelly formations, and abundant chert in the crinoidal Kelly formation.

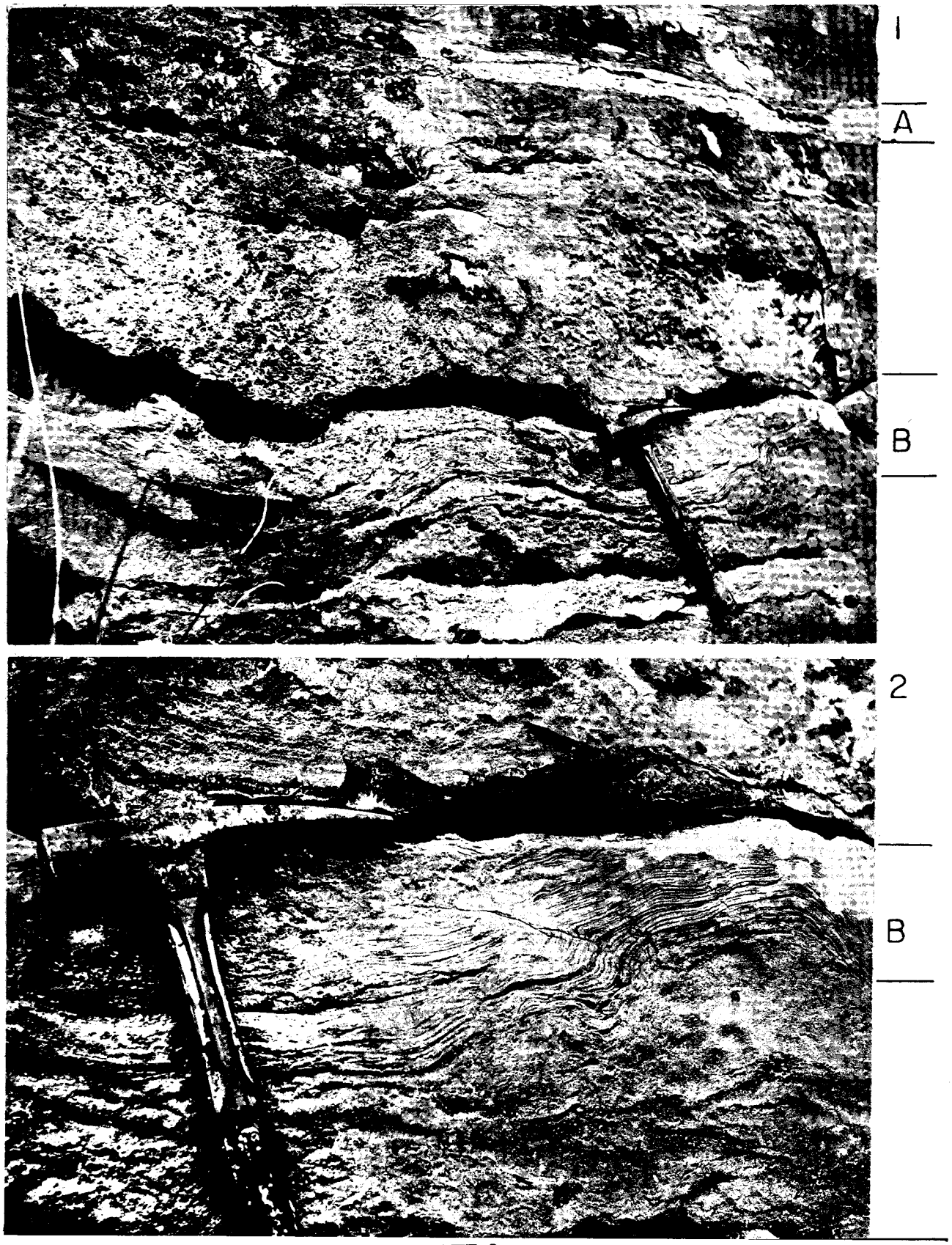


PLATE 2

Figures

1 Lower part of the massive limestone unit of the Caloso formation, at the same locality as shown in plate 1, figure 4. (A) is an edgewise conglomerate lens or band. (B) Persistent stromatolitic band at the base of the massive Caloso limestone unit.

2. Close up view of above photograph illustrating wavy nature of original algal mat.

PALEONTOLOGY, PALEOECOLOGY, PALEOGEOGRAPHY

The Caloso Formation contains a sparse megafauna. This fact combined with the sedimentary structures and the fine microcrystalline nature of the magnesium-rich carbonate rocks strongly suggests a restricted environment during deposition. This view is further strengthened by the generic and specific character of the Caloso fauna when compared to the biostratigraphic equivalents to the south. The fauna

TABLE 1. OCCURRENCE OF CALOSO BRACHIOPODS IN SOUTHERN NEW MEXICO, ILLINOIS, IOWA, AND MISSOURI

	NEW MEXICO				ILLINOIS-IOWA-MISSOURI†			
INDEX FOSSILS OF THE CALOSO FORMATION	CABALLERO FM.*	LAKE VALLEY FM.*	ESCABROSA GP.φ KEATING FM.	KINDERHOOK	FERN GLEN	L. BURLINGTON	U. BURLINGTON	KEOKUK
Camarotoechia tuta (Miller)	×	×	×	×	—	×	—	×
Dielasma chouteauensis Weller	—	—	×	×	—	×	—	—
Spirifer centronatus ladronensis, n. subsp.	—	—	—	—	—	—	—	—
Spirifer louisianensis Rowley	×	×	×	×	—	×	—	—

φArmstrong (1962).
*Laudon and Bowsher (1949).
†Moore (1928).

collected from the Caloso Formation is not diagnostic of either upper Kinderhook or lower Osage (see tables 1 and 2). The Caloso Formation is believed to be younger than Kinderhook. This assumption is based on a logical consideration of the distribution and lithology of known Kinderhook strata in New Mexico (Armstrong, 1962, p. 17). In the region west of the Rio Grande and north of the mining district of Lake Valley, the Kinderhook Caballero Formation is absent, and the Osage either rests on the Upper Devonian Percha Shale or the Precambrian. East of the Rio Grande, the Kinderhook is not known north of Hembrillo Canyon in the San Andres Mountains (Kottlowski et al., 1956). Furthermore, the majority of the exposures of the Caballero Formation contain an appreciably higher proportion of terrigenous-derived sediments which are principally calcareous shale; whereas, in comparison, the Caloso Formation in west-central New Mexico is shale poor. The writer believes the Caloso Formation is a northward facies and time equivalent of the lower Osagian Andrecito and Alamogordo Members of the Lake Valley Formation (see figure 4).

TABLE 2. FOSSILS FROM THE CALOSO FORMATION COYOTE HILLS AND MAGDALENA, LEMITAR, AND LADRON MOUNTAINS, NEW MEXICO AFTER ARMSTRONG (1958b)

	COYOTE HILLS	MAGDALENA MOUNTAINS	LEMITAR MOUNTAINS	LADRON MOUNTAINS
BRACHIOPODA				
Schuchertella? sp.	—	×	—	—
Camarotoechia tuta (Miller)	×	×	×	—
Rhynchotreta? sp.	—	×	—	—
Dielasma chouteauensis Weller	—	—	?	×
Spirifer louisianensis Rowley	—	×	—	—
Spirifer centronatus ladronensis, n. subsp.	—	?	—	×
Composita? sp.	—	×	—	—
Syringothyris? sp.	×	×	—	—
Streptorhynchus? sp.	—	×	—	—
MOLLUSCA				
Conocardium sp.	—	—	—	×
Pelecypods, several genera	×	×	—	×
Straparolus luxus (White)	×	?	—	×
COELENTERATA				
Michelinia sp.	—	×	—	—
Syringopora sp.	—	×	×	—
Cyathophyllum? sp.	—	×	×	×

The lower part of the Lake Valley Formation was deposited in an open, well-agitated, shallow sea with free exchange of water with the extensive, but not necessarily deeper, Escabrosa seaway. The lower part of the Lake Valley Formation contains a rich and well-diversified fauna of invertebrates typical of lower Mississippian epicontinental seas. In contrast, the Caloso Formation was deposited to the north in a very restricted environment in which marine invertebrates did not thrive. It is believed that the Caloso Formation, particularly the massive carbonate unit, was deposited in shallow to very shallow marine water subject to fluctuations in salinity. The salinity fluctuations were possibly the result of annual rains and concordant runoff from the low-lying but emergent Penasco dome to the north. It is interesting to note that the majority of the Caloso fossils, particularly the larger and more robust individual animals, have been found in the lower 10 feet of the formation where supposedly they may have been concentrated in tidal channels. The most prolific organisms during Caloso deposition were probably carbonate-secreting green algae living in a manner described by Lowenstam (1955) and Lowenstam and Epstein (1957). For the Caloso Formation, these green algae may have been the major producers of carbonate muds. Rather abundant branching Codiaceae algae also lived on the bottom and are by far the most significant bioclasts within the lime-mud matrix.

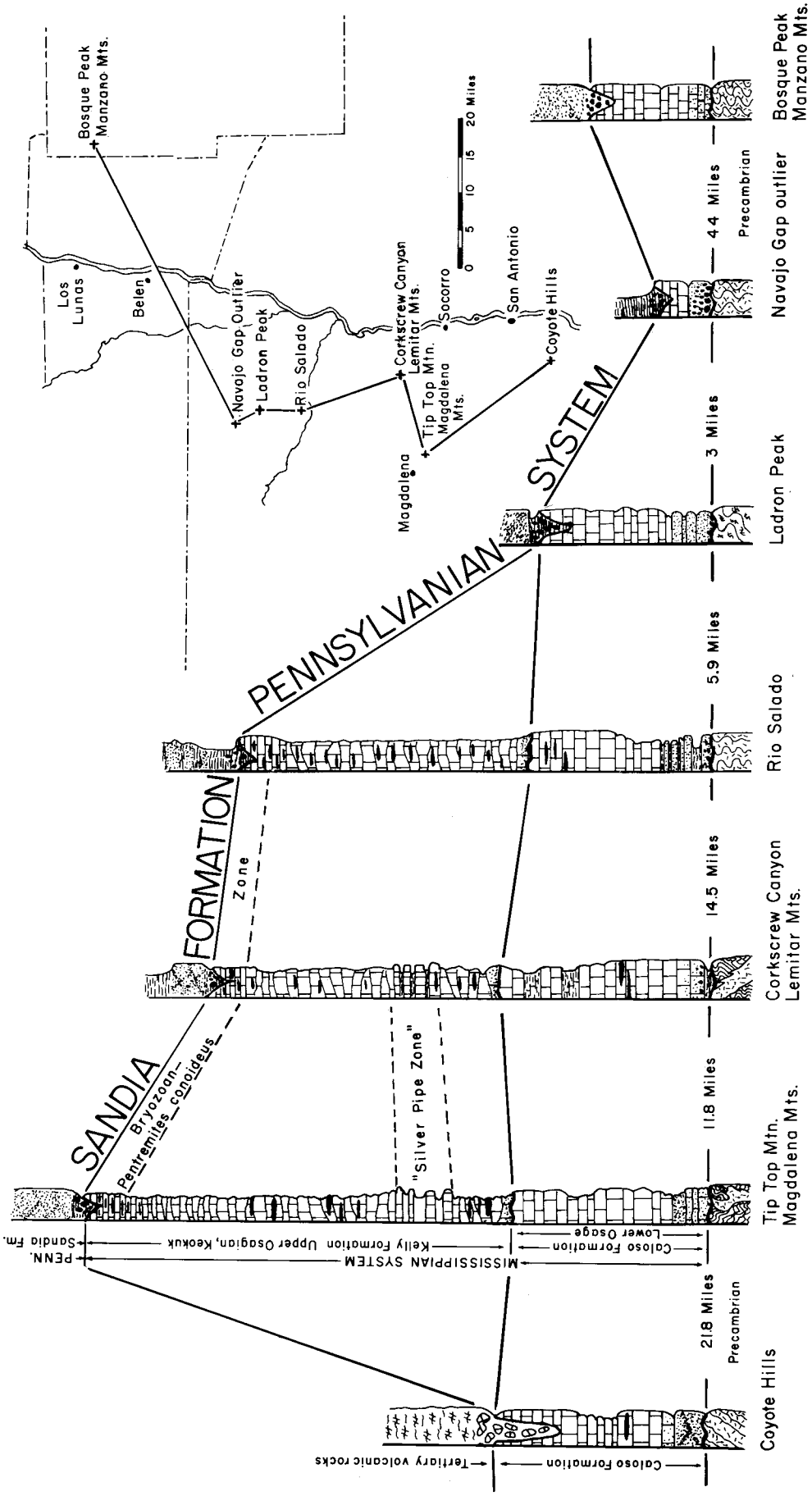


FIGURE 4
Correlation of Mississippian strata in Socorro County

KELLY FORMATION

LITHOLOGY

The Kelly Formation overlies the Caloso Formation by a paraconformity. A hiatus exists between the two formations which represents at a minimum all of middle Osage time. The contact between the two formations is defined by a sharp lithologic break between the dark olive-gray microcrystalline dolomitic limestones of the Caloso Formation and the light, buff-colored, coarse encrinites of the Kelly Formation.

Throughout west-central New Mexico in the area of exposure, the Kelly Formation is consistent in lithology and is a gray to buff, fine- to coarse-grained bioclastic limestone in which echinoderm fragments predominate. The cement between the bioclastic grains is generally microcrystalline calcite but may be sparry calcite (see plate 3, figure 2). Nodular, white to gray chert is present in lenses up to 4 inches thick. The paraconformity between the Caloso Formation and the Kelly Formation is marked at the top of the Caloso Formation by a slightly irregular surface filled with 1 to 6 inches of clean, rounded quartz sand which intergrades vertically into the encrinites of the Kelly Formation.

The "silver pipe zone" of the Kelly Formation is a very characteristic horizon marker in the Magdalena and Lemitar mountains. It is absent in the Ladron Mountains. This zone is from 12 to 15 feet above the contact with the Caloso Formation. The "silver pipe zone" is 6 to 10 feet thick and consists of microcrystalline, fine-grained, argillaceous, light to dark gray, dolomitic limestone and thin, calcareous shales. Miners in the Magdalena Mountains first recognized this zone as it appears to have had a significant role in the migration of Tertiary ore-bearing fluids and emplacement of ore bodies (Loughlin and Koschmann, 1942, p. 15).

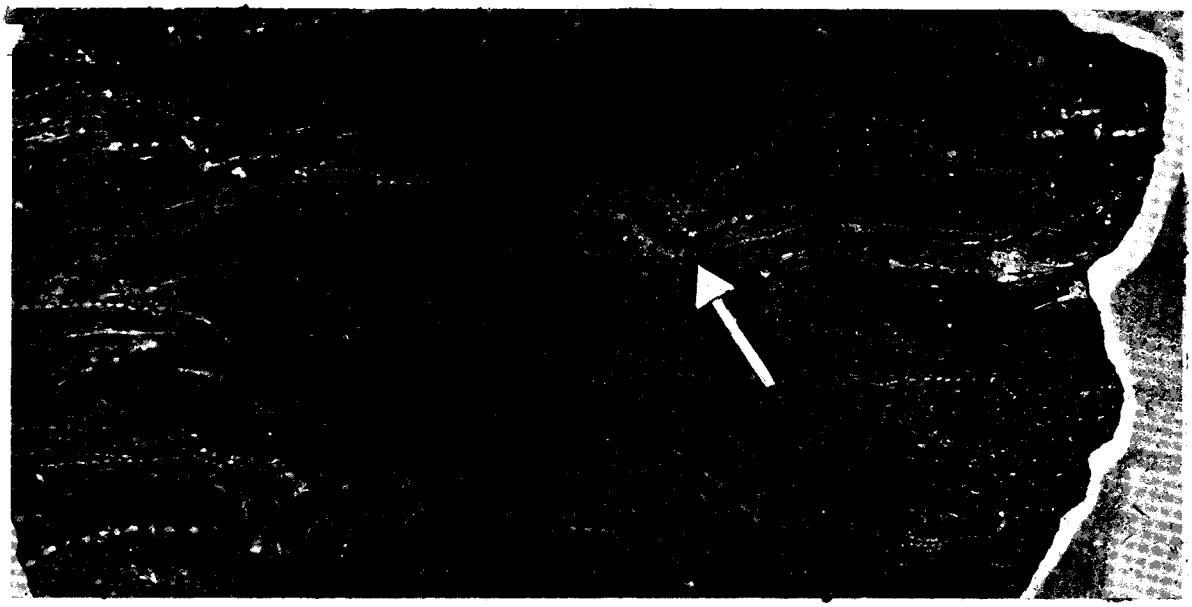
Some 40 to 50 feet above the base of the Kelly Formation, the encrinites and bioclastic limestones become finer-grained and thinner-bedded; and the chert becomes ribbonlike and distinctly brown in color. Furthermore, this platy-bedded limestone in many places displays, on its bedding surfaces, abundant impressions of fenestrate bryozoans (see plate 3, figure 1). This distinctive horizon marker (as shown on the correlation diagram) is called the Bryozoan-*Pentremite conoideus* zone (Armstrong, 1958b).

PALEONTOLOGY, PALEOECOLOGY, PALEOGEOGRAPHY

The Kelly Formation of west-central New Mexico contains a rich and diversified fauna of corals, brachiopods, and echinoderms (see table 3). This fauna was described and illustrated by Armstrong (1958b). It has yielded 18 species of brachiopods belonging to 13 genera. One of the most important genera in the Kelly Formation is *Tetracamera*, represented by two species: *Tetracamera subcuneata* (Hall), which is characteristic of the *Tetracamera* zone of the Mississippi Valley in beds ranging from Keokuk to Salem in age, and *Tetracamera* cf. *T. subtrigona* (Meek and

TABLE 3. FAUNA OF THE KELLY FORMATION OF THE MAGDALENA, LEMITAR, AND LADRON MOUNTAINS, NEW MEXICO AFTER ARMSTRONG (1958b)

	MAGDALENA MOUNTAINS	LEMITAR MOUNTAINS	LADRON MOUNTAINS
BRACHIOPODA			
"*Orthotetes?*" sp.	×	×	×
Streptorhynchus? sp.	×	—	—
Rhipidomella sp.	×	×	×
Linoproductus sp.	×	×	×
Productus, sensu lato, several species	×	×	×
Echinoconchus? sp.	×	—	—
Chonetes cf. *illinoisensis*	—	—	×
Tetracamera cf. *subtrigona* (Meek and Worthen)	×	×	×
Tetracamera subcuneata (Hall)	×	×	×
Rhynchopora persinuata (Winchell)	—	—	×
Spirifer tenuicostatus Hall	×	×	×
Spirifer grimesi Hall	×	×	×
Spirifer? sp.	×	×	×
Spirifer? sp.	×	×	×
Brachythyris suborbicularis (Hall)	×	×	×
Athyris aff. lamellosa (Léveillé)	×	×	×
Cleiothyridina hirsuta (Hall)	×	×	×
Cleiothyridina? parvirostris (Meek and Worthen)	×	—	—
Cleiothyridina obmaxima (McChesney)	×	×	×
Dimegelasma neglectum (Hall)	—	×	×
BLASTOIDEA			
Pentremites conoideus Hall	×	×	×
Orbitremites floweri, n. sp.	×	×	×
MOLLUSCA			
Platyceras sp.	×	×	×
Straparolus spp.	×	×	×
Pelecypods, several genera	×	×	×
COELENTERATA			
Zaphriphyllum casteri, n. sp.	×	×	×
Rare fragments of an indeterminable genus	×	×	×
BRYOZOA			
Large fauna, unstudied	×	×	×
ARTHROPODA			
"*Phillipsia*" sp.	×	×	×
VERTEBRATA			
Shark's tooth	×	×	×
PROTOZOA			
Plectogyra sp.	×	×	×



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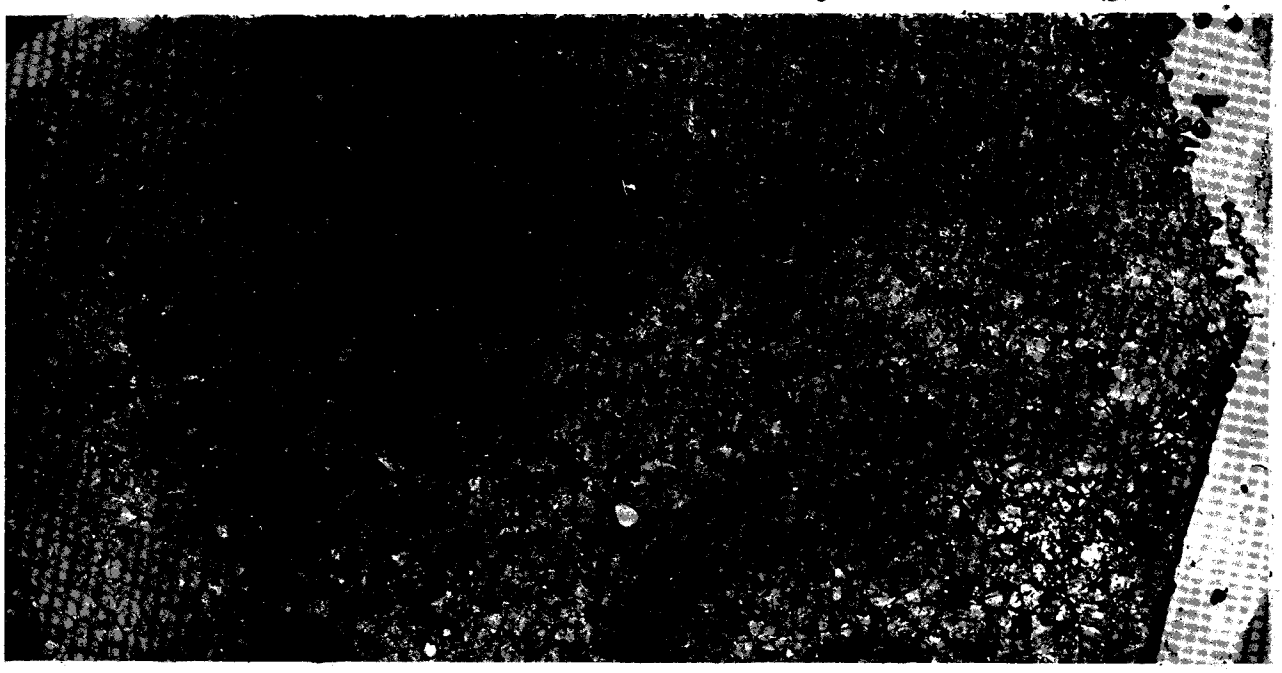

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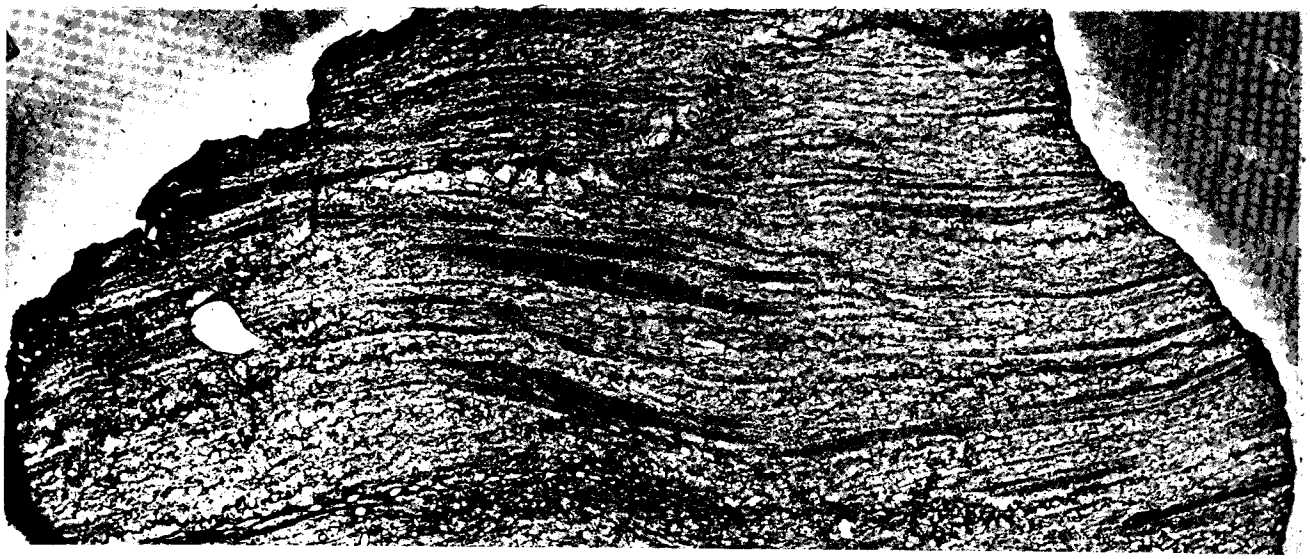

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TABLE 4. STRATIGRAPHIC RANGE OF KELLY FORMATION SPECIES IN NEW MEXICO AND OTHER AREAS

	NEW MEXICO					ILLINOIS-IOWA-MISSOURI†			
	CABALLERO FM.*	LAKE VALLEY* FM.	ESCABROSA GP.φ KEATING FM.	HACHITA FM.	FERN GLEN	L. BURLINGTON	U. BURLINGTON	KEOKUK	WARSAW
Chonetes illinoisensis? Worthen	×	×	×	—	×	×	×	×	×
Tetracamera subtrigona (Meek and Worthen)	—	—	—	—	—	—	—	×	—
Tetracamera subcuneata (Hall)	—	—	—	—	—	—	—	×	×
Rhynchopora persinuata (Winchell)	—	×	—	—	×	×	—	—	—
Spirifer grimesi Hall	—	?	—	—	—	×	×	×	—
Spirifer tenuicostatus Hall	—	—	—	—	—	—	—	×	×
Brachythyris suborbicularis (Hall)	—	×	×	×	?	×	×	×	×
Cleiothyridina? parvirostris (Meek and Worthen)	—	—	—	—	—	×	×	×	×
Cleiothyridina hirsuta (Hall)	—	—	—	×	—	—	?	—	×
Cleiothyridina obmaxima (McChesney)	—	×	×	×	×	×	?	×	—
Dimegelasma neglectum (Hall)	—	—	—	—	—	—	—	×	×
Pentremites conoideus Hall	—	—	—	×	—	—	—	—	×

φ Armstrong (1962).
* Laudon and Bowsher (1949).
† Moore (1928).

Worthen), which is restricted in the Mississippi Valley to beds of Keokuk age (see table 4). *Spirifer tenuicostatus* Hall is a Keokuk and Warsaw species and is not known in lower Osage rocks. *Dimegelasma neglectum* (Hall) is also a Keokuk and Warsaw species. The Kelly Formation contains numerous specimens of *Spirifer grimesi* Hall and *Spirifer logani* Hall, which indicate a late Osage age.

The blastoids are represented by two species, a new species so far restricted to the Kelly Formation, *Orbitremites floweri* Armstrong, and the species *Pentremites conoideus* Hall, which ranges from Keokuk to Ste. Genevieve time in the midcontinent.

The coelenterates are represented by a new species of the rugose coral *Zaphriphyllum*, *Z. casteri* Armstrong. The only other known occurrence of the genus *Zaphriphyllum* is in the Northwest Territory of Canada, where Sutherland (1954, p. 363-365) described it from rocks containing a fauna suggestive of Middle Mississippian age.

The Kelly Formation fauna has strong upper Osage affinities with some species faintly suggestive of lower Meramec. The Kelly Formation in west-central New Mexico can be assigned without question to an upper Osage–Keokuk age.

The abundance of bioclasts of echinoderms and lesser amounts of brachiopods, bryozoans, and gastropods all indicate that the Kelly Formation was deposited in an environment of high organic activity, particularly those organisms which secrete heavy cal-

PLATE 3

All photographs are 3× enlargements made from acetate peels of polished rock slabs; all sections are cut normal to bedding.

All specimens were collected in the southern Ladron Mountains, at location of photograph, plate 1, figure 4.

Figures

1. Kelly Formation, from the Bryozoan—*Pentremites Conoideus* zone. Thinsection illustrates (one example by arrow) numerous Bryozoan fronds, supported in a matrix of lime mud and silt-size bioclasts.
2. Kelly Formation, typical example of the encrinite. Primarily composed of bioclasts of echinoderm, cemented by sparry calcite and microcrystalline ooze. Dark areas between bioclasts are secondary weathered cavities filled with insoluble clays.
3. Basal carbonates of the stromatolite Caloso formation, shown in plate 2.

careous skeletons. The echinoderms are very sensitive indicators of environment; thus, the abundance of crinoid remains in the Kelly Formation indicates agitated water of normal marine salinity which was consistently in exchange with the open sea. The rather poor sorting of the bioclastic material, as shown by large spirifers and gastropods mixed with smaller crinoid fragments, indicates that the larger invertebrates were buried where they lived and that the crinoid fragments were probably transported at best only a short distance after death.

The Kelly Formation of west-central New Mexico represents a northern extension of the upper part of Tierra Blanca Member of the Lake Valley Formation and the "Kelly Formation" of the Silver City area (Laudon and Bowsher, 1949). To the south and southwest of the Black Range, the Kelly Formation equivalents are represented in the Sonoran embayment by the central part of the Hachita Formation. To the southeast and south in the San Andres and Sacramento mountains, the Kelly Formation is represented by the Dona Ana member of the Lake Valley Formation.

Strata of Kelly lithology are not known north of Ladron Peak. Undoubtedly, this facies extended many tens of miles northward. Early Pennsylvanian erosion was very extensive in the Lucero uplift, Los Pinos and Manzano mountains, and no trace of the Kelly Formation remains. It is conceivable that the lower part of the Arroyo Penasco Formation in the Nacimiento and Sangre de Cristo mountains may represent a northward facies of the Kelly Formation.

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