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The Mississippian System of southwestern New Mexico and southeastern Arizona

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THE MISSISSIPPIAN SYSTEM OF SOUTHWESTERN NEW MEXICO AND SOUTHEASTERN ARIZONA

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INTRODUCTION

This report focuses on the Mississippian rocks of southwestern New Mexico and southeastern Arizona and, in particular, the Pedregosa basin. Greenwood and others (1977) give the geologic history of this basin and summarize its petroleum potential and stratigraphy. The data for northern and central Arizona are taken from McKee and Gutschick (1969) and McKee and Crosby (1975). A detailed description of the Mississippian rocks of north and north-central New Mexico is given by Armstrong and Mamet (1974, 1976, 1977a). This report is preliminary, and detailed analysis of the microfacies, microfossils and diagenesis of the carbonate rocks is in preparation. Mamet's microfossil zonations, as defined in Sando and others (1969), Mamet (1976), and Mamet *(in* Armstrong and Mamet, 1977b), are used in this report. The carbonate rock classification used is Dunham's (1962).

PREVIOUS WORK

Mississippian rocks at Lake Valley, New Mexico (fig. 1, loc. 44), were first described by White (1881). Cope (1882a,b) referred to the rocks at Lake Valley and proposed the name Lake Valley Limestone.

Herrick (1904) used the name Kelly Limestone for the Mississippian rocks of the Magdalena mining district. In two papers Laudon and Bowsher (1941, 1949) divided the Mississippian System of south-central New Mexico into a series of five formations and the Lake Valley Limestone into six members (fig. 2). They used the name Caballero Formation for rocks in the Sacramento and San Andres mountains and at Lake Valley, New Mexico, that are mostly of Kinderhookian age, and the Las Cruces and Rancheria formations for rocks in the Franklin Mountains of west Texas and the southern San Andres and Sacramento mountains of New Mexico that are mostly Meramec age. Beede (1920, p. 8) designated all the rocks between the Silurian and the Pennsylvanian systems in the Hueco Mountains of west Texas as the Helms Formation. Laudon and Bowsher (1949, p. 19) restricted the Helms to the Chesterian green shales, shaly sandstone and impure limestones.

Laudon and Bowsher (1941, 1949) gave macrofaunal lists for the Lake Valley, Rancheria and Helms Formations.

The Escabrosa Limestone of Mississippian age was named by Girty *(in* Ransome, 1904) from the lower Carboniferous section in the Escabrosa Cliffs, west of Bisbee, Cochise County, southeastern Arizona. Huddle and Dobrovolny (1952) made a detailed study of the Mississippian strata of central Arizona that included the northern parts of the Escabrosa Limestone and presented an excellent description of the upper contact and effects of solution on the Redwall and Escabrosa Lime stones. Gilluly and others (1954) described the late Paleozoic rocks, which included the Mississippian System of Cochise County, Arizona. The Escabrosa Limestone in the Chiricahua Mountains of southeastern Arizona and southwestern New Mexico was elevated to the Escabrosa Group by Armstrong (1962, p. 5) and divided into two newly named formations: the Keating Formation with two members, A and B; and the overlying Hachita Formation (figs. 2, 9). This nomenclature was extended into Luna, Hidalgo and Grant Counties, southwestern New Mexico, and the Chiricahua Mountains of Arizona (fig. 8). The two informal members of the Keating Formation were named the Bugle and Witch members by Armstrong and Mamet (in press). The brachiopod and coral faunas for the Escabrosa Group are illustrated and described by Armstrong (1962).

The Paradise Formation was named by Stoyanow (1926) for outcrops a few miles east of the old mining camp of Paradise, on the east side of the Chiricahua Mountains. The macrofauna of the Paradise Formation in the Chiricahua Mountains was studied and described by Hernon (1935). Zeller (1965) gives M. K. Elias' macrofossil lists of the Paradise Formation in the Big Hatchet Mountains.

GEOLOGIC SETTING

Lower boundary of the Mississippian

Leadville Limestone of the San Juan Mountains, Colorado, and in the subsurface of San Juan County, New Mexico (fig. 2), has at its base a Tournaisian (Osage) microfossil assemblage of Zone 9 (Armstrong and Mamet, 1976, 1977a), and the underlying Ouray Limestone contains a well-defined fauna of Upper Devonian brachiopods near its top (Armstrong and Mamet, 1976). In north-central New Mexico Mississippian rocks of Zone 9 age unconformably overlie Precambrian metamorphic and igneous rocks (fig. 2). In west-central New Mexico Zone 8 rocks overlie the Precambrian. In the northern Sacramento Mountains rocks of pre-Zone 7 overlie shale and limestone of Late Devonian age. In the northern San Andres Mountains Tournaisian age rocks rest unconformably on Upper Devonian shale and marls; in the southern part of the range, pre-Zone 7 beds unconformably overlie Upper Devonian strata. In the Mimbres Range and Silver City region, pre-Zone 7 rocks unconformably overlie Upper Devonian Percha Shale. In the southwestern part of New Mexico and southeastern Arizona pre-Zone 7 carbonate rocks unconformably overlie Upper Devonian sedimentary rocks (figs. 2-5).

Units overlying the Mississippian

Pennsylvanian rocks unconformably overlie the Mississippian at most places in New Mexico and southeastern Arizona.

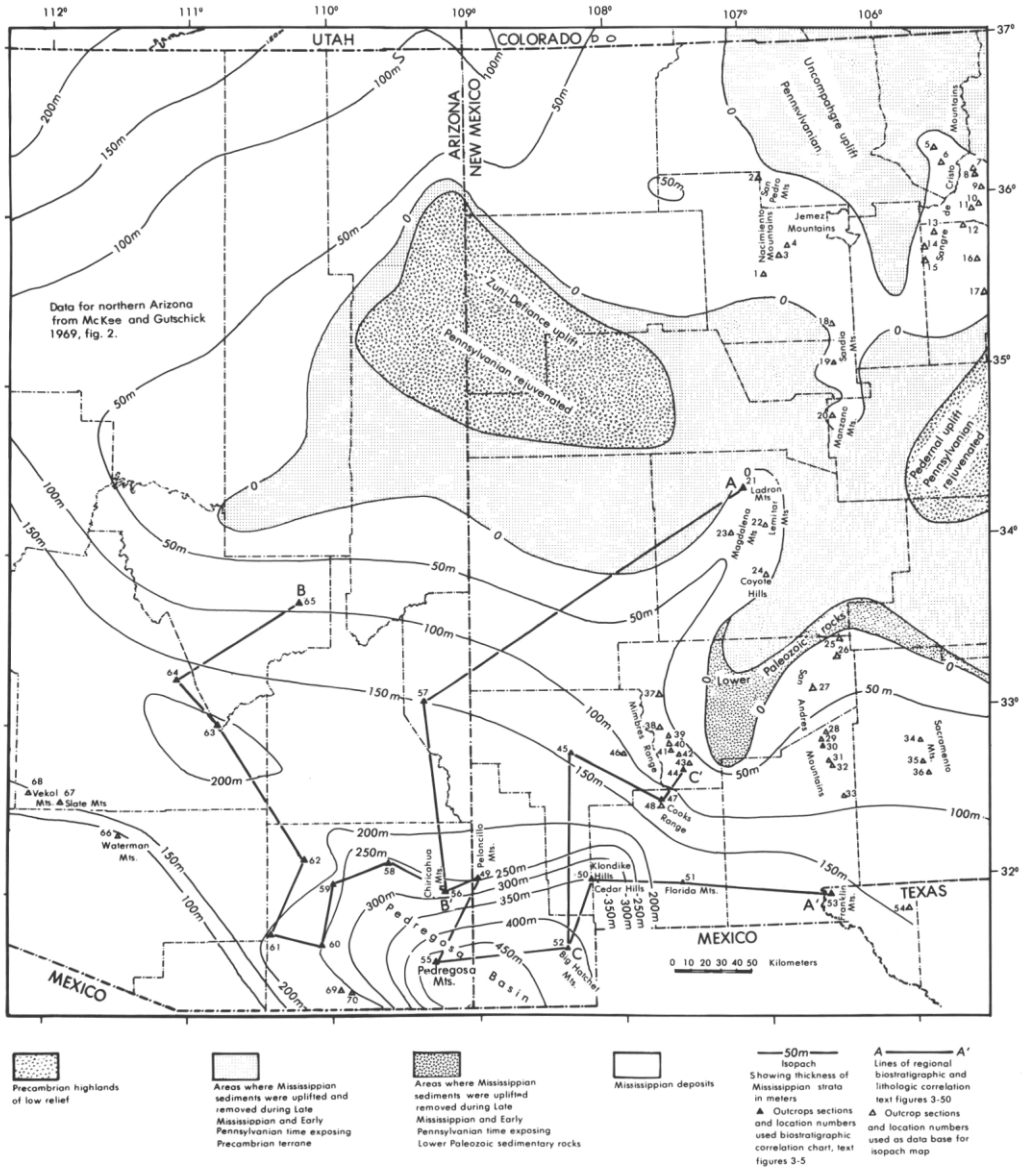


Figure 1. Index map of western New Mexico and eastern Arizona showing location of Mississippian sections, Mississippian isopachs and paleogeography in pre-Pennsylvanian time, and location of correlation charts shown in Figures 3-5.

In the mountains of north-central New Mexico, the Mississippian Arroyo Penasco Group or the Log Springs Formation are overlain by Pennsylvanian strata (Armstrong and Mamet, 1974, 1977a). During the hiatus Mississippian rocks representing Zones 17 to 20 (Chesterian to Morrowan) time were eroded. In west-central New Mexico in the Lemitar, Ladron and Magdalena Mountains the Mississippian carbonate rocks are unconformably overlain by nearshore elastic rocks of the Pennsylvanian Sandia Formation of the Magdalena Group (figs. 2, 3) (Armstrong, 1958).

Pennsylvanian strata in northern, central and southern New Mexico and southwestern Arizona truncate Mississippian sedimentary rocks of Namurian, Visean and Tournaisian (Chesterian to Osagean) age. In the Big Hatchet Mountains of New Mexico and the Pedregosa Mountains of southeastern Arizona the contact between the Paradise Formation and the overlying Pennsylvanian Horquilla Limestone is at the Zone 19/20 boundary, and a hiatus, if present, must be short. In the Florida Mountains, the Mississippian starved-basin carbonate rocks of the Rancheria Formation are unconformably overlain by Permian (Wolfcampian) carbonate rocks. The Mississippian Escabrosa Limestone to the west in the Papago Indian Reservation in the Waterman, Slate and Vekol mountains is from 90-130 m thick, is predominately dolomite, is Tournaisian (Osagean) in age and was extensively eroded before Pennsylvanian carbonate sedimentation. The upper half of the section in the Slate and Vekol mountains contains well-developed subtidal, intertidal and supratidal sedimentary features such as abundant algal stromatolites, mud cracks, interformational conglomerates, birdseye structures and abundant dolomite pseudomorphs and vugs after anhydrite and gypsum.

Structural Events During the Mississippian

A generalized isopach map of Mississippian rocks is shown in Figure 1 and is based upon Mississippian remnants of extensive sheets that were dissected and beveled in northern and

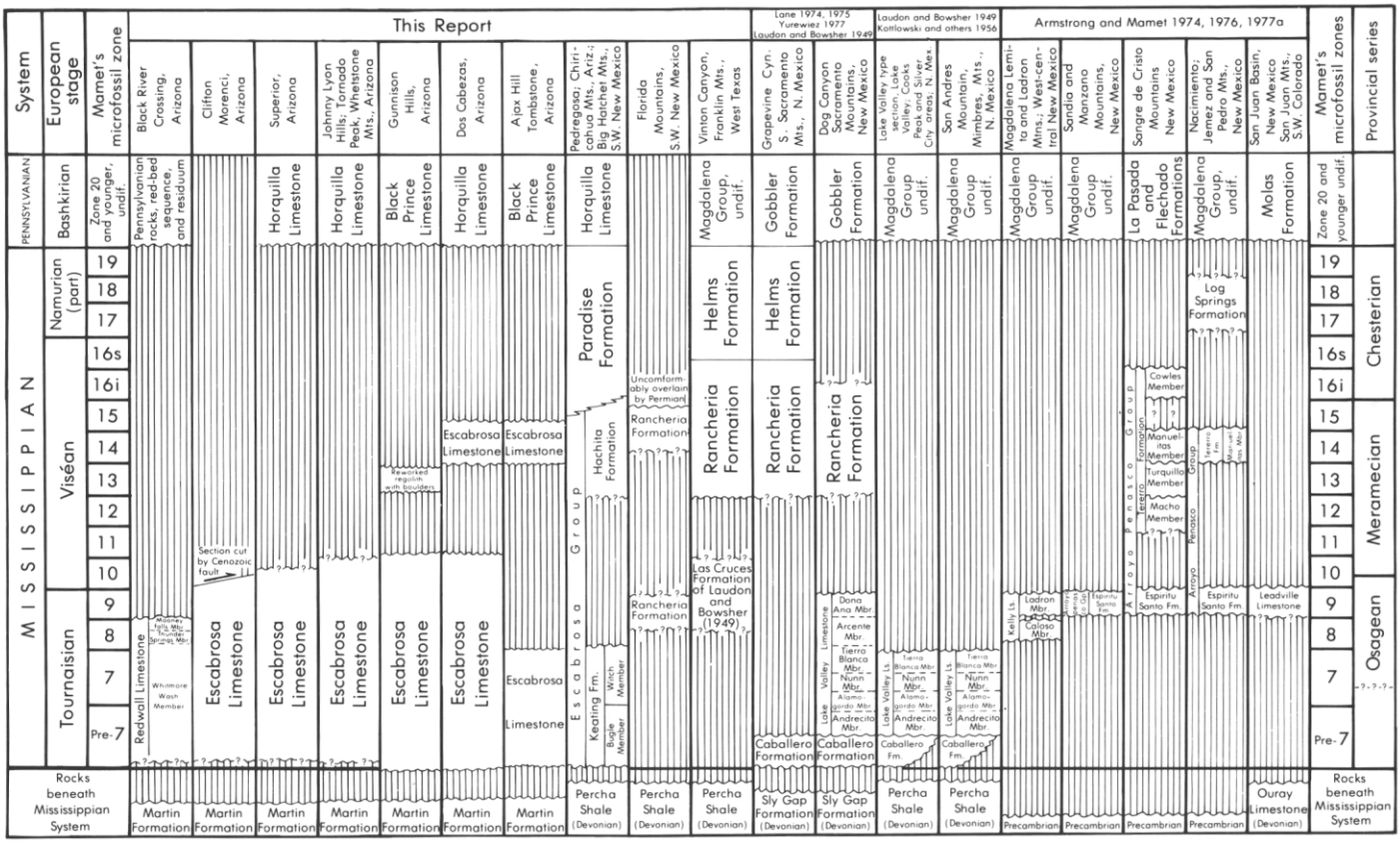


Figure 2. Correlation chart of Mississippian rocks of western New Mexico and southeastern Arizona.

central New Mexico and west-central and north-central Arizona during Namurian (Chesterian) time. Large areas were eroded on structurally active features, such as the Zuni-Defiance uplift, Pedernal uplift and Florida uplift, in Pennsylvanian and Permian time. In the Pedregosa basin and adjacent areas the isopach map may not show a correct representation of the original basin of Mississippian deposition. Purves' (1976) stratotectonic map of the Mississippian System of Arizona depicts a segmentation of the state into geologically unique, laterally offset blocks bounded by northeast- and northwest-trending faults. He describes the chronology of fracture systems and infers that they are related to possible spreading ridges and motion of the North American plate.

Marine encroachment began in early Tournaisian (pre-Zone 7) time in the Pedregosa basin and southern parts of the region, forming the Escabrosa carbonate platform (figs. 6-9). By the end of Tournaisian (Osagean) time, epicontinental seas covered northern and eastern Arizona and New Mexico. Two low islands may have existed, the Zuni highlands and remnants of the transcontinental arch, the Pedernal uplift (fig. 1). The Espiritu Santo Formation is composed of carbonate tidal deposits in the Sangre de Cristo, Sandia, Nacimiento and San Pedro mountains of north-central New Mexico (Armstrong, 1967; Armstrong and Mamet, 1977a; Vaughan and others, 1977). The Leadville Limestone is the time-stratigraphic, shallow-water equivalent in Colorado and the San Juan Basin of northwestern New Mexico and is an eastern extension of the lower part of the Redwall Limestone (Horseshoe Mesa Member) of Arizona (McKee and Gutschick, 1969). The end of Tournaisian (Osagean) time is marked by marine regression, regional uplift and extensive erosion of the Tournaisian (Osagean) carbonates (figs. 2-5).

The geographic and stratigraphic extent of this hiatus at the end of the Tournaisian (Osagean) is shown in Figures 2-5. A major regional marine transgression occurred in middle Visean (Meramedian) and is represented by the massive encrinites of the Hachita Formation in the southwestern part of New Mexico and the upper parts of Escabrosa Limestone of southwestern Arizona and the Horseshoe Mesa Member of the Redwall Limestone of northern Arizona (figs. 8, 9). The middle Visean in New Mexico is represented by the deeper water carbonates of the Rancheria Formation in the southern San Andres and Sacramento mountains and in north-central New Mexico by the shallow-water Turquillo Member (Meramedian) of the Tererro Formation. Late Visean carbonate rocks of Zone 16i (Chesterian) are also widely distributed in disjunct outcrops. These are the Cowles Member of the Tererro Formation, the upper part of the Rancheria Formation in New Mexico and west Texas, and the lower part of the Paradise Formation in the Pedregosa basin.

Marine sedimentation ceased in northern and central New Mexico at the end of Zone 16i time. In southwestern New Mexico and southeastern Arizona marine sedimentation continued through Zone 19. The Paradise Formation (figs. 2, 3-5) is a series of shallow-water lime mudstone-foraminifer-echinoderm-bryozoan-brachiopod molluscan wackestone to packstone and nearshore oolitic carbonates and plant-bearing cross-bedded sandstone and siltstone. The Helms Formation to the east appears to be a deeper water facies equivalent of the Paradise Formation (figs. 2, 3).

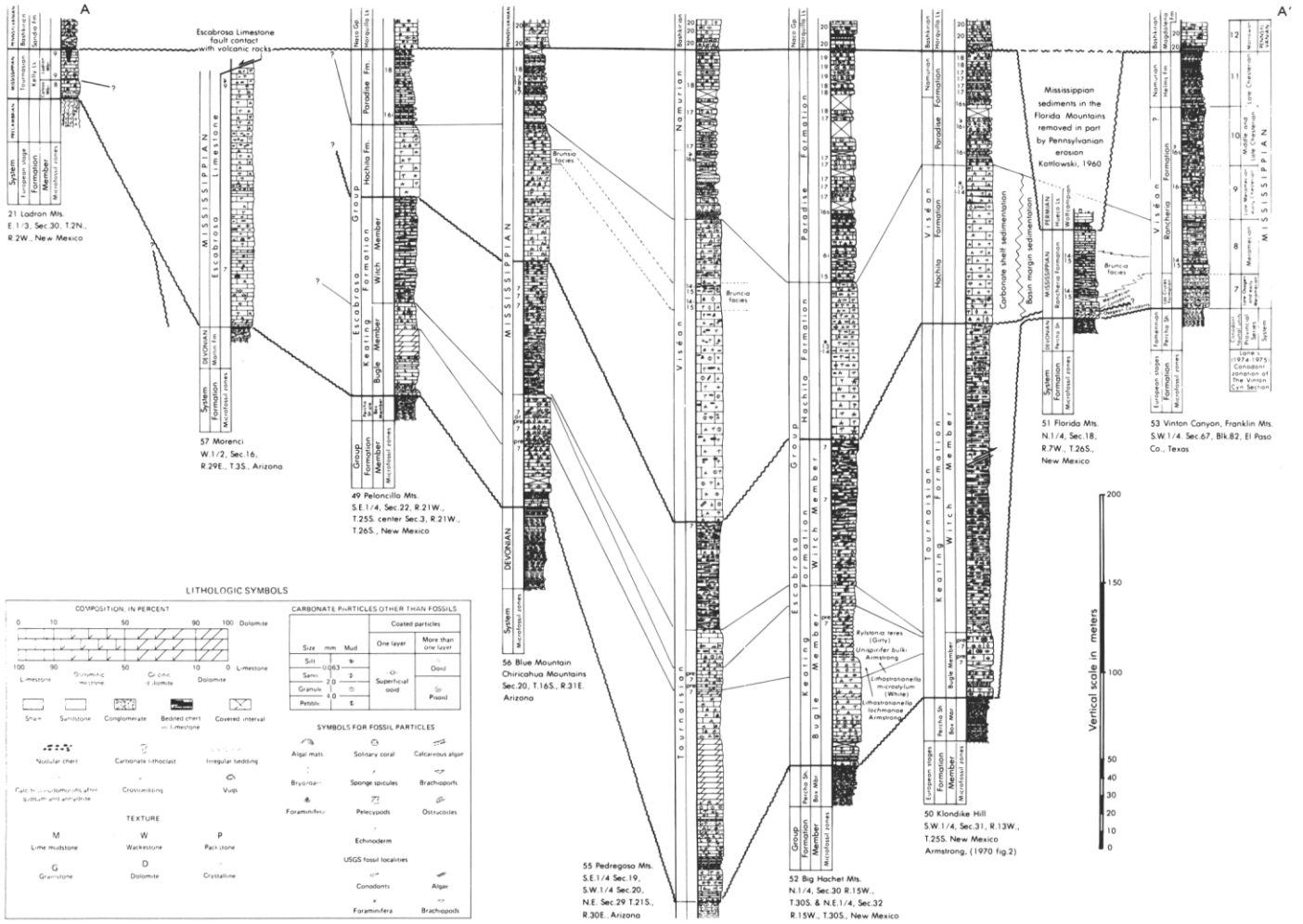


Figure 3. Regional biostratigraphic and lithologic correlation (A-A') for Mississippian starved-basin strata from Vinton Canyon, Franklin Mountains, west Texas, to the Florida Mountains, to the shelf carbonates of the Klondike Hills, and Big Hatchet Mountains, southwestern New Mexico, to the Pedregosa and Chiricahua mountains, southeastern Arizona, Peloncillo Mountains, New Mexico, Clifton, Arizona, and the Ladron Mountains, west-central New Mexico.

The fauna and lithology of the Mississippian carbonate rocks in the San Andres and Sacramento mountains of south-central New Mexico are well described. The first modern studies of the Mississippian of the Sacramento and San Andres mountains were by Laudon and Bowsher (1941, 1949) on the stratigraphy and megafaunas of the Mississippian Caballero and Lake Valley Formations and the Lake Valley Formation bioherms. They described the wedge-on-wedge relations of these Lower Mississippian strata to the Upper Mississippian Rancheria and Helms Formations. Pray (1958) gives a detailed petrographic and microfacies analysis of the Lake Valley Formation bioherms.

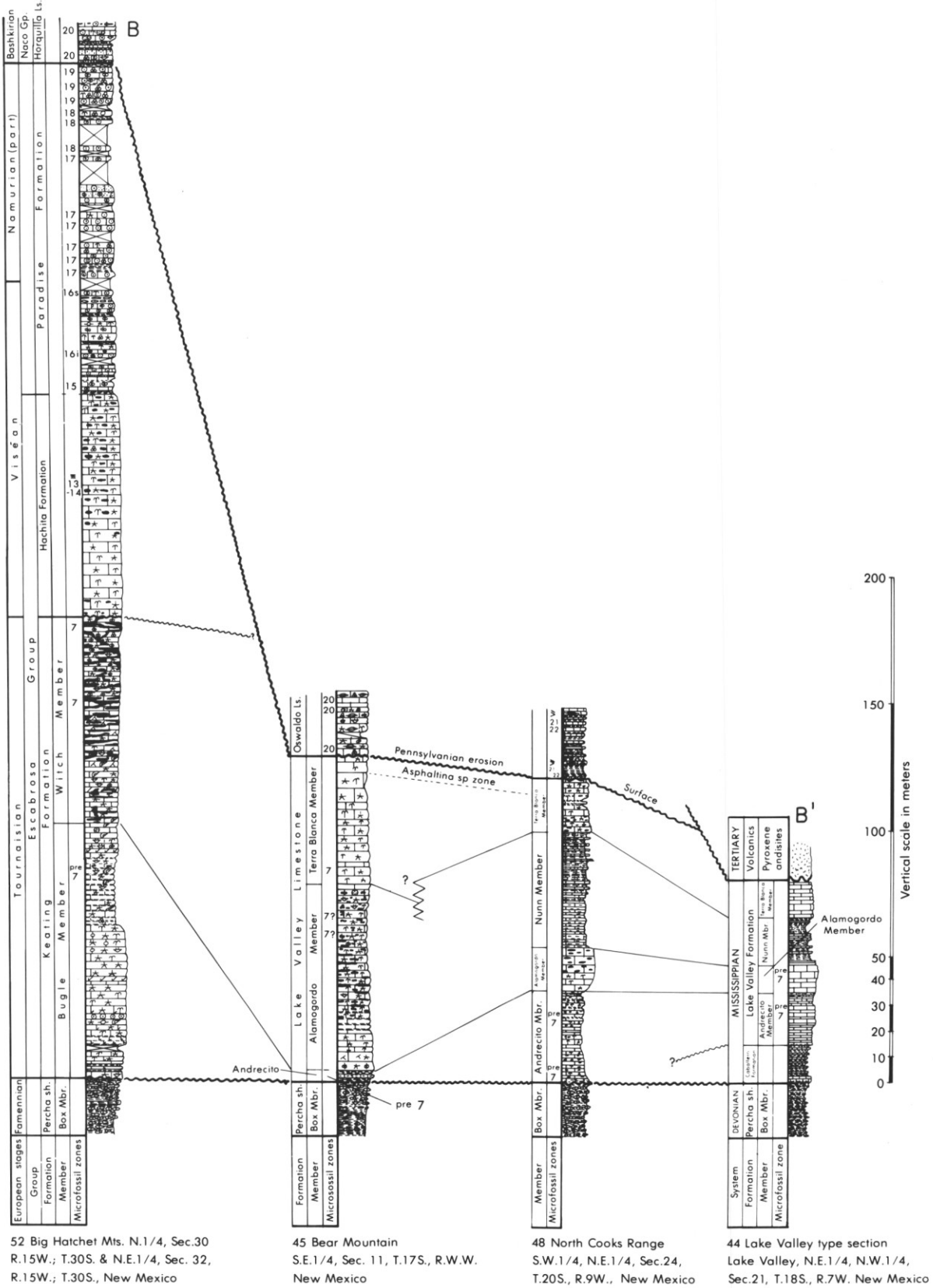
A detailed account of the complex nature of the stratigraphic and tectonic implications of the Late Mississippian Rancheria and Helms Formation to the Lower Mississippian shelf carbonates of the Lake Valley Limestone in south-central New Mexico and west Texas is given in Wilson (1969, 1971, 1975) and Kottlowski (1970).

Meyers' (1974, 1975) and Meyers and James' (1978) reports on the Mississippian sediments and diagenesis in the Sacramento Mountains are based on petrographic, stable isotope and cathodo-luminescence studies of the carbonate sedimen tary rocks, their cementation, and cherts. Meyers demonstrated that the non-ferroan calcite cement zones in the Lake Valley Limestone reflect ancient phreatic lenses established during pre-Visean (pre-Meramec) and pre-Bashkirian (pre-Morrowan) periods when meteoric waters cemented these rocks below unconformities.

Investigation of the basin margin sediments of the Visean and Namurian (Meramecian) Rancheria Formation in the Sacramento and Franklin Mountains by Yurewicz (1973, 1977) showed that the Rancheria Formation is younger than the Lake Valley Limestone and is separated from it by an unconformity.

Study of the conodont faunas of the Lake Valley, Rancheria and Helms Formations by Lane (1974, 1975, fig. 6) conclusively demonstrates that the Visean and Namurian Rancheria Formation of the Franklin Mountains of east Texas and the southern San Andres and Sacramento mountains of New Mexico has a wedge-on-wedge relation separated by an unconformity from the Tournaisian (Osagean) shelf carbonates and bioherms of the Lake Valley Limestone.

Conodont samples were collected with the foraminiferal samples from the Florida Mountains section of the Rancheria



52 Big Hatchet Mts. N.1/4, Sec.30 R.15W.; T.30S. & N.E.1/4, Sec. 32, R.15W.; T.30S., New Mexico

45 Bear Mountain S.E.1/4, Sec. 11, T.17S., R.W.W. New Mexico

48 North Cooks Range S.W.1/4, N.E.1/4, Sec.24, T.20S., R.9W., New Mexico

44 Lake Valley type section Lake Valley, N.E.1/4, N.W.1/4, Sec.21, T.18S., R.7W. New Mexico

Figure 4. Regional biostratigraphic and lithologic correlation (B-B') for Mississippian strata from the Big Hatchet Mountains, to Bear Mountain and the Mimbres Range, southwestern New Mexico.

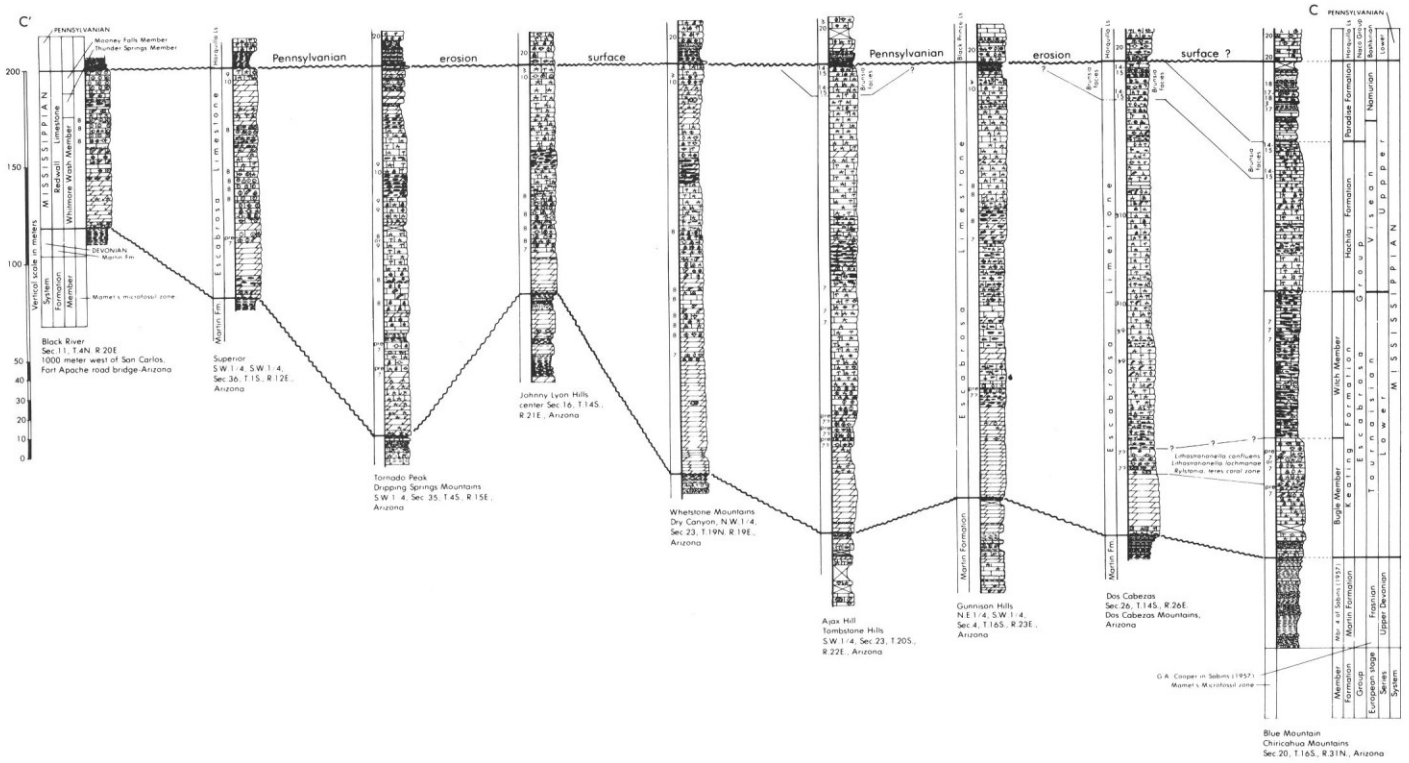


Figure 5. Regional biostratigraphic and lithologic correlation (C-C') for the Mississippian strata from Blue Mountain, Chiricahua Mountains, to the Dos Cabezas Mountains, Gunnison Hills; Ajax Hill, Tombstone Hills, Whetstone Mountains, Johnny Lyon Hills, Tornado Peak, Superior, and to the Redwall Limestone at Black River, Arizona.

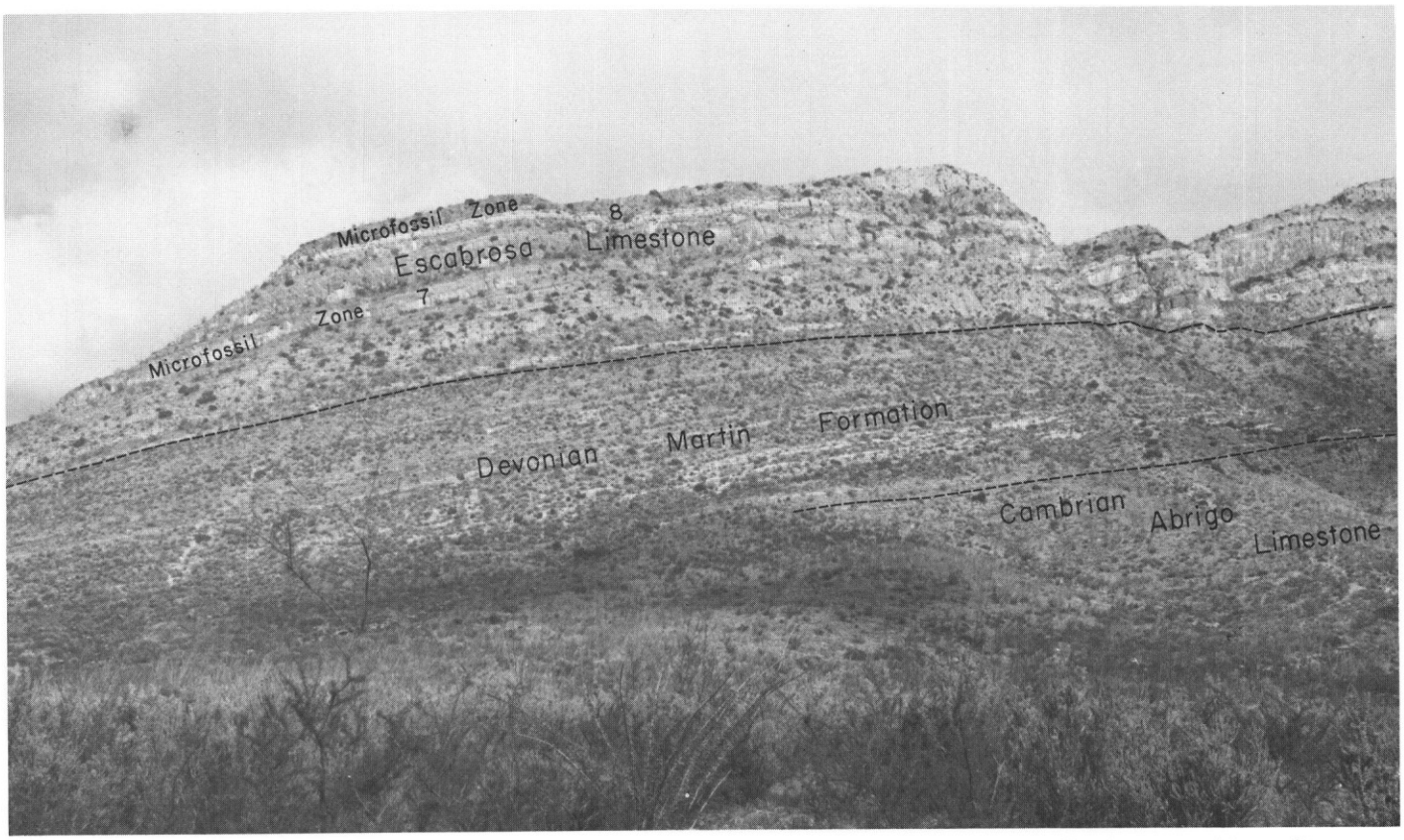


Figure 6. Southeastern side of the Whetstone Mountains, north side of Dry Canyon, showing the Cambrian Abrigo Limestone, Devonian Martin Formation, and the massive cliffs of the lower half of the Escabrosa Limestone.

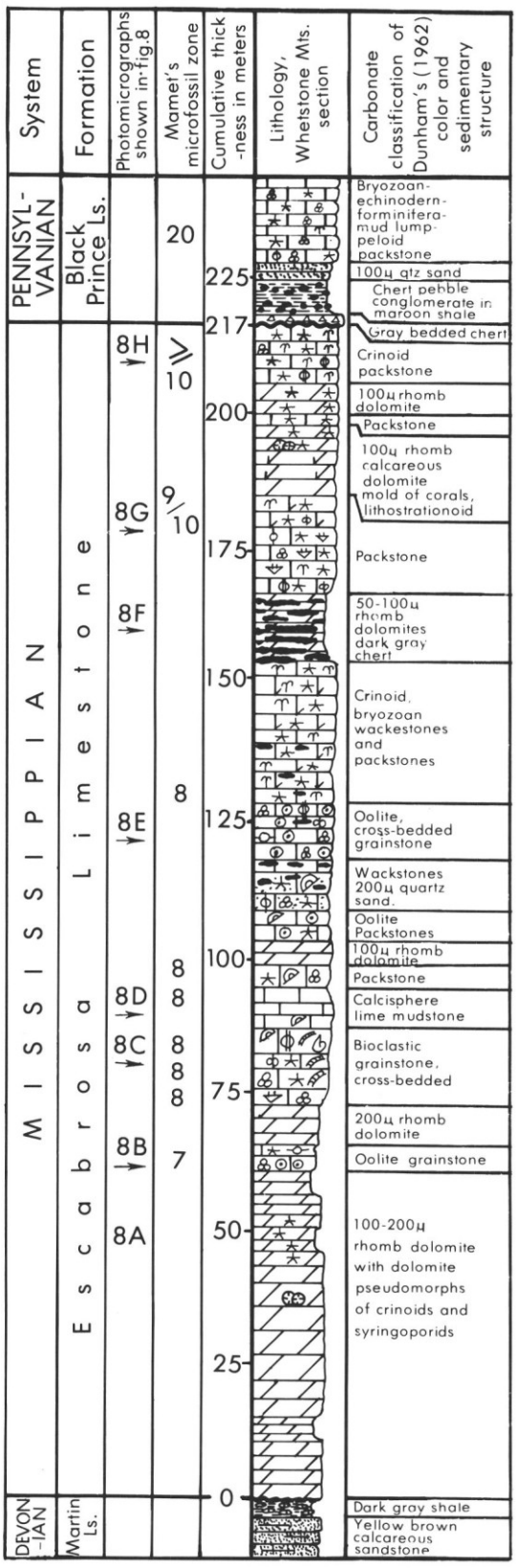


Figure 7. Detailed graphic representation of the carbonate stratigraphy of the Escabrosa Limestone section 71Z-1, 2; Dry Canyon, NW¼ sec. 23, T. 10 N., R. 19 E., Whetstone Mountains, Arizona (fig. 6).

Formation. Mamet found foraminifers of Zone 14/15 Meramecian *Brunsia* facies from 12 m above the base to the top of the section beneath Wolfcampian limestones. John Repetski (U.S.G.S., Washington, D.C., written commun., 1978) found Meramecian-age conodonts in the *Brunsia* facies. He reported that the following conodonts were recovered in a sample 1.5 m above the base of the Rancheria section:

"*Gnathodus* sp. (juvenile?)	1
Polygnathus communis Branson and Mehl	4
Spathognathodus cf. *S. cristulus* Youngquist and Miller	6
Spathognathodus sp.	1
ozarkodiniform element	1
neoprioniodiform (N) elements	3
synprioniodiniform (N) elements	2
hindeodelliform (A1) elements	11
ligonodiniform (A2) element	1
hibbardelliform (A3) elements	4

Age: Mississippian, probably Osagean."

Repetski stated:

> *Polygnathus communis* has a known range of the upper two-thirds of the Famennian (Upper Devonian) through the lower half of the Osagean. Burton (1964) . . . reported (p. 75) finding *P. communis* through the Rancheria Formation in the southern Sacramento Mountains of New Mexico, and he referred to the Rancheria Fm. to the Meramecian. However, on another page (p. 73) . . . [Burton] stated that the faunas from the Rancheria Fm. "are small and reworked and thus are of limited stratigraphic value." The specimens [from the Florida Mountains] in sample 72N-5+4 do not appear to have suffered reworking.

Repetski recovered the following conodonts from a sample 3 m above the base of the Rancheria Formation in the Florida Mountains:

"*Cavusgnathus* sp.	4
Gnathodus texanus Roundy	38
Gnathodus sp. (fragments)	3
Spathognathodus sp. (frag.)	1
ligonodiniform (A2) elements	10
lonchodiniform elements	7
neoprioniodiform (N) element	1"

Repetski reported the age to be Meramecian and said "*Cavusgnathus* first appears in the Meramecian and ranges into the Chesterian. *Gnathodus texanus* ranges from upper Osagean into the lower Chesterian."

"The *Cavusgnathus* specimens are broken, as are the specimens of *Gnathodus* sp. The latter have widely-expanded outer lobes, similar to *G. bilineatus* (Roundy). The *G. texanus* collection shows a wide range of variation in platform ornamentation."

The Visean and Namurian (Zones 14-19, Meramecian and Chesterian) Rancheria and Helms Formations of west Texas and the truncated Rancheria Formation outcrops in the Florida Mountains, New Mexico, also appear to have a wedge-on-wedge relation separated by a post-Zone 9-pre Zone 14 unconformity from the Tournaisian Keating Formation of southwestern New Mexico (fig. 5).

Location of outcrop sections used in this report can be found in the following publications:

1-20. Armstrong (1967); Armstrong and Mamet (1974); Baltz and Read (1960); Fitzsimmons and others (1956); the areas are the San Pedro, Nacimiento, Sangre de Cristo, Sandia, Manzano and Jemez mountains, New Mexico.

21-24. Armstrong (1958); Ladron, Magdalena, Lemitar mountains and Coyote Hills, New Mexico.

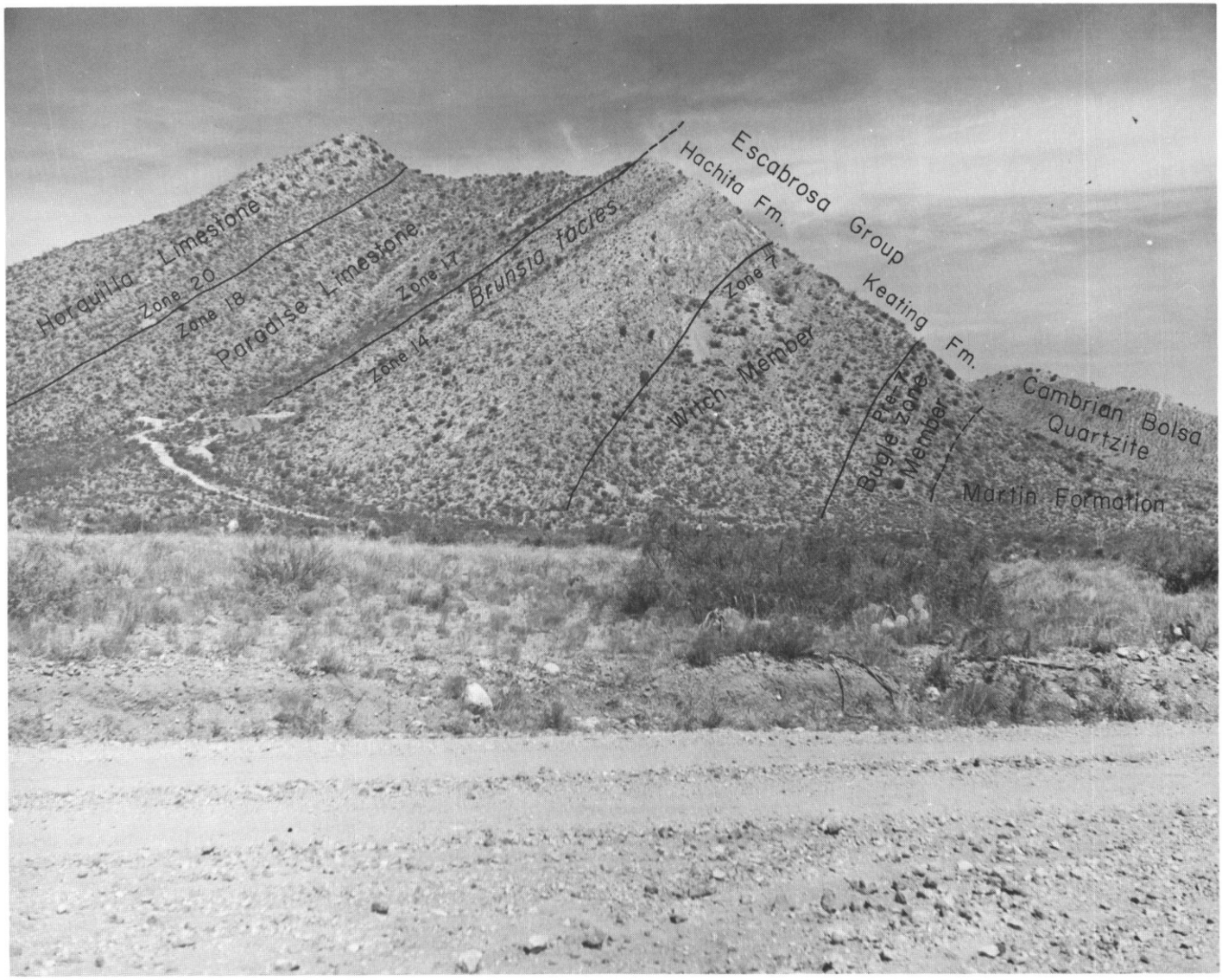


Figure 8. View from the south showing Blue Mountain and the Chiricahua Mountains. The topographic and sharp contact between the Bugle and Witch members of the Keating Formation and the Hachita and Keating formations of the Escabrosa Group and the Paradise Formation are easily seen. The bold cliffs of the Lower Pennsylvanian Horquilla Formation are seen at the crest of the ridge.

25-33. Laudon and Bowsher (1949), Kottlowski and others (1956), Kottlowski (1975); San Andres Mountains, New Mexico.

34-36. Laudon and Bowsher (1941, 1949), Pray (1958, 1961, 1965), Meyers (1973, 1974, 1975), Lane (1974, 1975), Yurewicz (1973, 1977); Sacramento Mountains, New Mexico.

37-38. Laudon and Bowsher (1949); Mimbres and Cooks ranges, Silver City area, New Mexico.

49-52. Armstrong (1952, 1970); Peloncillo, Big Hatchet and Florida mountains, Klondike Hills, New Mexico.

53, 54. Laudon and Bowsher (1949), Lane (1974, 1975); Vinton Canyon, Franklin Mountains, and Hueco mountains, west Texas.

55. Epis (1956); Pedregosa Mountains, Arizona.

56, 58. Sabins (1957); Chiricahua Mountains, Arizona.

57. Lindgren (1905); Clifton-Morenci district, Arizona.

59-61. Gilluly and others (1954).

62. Creasey (1967).

63-65. Huddle and Dobrovolny (1952), McKee and Gutschick (1969).

66-68. McClymonds (1959a, b).

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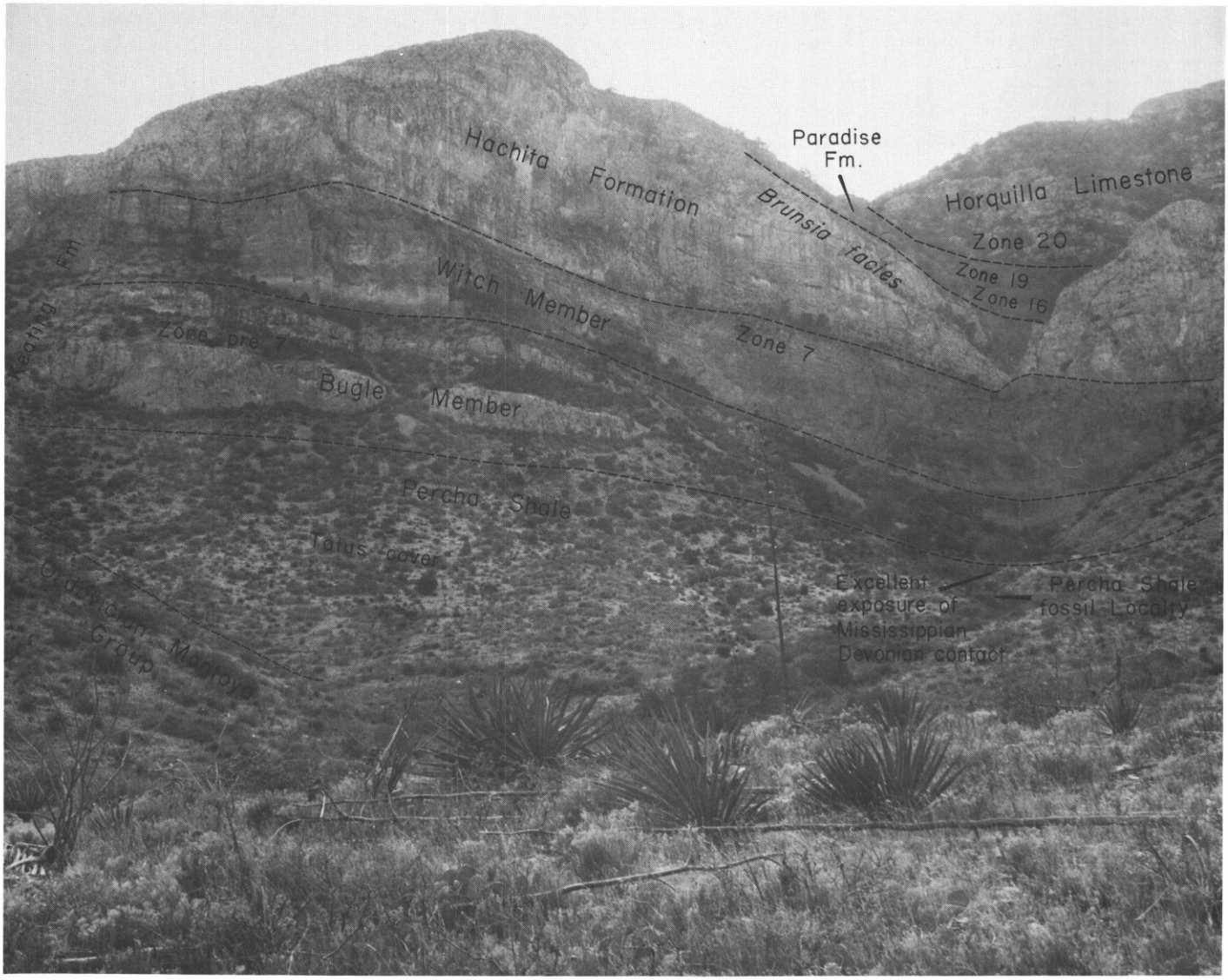


Figure 9. Northeast side of the Big Hatchet Mountains, showing the type section of the Bugle and Witch members of the Keating Formation and the contact between the Percha Shale, Keating, Hachita and Paradise formations. The Hachita and Keating formations form massive bold cliffs.

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