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1970, pp. 33-44. https://doi.org/10.56577/FFC-21.33

in:

Tyrone, Big Hatchet Mountain, Florida Mountains Region, Woodward, L. A.; [ed.], New Mexico Geological Society 21st Annual Fall Field Conference Guidebook, 176 p. https://doi.org/10.56577/FFC-21

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UPPER PALEOZOIC AND CRETACEOUS STRATIGRAPHY OF THE HIDALGO COUNTY AREA, NEW MEXICO

By

EUGENE GREENWOOD, FRANK E. KOTTLOWSKI, AND AUGUSTUS K. ARMSTRONG

The main upper Paleozoic units in southwesternmost New Mexico are thick to thin Pennsylvanian sequences making up most of the Horquilla Limestone, and the Permian upper Horquilla, Earp, Abo, Hueco, Colina, Epitaph, Scherrer, and Concha formations.

No Triassic or Jurassic rocks are known in Hidalgo County, but marine Jurassic strata crop our far to the southeast in Chihuahua. The major Cretaceous formations in the Hachita area are the Hell-to-Finish, U-Bar, Mojado, and Ringbone. Deposition of the Ringbone Formation appears to have extended into early Tertiary time. The Hidalgo volcanic sequence, unconformable on the Ringbone, is probably of early Tertiary age. In the Grant and Luna Counties area, Cretaceous units are the Sarten Sandstone, Beartooth orthoquartzite, Colorado Shale, some of the beds called the Lobo Formation, and thick unnamed units.

Descriptions of the Mississippian strata* are by Augustus K. Armstrong, U.S. Geological Survey, Menlo Park, of the Pennsylvanian and Permian beds are by Eugene Greenwood, Midland, and of the Mesozoic rocks by Frank E. Kottlowski, New Mexico Bureau of Mines and Mineral Resources.

MISSISSIPPIAN STRATA

This brief resume covers the Escabrosa Group and Paradise Formation of extreme southwestern New Mexico. For detailed information on the Mississippian strata of the region see Laudon and Bowsher (1949) and Armstrong (1958, 1962, and 1963). Formal systematic faunal studies and documentation of stratigraphic zonation used are in E. J. Zeller (1957), Armstrong (1958, 1962), and Hernon (1935). The classification of carbonate rocks used is Dunham's (1962).

ESCABROSA GROUP

The Escabrosa Limestone of Mississippian age was named by Girty (*in* Ransome, 1904) for the lower Carboniferous section in the Escabrosa Cliffs, west of Bisbee, Cochise County, southeastern Arizona. The Escabrosa Limestone in the Chiricahua Mountains of southeastern Arizona and southwestern New Mexico was elevated by Armstrong (1962, p. 5) to the Escabrosa Group and divided into two newly named formations: the Keating Formation with two members, A and B; and the overlying Hachita Formation (Fig. 1). This nomenclature was extended into Luna, Hidalgo, and Grant Counties, southwestern New Mexico. Within this region the Escabrosa Group is a thick sequence of shelf to miogeosynclinal bioclastic carbonates. The Escabrosa Group is separated from the underlying Upper Devonian rocks by a disconformity. This hiatus represents a small part of Late Devonian and a significant part of Early Mississippian (Kinderhook) time. The top of the Escabrosa Group is Late Mississippian (Meramec) in age and is defined as the first appearance of thin-bedded, argillaceous limestone and shale beds.

Paleontologic and field studies indicate no significant hiatus within the Escabrosa Group. The contact between the Escabrosa Group and the overlying Paradise Formation is gradational. The shale, silt, and shallow water, thin-bedded limestone of the Paradise Formation reflect development of the Chester-age highlands of central New Mexico and the resulting influx of terrigenous sediments into the Paradise sea (Armstrong, 1967). Extensive erosion in southwestern and central New Mexico in late Chester and Early Pennsylvanian time removed a considerable thickness of Mississippian strata and produced everywhere a pronounced unconformity between Mississippian and Pennylvanian strata.

KEATING FORMATION

The type section of the Keating Formation (Figs. 2, 3) was established by Armstrong (1962, p. 5) in sec. 20, T. 26 S., R. 30 E., on the southeast side of Blue Mountain, Chiricahua Mountains, Cochise County, southeastern Arizona. The name was derived from Keating Canyon, a few miles north of the type section. The thickest sections in New Mexico are in the Klondike Hills, where the formation is 700 feet thick, and on the north side of the Big Hatchet Mountains, where it is 590 feet thick. The Keating Formation thins to the north in the Peloncillo Mountains. It is readily divisible into two lithic members, A and B (in ascending order).

Member A contains a brachiopod and coral fauna (Fig. 4) of latest Kinderhook and early Osage age. It rests with a disconformity on marine shales and carbonates of the Late Devonian Percha Shale.

Carbonates of member A are the initial phase of a carbonate transgression over a weathered and peneplaned Devonian surface. The lowest beds contain appreciable amounts of calcareous shale, silt, and fine-sand-size quartz disseminated in the limestone. The higher beds of member A arc almost pure carbonate rocks composed of bryozoan, echinoderm, brachiopod, and coral lime wackestones and packstones with occasional lenticular bodies of oolite packstones.

* Publication of the Mississippian chapter is authorized by the Director of the U.S. Geological Survey.

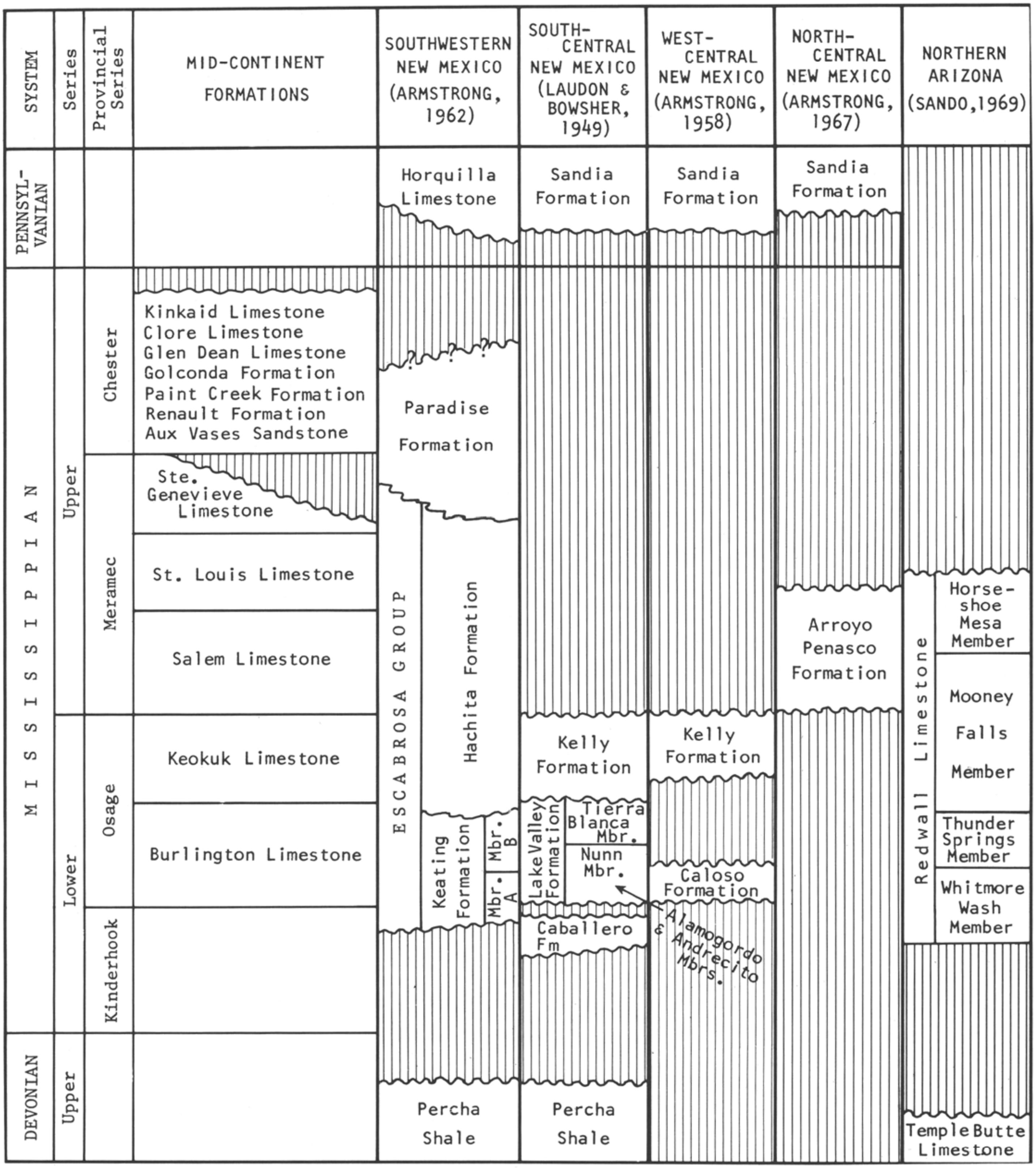


FIGURE 1.

Correlation chart of the Mississippian rocks of New Mexico west of the Rio Grande River.

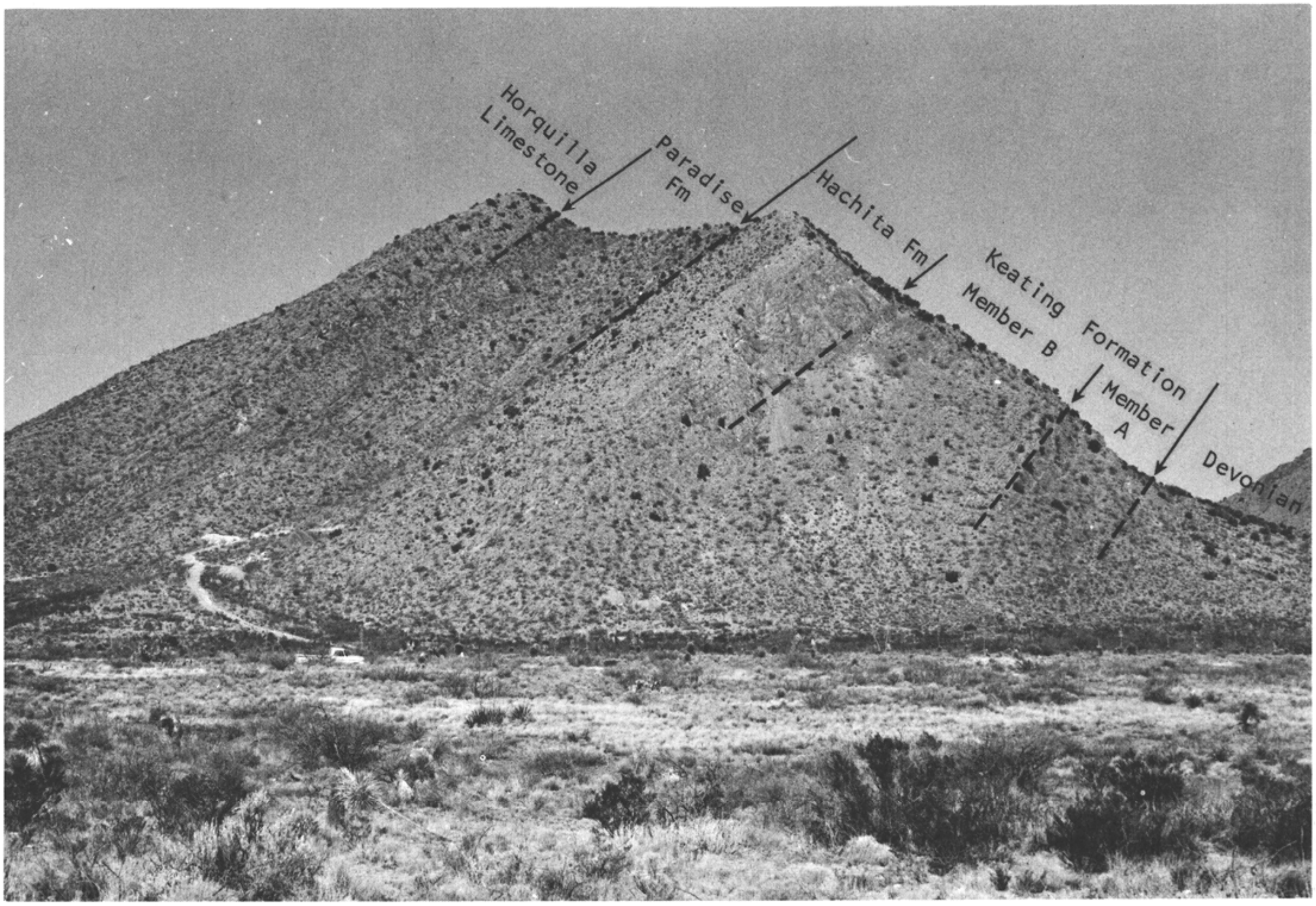


FIGURE 2.

South face of Blue Mountain, Chiricahua Mountains, Arizona. This is the type section (Armstrong, 1962) of the Keating and Hachita Formations of the Escabrosa Group.

The most characteristic features of member A are its massive bedding and chert-free carbonate rocks.

In contrast, member B is characterized by thin-bedded mudstone and wackestone to packstone with dark-gray to black lenticular chert. The chert bodies are generally parallel to the bedding but are commonly grown together in coalescing masses. Field observations and thin-section study indicate that the chert formed by diagenetic or post-diagenetic replacement of the original carbonate.

The gradational contact between members A and B is a zone 10 to 30 feet thick in which the bedding becomes thinner and the percentage of chert increases upward.

The lower beds of member B are soft pellet lime mudstone and pellet packstone; higher horizons contain progressively larger percentages of echinoderm bioclasts. The upper beds of member B generally are echinoderm packstone and grainstone.

HACHITA FORMATION

The type section of the Hachita Formation (Figs. 2, 3) was established by Armstrong (1962, p. 10) in S1/2 sec. 20, T. 26 S., R. 30 E., at the south end of Blue Mountain, Chiricahua Mountains. The Hachita Formation is lithologically and topographically the most characteristic part of the Escabrosa Group. The lower two-thirds of the Hachita Formation is almost devoid of bedding and is composed of crinoid fragments to the virtual exclusion of other organic remains. The upper third of the formation is darker gray, has persistent massive bedding, and is composed to a large extent of crinoid packstone, although it also contains appreciable amounts of brachiopod and bryozoan remains.

The thickest known section of the Hachita Formation, 380 feet, is at the northern end of the Big Hatchet Mountains. The formation thins to the north and west, apparently because of differential depositional rates.

PARADISE FORMATION

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. He described the Paradise Formation as 134 feet thick and composed of black and gray, moderately thick and thin-

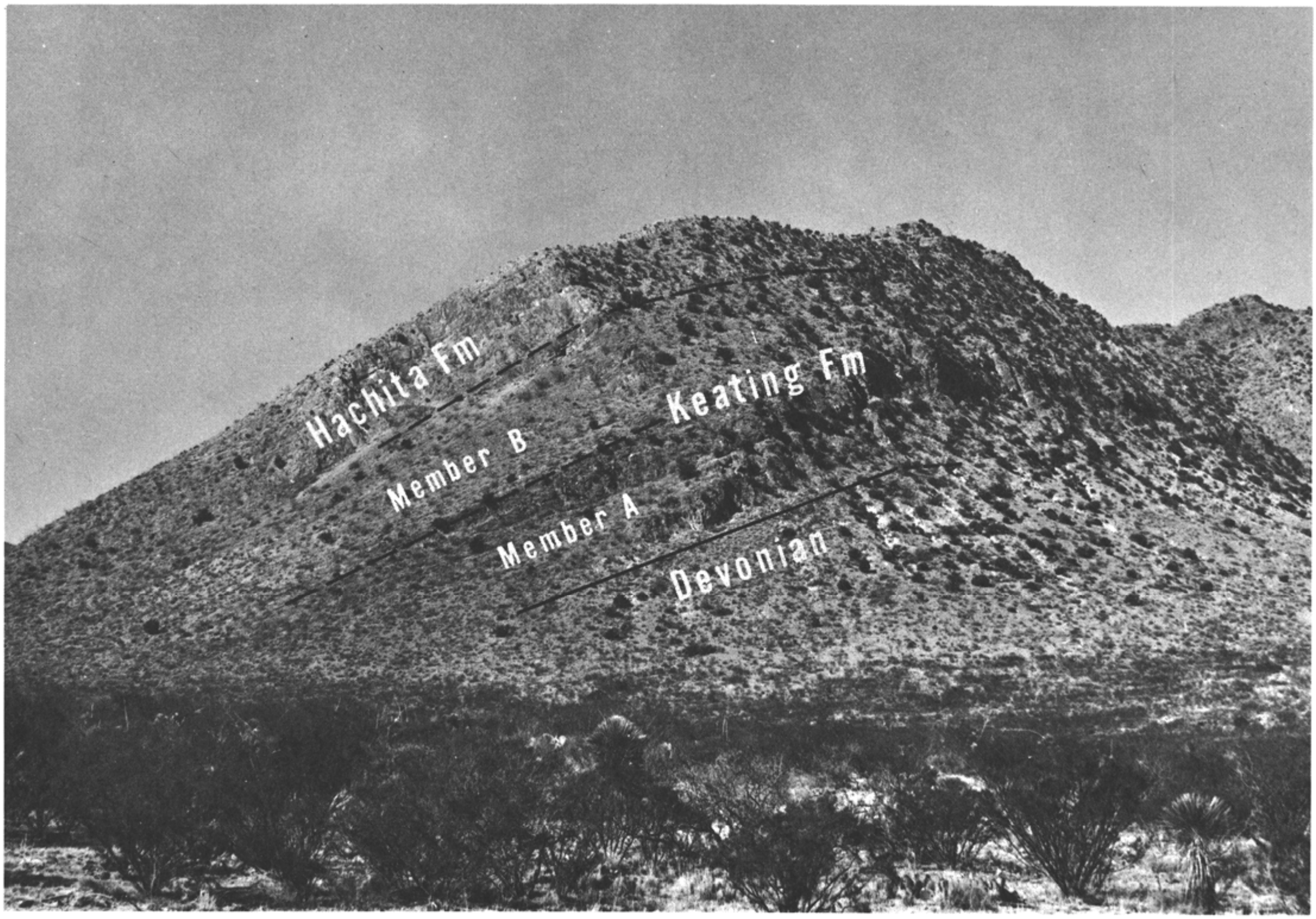


FIGURE 3.
Blue Mountain, Chiricahua Mountains, Arizona. View of east face, from road; location of type sections of Keating and Hachita Formations, Escabrosa Group. These are the same sections as shown in Figure 2, except photo is taken at a different angle.

bedded crystalline limestone, olive and yellow when weathered, alternating with sandstone, shale, oolite, crossbedded calcareous sandstone and arenaceous limestone." It is 250 to 300 feet thick in the Big Hatchet Mountains, 220 feet thick in the Klondike Hills, and less than 50 feet in the Peloncillo Mountains north of Granite Gap, New Mexico. It thins rapidly to the north and east as a result of Late Mississippian (late Chester) and Early Pennsylvanian erosion. Zeller (1965) gave a detailed description of the Paradise Formation outcrops in the Big Hatchet Mountains.

The fauna of the Paradise Formation in the Chiricahua Mountains was studied and described by Hernon (1935) . The microfossils and megafauna of the Paradise Formation of southwestern New Mexico have not as yet been adequately studied or described.

The thin-bedded carbonate rocks and terrigenous elastics of the Paradise Formation clearly indicate deposition in very shallow to shoaling waters. The younger beds were deposited under shallow marine to fluctuating nearshore con ditions. Within the Paradise Formation the overall trend was one of marine regression and increasing influence of a terrestrial elastic source area.

REGIONAL RELATIONSHIPS OF THE ESCABROSA CORAL FAUNA

Sando's (1969) study of the coral fauna of the Redwall Limestone clearly indicates that it is most closely related to faunas of the Madison Group and slightly younger faunas in the northern Cordilleras. In contrast, the faunas of the Escabrosa Group do not appear to have many points in common with faunas of the Redwall Limestone.

Sando (1969) indicated that "it has been known for some time that the Mississippian coral faunas of the Rocky Mountain region are not closely comparable to those found in essentially contemporaneous strata in the Mississippi Valley area. Bowsher's study (1961) showed a close correspondence between the Lower Mississippian coral faunas of central New Mexico and those of the type Mississippian.

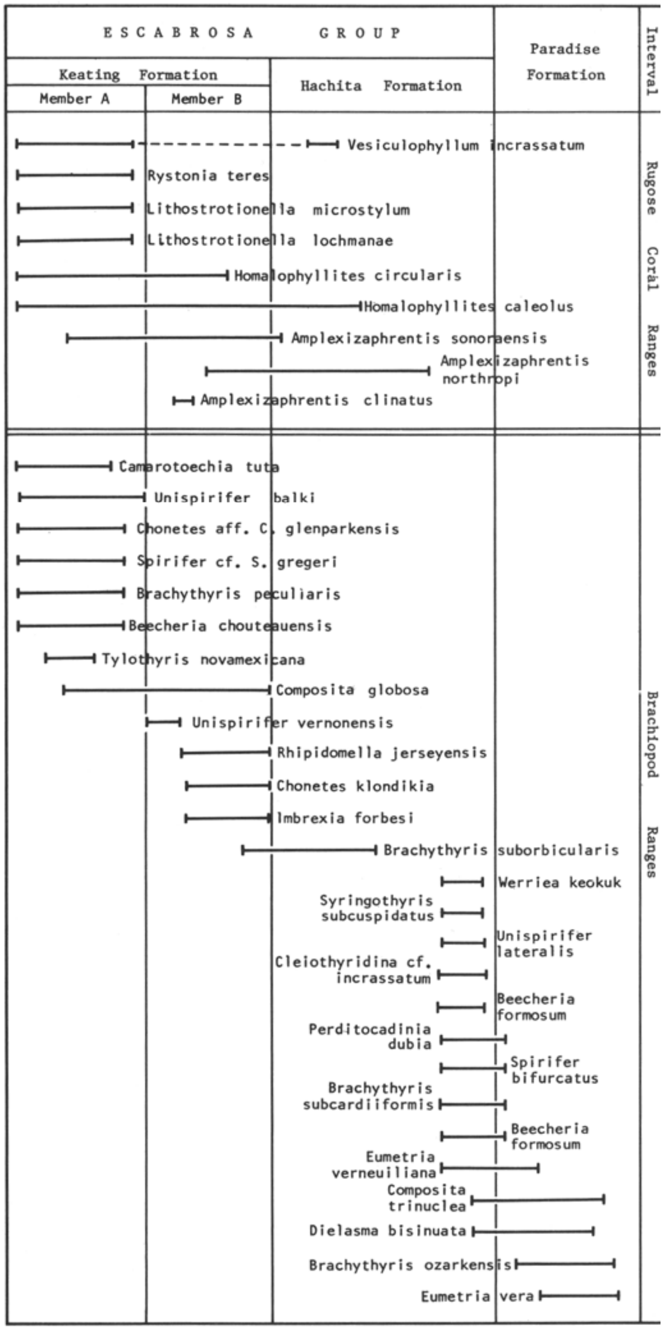


FIGURE 4.

Ranges of rugose corals and brachiopods within the Escabrosa Group of southestern New Mexico. Descriptions and illustrations of these fossils can be found in Armstrong (1962).

It seems reasonable to assume that a link between the Mississippi Valley faunas and the Cordilleran faunas might be established through the Escabrosa Group of southwestern New Mexico and southeastern Arizona and the Redwall Limestone of northern Arizona. Armstrong's study (1962) of the Escabrosa Group supported this possibility. However, the present study of the Redwall coral faunas indicates a closer similarity to the faunas of the northern Rocky Mountain region, suggesting that a tentative boundary separating Cordilleran and Mississippi Valley faunal provinces can be drawn between the areas of Redwall and Escabrosa deposition. Recognition of this faunal differentiation does not necessarily imply a lack of connection between the Cordilleran and Mississippi Valley seas. The two provinces have elements in common, suggesting that ecologic barriers may account for the observed differences."

PENNSYLVANIAN AND PERMIAN STRATA

Pennsylvanian and Permian strata are present in southwestern New Mexico, southeastern Arizona and in Sierras de Palomas, Sierra de los Chinos, Sierra de Sta. Rita, Sierra de Teras, Sierra Hatchita Hueco, and Sierra Huachinera in northern Chihuahua, Mexico. Detailed data on the strata are in Zeller (1965), Diaz and Navarro (1964), Bryant (1955), Kottlowski (1963), and Epis (1956).

Near the end of Mississippian deposition in the area, the area was exposed to weathering of the shallow-water limestones of Mississippian age before the Pennsylvanian orogeny began (Packard, 1955). Clastics were supplied from the Florida positive area to the east and Defiance-Zuni uplift to the north (Kottlowski, 1962). An erosional unconformity occurs in the Big Hatchet Mountains (Zeller, 1965) above the Paradise Formation which thins and thickens abruptly, changes facies rapidly, and contains thick, erratic lenses of terrestrial sandstone. The Permo-Pennsylvanian Horquilla beds are nearly identical throughout the region in contrast to the great variation of lithology in the Paradise. The unconformity is greater to the east of the Big Hatchet Mountains in Mexico, where several hundred feet of the Paradise Formation are cut out in a lateral distance of 2500 feet in the Sierra Boca Grande. Kottlowski and others (1956) recorded Pennsylvanian strata resting on Precambrian rocks in the northern San Andres Mountain. An unconformity is recognized in the Chiricahua Mountains by Sabins (1957), and in central Cochise County by Gilluly, Cooper, and Williams (1954); Nations (1963) documented that reworked Mississippian fossils were deposited in Pennsylvanian rocks.

Pennsylvanian rocks thin to the north, west, and east from the center of the Pedregosa basin (Kottlowski, 1962). Most of the Pennsylvanian strata in the Big Hatchet Mountains are shallow-water limestones with 1200-foot-thick reefs (Zeller, 1965) exposed at Big Hatchet Peak. This same shallow-water carbonate facies is found from the Tombstone Hills north of Douglas, Arizona to the Sierra Boca Grande to the east in Chihuahua. Throughout the lower half of the Horquilla, massive beds of crinoidal limestone are common. These crinoidal limestones are similar to those of the crinoidal reefs in the lower Mississippian but contain fusulinids of early Pennsylvanian age. Much of the lower Horquilla Limestone has a pink tint in central Cochise County, southern Hidalgo County, and northern Chihuahua. Fusulinids are profuse and in places form the main bulk of a limestone ledge. No quartz sand or dolomite and little shale occurs in Pennsylvanian sequences in the southern part of the area.

The upper half of the Horquilla Limestone changes rapidly from place to place with nonmarine elastics encroaching from the north, west, and east. In the Big Hatchet Mountains area, the outstanding characteristic is the massive limestone cliffs with thin shale partings and calcarenite stringers (Zeller, 1965). The limestones have been exposed to weathering as shown by excellent secondary porosity and partial dolomitization. This secondary porosity is the same enhancement observed in the better Pennsylvanian fields in West Texas. A wide range is recorded in producing characteristic in reef fields with the fields that exhibit erosion producing much greater quantities of oil. The massive cliffs in the Big Hatchet Mountains are called bioherms (Zeller, 1965) for the following reasons: (1) they are extremely massive and lack stratification, (2) thin beds may be traced into massive beds having no stratification, (3) massive beds are flanked by thin beds that dip into the basinal area to the southwest, (4) thin beds arch over the massive beds, and (5) massive limestones are composed of shell fragments held together by calcareous algae.

According to Zeller (1965), the relation of these massive reefs to the basinal deposits in the Humble No. 1 BA State well drilled southwest of the Big Hatchet Mountains suggests reefs formed along a basin margin. The maximum thickness of the shelf Horquilla Limestone of Pennsylvanian and Wolfcampian age is about 3600 feet and the basinal section cut in the Humble well is about 4600 feet thick.

The Horquilla Limestone as defined in central Cochise County by Gilluly, Cooper, and Williams (1954) is 1600 feet of pink, crinoidal limestone. Based on fossils, the upper part of the type Horquilla is of middle late Pennsylvanian age. Above the limestone to the west, north, and east are red beds of the Earp Formation. No unconformity, either erosional or angular is known between the two units and the lateral equivalency of part of the lower Earp to part of the upper Horquilla is accepted.

During deposition of the Horquilla Limestone, a shallow, clear sea in northern Chihuahua, southeastern Arizona, and southwestern New Mexico received thick limestone deposits around the edge of the Pedregosa basin, centering between the Big Hatchet Mountains on the east and the Pedregosa Mountains in Cochise County on the west. Clastics from distant highlands were deposited to the west, north, and east and gradually encroached upon the marine deposits during Wolfcampian time.

The Permo-Pennsylvanian contact is gradational in southwestern New Mexico, southeastern Arizona, and in northern Chihuahua. As in West Texas and the southern part of New Mexico no break in sedimentation is normally found. In the Big Hatchet Mountains at New Wells Peak, the contact between the Permian and Pennsylvanian, based on the presence of fusulinids, occurs within a fifty-foot limestone (Wendell Stewart, personal commun.). The most interesting note on stratigraphy during Wolfcampain time is the presence of thick shale beds in the Humble No. 1 BA State well that correlate with the lower Wolfcam pian limestone that forms the top of the Horquilla reef in the Big Hatchet Mountains (Zeller, 1965) .

No unconformity between the Horquilla and the Earp was identified by Zeller in the Big Hatchet Mountains although he noted the sharp changes in lithology between the Horquilla limestones and the red elastics and dolomitic limestone of the Earp and cited it as evidence for a local disconformity. Regional evidence which leads to the strong possibility that the area was exposed to broad uplift and some erosion as well as the possibility of overthrusting, similar to that documented during middle Wolfcampian time at the type locality of the Wolfcamp in the Glass Mountains (Ross, 1962), includes: in Arizona Earp red beds rest "conformably and gradationally" (Bryant, 1955) on Horquilla of Missourian age; near Bavispe, Chihuahua, about 100 kilometers south of the Arizona—New Mexico line, strata of Leonardian age rest on late Pennsylvanian strata (Pemex, personal commun.); and in the Franklin Mountains of Texas the upper part of the Panther Seep Formation is eroded (Wendell Stewart, personal commun.) .

Some additional evidence of this uplift and thrusting was documented by Zeller (1965). He noted that the lower part of the Earp Formation is commonly faulted against the upper part of the Horquilla Limestone by thrusting. This same orogeny caused some gentle folds in the area normal to the direction of force; i.e., east-west folds. John Skinner, in a letter to Zeller in 1954, said, "The highest fusulinids below . .. (the Earp Formation) are late Wolfcampian in age. The only ones above that we have seen are up in the Concha. They are probably middle Leonardian in age. Consequently, the red beds are either upper Wolfcampian or lower Leonardian, or both. I'm inclined to believe they are early Leonardian, but I can't prove it."

At the Earp Formation type section on Earp Hill in southeastern Arizona, Gilluly, Cooper, and Williams (1954) defined the base of the Earp as "where the thin shaly limestones and reddish shales become dominant over the more massive limestones of the Horquilla." At the type locality their geologic map shows the Earp in fault contact with the Horquilla. This interpretation adds strength to the suggestion of structural movement and erosion in mid Wolfcampian time preceding deposition of the Earp Formation. The thickest Earp occurs in the Chiricahua Mountains (2710 feet thick) and the Earp thins to the west and east. Zeller (1965) noted that the change of thickness was due in part to a difference in where the base was picked. An alternate hypothesis is that uplift and erosion in pre-Earp time left an irregular topographic surface that was covered by the Earp elastics.

Regionally, the Earp appears to correlate in part with the Supai and Abo Formations. Lithologically, they are similar and are deposited on progressively younger lower Permian to Pennsylvanian rocks in basinward directions.

The Colina basinal dark silty limestone occurs above the Earp Formation in isolated exposures in the Big Hatchet Mountains and contains no fossils (Zeller, 1965). No chert is present and the formation is plainly marked on the outcrop by its thin-bedded nature, occasional dolomite stringers, and marked color contrast with the red beds of the Earp. At the type locality in the Tombstone Hills, Arizona, Williams (in Gilluly, Cooper, and Williams, 1954), found the strata to be Wolfcampian and Leonardian in age. Sabins (1957) in the Chiricahua Mountains decided that most of the Colina was Leonardian in age.

There is an obvious analogy of the Colina to the dark silty limestones of the Bone Spring Formation of the Delaware basin of West Texas and southeast New Mexico. The Bone Spring is Leonardian in age and has similar relationship to the Abo red bed and the Abo shelf margin equivalent strata of southeastern New Mexico. If this analogy is correct, there is the possibility of shelf-margin carbonate build ups around the Pedregosa basin like those that circle the northwest side of the Delaware basin and produce oil at Empire Field in Eddy County, New Mexico.

The Epitaph Dolomite is a locally dolomitized upper part of the Colina-Epitaph sequence (Zeller, 1965) . Only where the Epitaph has been dolomitized can the two units be differentiated. In the type area in the Gunnison Hills of southeastern Arizona, Gilluly, Cooper, and Williams (1954), recognized the possibility that the lower Epitaph was a facies of the Colina Limestone. They also proposed that the upper part of the Epitaph Dolomite was a facies of the overlying Scherrer Formation. Sabins (1957) mapped the Chiricahua Mountains and found the Scherrer above the Colina Limestone with no Epitaph Dolomite. He agreed with the interpretation of Gilluly, Cooper, and Williams. Gillerman (1958) reported no Epitaph in the Peloncillo Mountains. Bryant (1959) agreed with Gilluly, Cooper, and Williams (1954) about the correlation of the Epitaph at the type section but assigned the lower 800 feet of the Scherrer in the Chiricahua Mountains to the Epitaph. Diaz and Navarro (1964) in northern Chihuahua indicated that the Colina and Epitaph represented continuous sedimentation and are distinguishable only where the Epitaph is dolomitic. Except for local areas, the Colina-Epitaph should be considered as a unit.

Of more interest to the working geologist, is the presence in the Big Hatchet Mountains of extensive dolomitization below the Scherrer Formation. This is an indication of exposure to processes of secondary dolomitization of the limestones (Adams and Rhodes, 1960) . Zeller noted the dolomitization of the Epitaph and drew the conclusion that it was related to the contact with the Scherrer. Anhydrite and gypsum found in the Epitaph of the Big Hatchet Mountain are similar to the lithologies exhibited in southeastern New Mexico in rocks of Permian age that indicate shallow lagoon-back reef environments. In the Mustang Mountains of southeastern Arizona, Zeller (1965) noted lens-shaped unstratified dolomite bioherms in the Epitaph and overlying Concha Limestone. Bryant (1955) noted 200 feet of gypsum in the upper Epitaph of the Whetstone Mountains. This close association of evaporite in the Whetstone Mountains and reefs in the Mustang Mountains suggested to Zeller (1965) that reefs would be found equivalent to those seen in the Mustang Mountains basinward of the evaporites of the Big Hatchet Mountains. Zeller (1965) also noted that the analogy between these rocks and those of the Permian basin of southeastern New Mexico and West Texas is striking and warrants further investigation, particularly by those interested in oil and gas exploration.

Regionally, Colina-Epitaph correlates with the Bone Spring-Yeso (Kottlowski and others, 1956) of southeastern New Mexico and in part with the upper Supai Formation of central Arizona. These correlations are based on the fact that the Yeso, Epitaph, and Supai are overlain by sandstones that are in turn overlain by a limestone that seem to correlate. The Supai, Colina, and Yeso also are deposited over a region-wide nonmarine red-bed sequence.

The Scherrer is the sandstone separating the Epitaph from the Concha Limestone in southwestern New Mexico. Only 50 feet thick in the Big Hatchet and Peloncillo Mountains, it thickens to 120 feet in the Chiricahua Mountains in Cochise County and 687 feet at the type locality in the Gunnison Hills. Sabins (1957) postulated a northwest source for the Scherrer sands. Regional correlation of the Concha Limestone and the San Andres Limestone helps correlate the Scherrer with the Glorieta Sandstone of north-central New Mexico. The Scherrer grades upward into the limestones of the Concha with no observed erosional unconformity.

The Concha Limestone was named by Gilluly, Cooper, and Williams (1954) in the Gunnison Hills of southeastern Arizona. Williams identified the fossils as Leonardian and possibly Guadalupian in age. It is the equivalent of the Chiricahua Limestone of Stoyanow (1926) . Stoyanow correlated the Chiricahua with part of the Kaibab Limestone of the Grand Canyon region. Sabins (1957) recommended that the Chiricahua be suppressed because "no type section was ever named or described. . . ." Cherty limestone with large chert nodules and silicified productid brachiopods characterize the lower Concha in southwestern New Mexico, southeastern Arizona, and northern Chihuahua. The upper half of the Concha is lighter in color and more dolomitized than the lower half but contains the chert nodules. A significant erosional unconformity occurs at the top of the Concha, with Lower Cretaceous rocks resting on the eroded Permian rocks. In places the upper Concha dolomite is absent and as much as 1000 feet of section is missing due to erosion.

Fusulinids from the Concha Limestone in the Big Hatchet Mountains were identified by Garner Wilde in 1954 as Leonardian in age. Sabins (1957) identified Leonardian and Guadalupian (?) fusulinids from the Concha Limestone in the Chiricahua Mountains, and Bryant (1959) reported early Guadalupian *Parafusulina* from the Concha in south-central Arizona. Fossils from the correlative San Andres Limestone in the San Andres Mountains are Leonardian near the base and Guadalupian in the upper limestone (John Skinner, personal commun.) . Only Leonardian fossils are reported in the Concha Limestone of northern Chihuahua (Diaz and Navarro, 1964; Zeller, 1965). If the fossil data are correctly interpreted, the Concha-San Andres facies may be inferred to be time transgressive, being of Leonardian and Guadalupian age in central New Mexico and central Arizona but only of Leonardian age in northern Chihuahua, southwesternmost New Mexico, and southeasternmost Arizona. However, Guadalupian rocks deposited in the Big Hatchet Mountains area as the uppermost (and now missing) part of the Concha Limestone probably have been removed by subsequent regional uplift and accompanying erosion.

MESOZOIC STRATA

No Triassic or Jurassic strata are known from Hidalgo, Luna, and Grant Counties, New Mexico, nor from eastern Cochise County, Arizona. Hayes, Simons, and Raup (1965) reported volcanic and associated sedimentary rocks of early Jurassic age (dated at about 173 m.y.) in southwest Cochise and southeast Santa Cruz Counties, Arizona, 75 miles west of the New Mexico-Arizona stateline. Jurassic sedimentary rocks occur far to the southeast in the eastern Chihuahua area; questionable Jurassic strata are reported south of Juarez in north-central Chihuahua.

To the north, the nearest Triassic rocks are east of Socorro, in the northern San Andres Mountains, and west of Sierra Blanca. The southern limit of these elastic red-bed Triassic rocks reflects some southward thinning but is mainly due to truncation beneath basal Cretaceous conglomerate and sandstone. Southwestern New Mexico appears to have been a low, broad, uplifted source of the early and middle Mesozoic elastic rocks deposited to the north in central New Mexico and central Arizona. Jurassic rocks to the north are abruptly cut off beneath the Cretaceous erosion surface along an east-west line about 160 miles north of Lordsburg.

The best exposed Cretaceous section of the area is in and near the Big Hatchet and Little Hatchet Mountains. In the Big Hatchet Mountains area, Zeller (1965) mapped three Early Cretaceous units, totaling about 10,000 feet in thickness. The lower unit, the Hell-to-Finish Formation, consists of conglomerate, red beds, and andesite flows; in the upper beds are some gypsum lenses and arenaceous limestones. The formation, about 1300 feet thick, is unconformable on underlying Permian units.

The middle unit is Zeller's (1965) U-Bar Formation, about 1,900 to 3,500 feet thick, composed of massive and thin-bedded fossiliferous limestone, with minor amounts of calcareous shale, gypsum, and sandstone. Bioclastic banks and coral-rudistid reef masses are common. The formation is divisible into five members, from base upward: brown limestone member, oyster limestone member, limestone-shale member, reef member, and suprareef member. Its rich fauna is Aptian to middle Albian in age, the Trinity and early Fredericksburg of the Gulf Series.

The upper unit, the Mojado Formation, is about 5,300 feet thick, and is mostly quartz sandstone with some shale and a few limestone interbeds near the base and near the top. Its fossils, mostly in upper beds, suggest a late Albian age, as does the late Fredericksburg and early and middle Washita of the west Texas region.

These three Early Cretaceous units have gradational contacts, with no apparent depositional break from the Hell-to-Finish, into the U-Bar, and up into the Mojado Formation. The uppermost beds are unconformably overlain by Tertiary fanglomerates in the Big Hatchet Mountains.

A few miles to the north in the Little Hatchet Mountains, Lasky (1947) defined an Early Cretaceous sequence that he believed was 15,300 to 21,000 feet in thickness. The fossils he collected indicated a Trinity age for the entire sequence, which from the base upward was listed as: (1) basal Broken Jug Limestone, 3,400 to 5,000 feet thick, of limestone and interbeds of sandstone, shale, and limestone conglomerate; (2) Ringbone Shale, 0 to 650 feet thick, fresh-water shale and sandstone with local basal conglomerate and upper basalt and andesite; (3) Hidalgo Formation, 0 to 5,000 feet thick, andesite and basalt flows and pyroclastic rocks; (4) Howells Ridge Formation, 1,100 to 5,200 feet thick, of lower red shale, mudstone, limestone, sandstone, and conglomerate, middle andesite, and upper massive reefoid limestone; (5) Corbett Sandstone, 1,500 to 4,000 feet thick; (6) Playas Peak Formation, 800 to 3,000 feet thick, local basal conglomerate overlain by fresh-water shale and sandstone and upper massive reefoid limestone; and (7) upper Skunk Ranch Conglomerate, 0 to 3,400 feet thick, red conglomerate and red shale with local augite basalt flows.

Zeller remapped the Little Hatchet Mountains and uncovered evidence of numerous thrust faults which considerably revised the stratigraphic sequence. His brief report, geologic map, and cross sections are published as Geologic Map No. 23 by the New Mexico Bureau of Mines and Mineral Resources.

The oldest sedimentary rocks Zeller found in the Little Hatchet Mountains contain fusulinids. He mapped them as the Horquilla Limestone and Earp Formation. Lasky (1947) had mapped these outcrops, near Granite Pass in the southern part of the range, as the Playas Peak Formation.

At the base of the Cretaceous sequence is a thin-bedded unit of marine limestone, dolomite, gypsum, and shale, about 1,500 feet thick. The unit appears to grade up into typical Hell-to-Finish Formation strata, thus it should be of Early Cretaceous age. Some of its beds are lithologically similar to Permian strata. Far to the southeast in Mexico, gypsum also occurs in Jurassic sequences.

Lasky (1947) mapped this unit as the basal part of his Broken Jug Limestone.

The beds mapped as the upper Broken Jug Limestone and lower Howells Ridge Formation by Lasky (1947) are of typical Hell-to-Finish Formation lithology; these include the only conspicuous post-Permian red beds in the area. The formation is a maximum of 6,000 feet thick. It correlates with the Glance Conglomerate and Morita Formation of southeast Arizona.

Most of the outcrops mapped by Lasky (1947) as the upper part of the Howells Ridge Formation are U-Bar Formation lithologies. The massive reef limestone of the U-Bar provided the basal resistant plate of most of the thrust sheets in the Little Hatchet Mountains. The formation is about 4,000 feet thick locally, and correlates with the Lowell and Mural formations of southeast Arizona.

Zeller's Mojado Formation, mostly quartz sandstone with shale interbeds, is essentially Lasky's (1947) Corbett Sandstone although locally some outcrops mapped as Broken Jug Limestone should be referred to the Mojado Formation.

Some lenses of the Mojado are limestone-boulder conglomerate; the maximum thickness in the Little Hatchet Mountains is about 5,000 feet. The formation correlates with the Cintura Formation of southeast Arizona, the Johnny Bull Sandstone of the Peloncillo Mountains (Gillerman, 1958), and the Sarten Sandstone of the Cooks Range. It is overlain unconformably by the Ringbone Formation, the Hidalgo Formation, or by younger Tertiary rocks. Fossils indicate a late Early Cretaceous age.

Lasky's (1947) Skunk Ranch Conglomerate, Playas Peak Formation, Ringbone Shale, and locally part of his Howells Ridge Formation were mapped as the Ringbone Formation by Zeller. Its continental elastic beds vary greatly in composition from place to place. Basal beds are mostly limestone-cobble conglomerates with clasts mainly of Paleozoic limestones. The lower two-thirds is black to gray shale, with thin interbeds of arkose, and much fossil wood. Upper strata are basalt and andesite flows, black shale, limestone and chert conglomerate, and some arkose.

The Hidalgo volcanic rocks or younger Tertiary strata are angularly unconformable on the Ringbone Fonnation, thus there is a large range in thickness. The maximum thickness noted by Zeller was 7,500 feet. Plant fossils date the Ringbone Formation as Late Cretaceous and Paleocene or Eocene in age.

Unconformable on the Ringbone Formation and locally on the Early Cretaceous units down to U-Bar limestones, is the Hidalgo Formation. Its upper contact in all areas of the Little Hatchet Mountain is an overthrust fault, thus the formation's original thickness is unknown. Maximum exposed thickness is 5,500 feet.

Lasky (1947) believed the Hidalgo Formation was overlain by the Howells Ridge Formation, but that contact is a thrust-fault plane. Thus, instead of the Hidalgo volcanics being one of the older, Early Cretaceous units, it is actually the youngest major unit in the Little Hatchet Mountains and is probably of Tertiary age.

The Hidalgo Formation consists mostly of dark purplish-gray andesite flows and brcccias. Locally, basal lenses of limestone-and-sandstone-cobble conglomerates occur; these also contain some clasts of basalt porphyry derived from the Ringbone Formation. In the upper part of the formation are interbeds of andesitic sandstone and shale. Fossil plants from these sedimentary beds appear to be of early Tertiary age.

Unconformable on all of the older rocks in the Little Hatchet Mountains are rhyolitic-latitic volcanic rocks, with some lenses of tuffaceous sandstone and bentonitic clay, similar to the Oligocene volcanic units that occur in many parts of southwest New Mexico.

The andesites of the Hell-to-Finish Formation are of Early Cretaceous age, the basalts and andesites of the Ringbone Formation are of Late Cretaceous and early Tertiary age, and the Hidalgo andesites of probable early Tertiary age. All of these units have been intruded by masses of diorite, monzonite, and quartz monzonite of "Laramide" age, as well as by younger granite (dated about 45 m.y.) and rhyolite.

Red beds equivalent to the Hell-to-Finish Formation crop out in the Animas Mountains, Apache Hills, and to the southeast in northwest Chihuahua, in Sierra de Palomas. U-Bar Formation correlatives occur in Sierra Rica, Animas Mountains, and as the Carbonate Hill Limestone of the Peloncillo Mountains (Gillerman, 1958). Mojado Formation outcrops are known in Sierra Rica, Animas Mountains, Apache Hills, Coyote Hills, and Brockman Hills. The Johnny Bull Sandstone of the Peloncillo Mountains (Gillerman, 1958), the Sarten Sandstone of the Cooks Peak area (Jicha, 1954), and the arenaceous units of the Washita faunal zone near El Paso on Cerro de Muleros are Mojado Formation equivalents.

In the Chiricahua Mountains of southeast Arizona, Sabins (1957) mapped basal Early Cretaceous beds as the Glance Conglomerate and overlying reddish siltstones, which appear to be equivalents of the Hell-to-Finish Formation. Above is a limestone sequence, similar to the U-Bar limestones, and the upper part of Sabins' Bisbee Group consists of sandstone and siltstone much like the Mojado Formation.

In the Cedar Mountains of southwesternmost Luna County, and in the Victorio Mountains west of Deming, interbedded conglomerate, siltstone, sandstone, and fossiliferous limestone are angularly unconformable on Paleozoic strata, are 600 to 80U feet thick, and may represent shoreline equivalents to the entire Hell-to-Finish, U-Bar, and Mojado sequence. The unit is overlain by andesitic breccia, tuff, and sandstone that appear to be less altered than the Hidalgo Formation volcanic rocks, and are probably of middle Tertiary age.

In the Santa Rita-Silver City area, the basal Cretaceous sandstone is the Beartooth Quartzite (orthoquartzite); it is similar in lithology and position to the Sarten Sandstone of the Cooks Peak area, and may be of Early Cretaceous age, an equivalent of the Mojado sandstones. Above the Beartooth is the Colorado Shale, which near Santa. Rita includes three units, a lower 200-foot-thick dark carbonaceous shale with thin interbeds of sandstone and fossiliferous arenaceous limestone, a middle 520-foot-thick, light-gray, calcareous, fossiliferous sandstone, and an upper 220-foot-thick unit of interbedded green shale, arenaceous shale, and sandstone. These strata contain Benton-age faunas, equivalent to the lower part of the Mancos Shale, and may correlate with some of the lower beds of the Ringbone Formation.

Near Santa Rita, unconformable on the Colorado Shale, are several hundred feet of andesitic breccia, tuff, and volcanic sandstone and shale. This sequence is somewhat similar to the Hidalgo Formation facies, and is intruded by the mineralized granodiorite-quartz monzonite stocks of the Chino copper-mine area. This mineralization is dated at about 63 m.y.

In the Steeple Rock district, about 40 miles north-northwest of Lordsburg, Elston (1960) mapped 60 feet of the Beartooth sandstones overlying Precambrian granite and conformably overlain by 800 feet of the Colorado "Shale" unit. At one locality, the Colorado Shale is overlain unconformably by the Virden Formation, but in nearby areas a thick sequence of andesite, dacite, and rhyolite unconformably underlies the Virden Formation, and presumably overlies the Colorado Shale in the subsurface.

The Virden Formation is a maximum of 4,000 feet in thickness and consists of fanglomerate, tuffaceous sandstone, and shale. It contains boulders of the underlying volcanic rocks and plant fossils that were tentatively identified as Late Cretaceous in age (Elston, 1960). Recent radioisotopic dating of the dacite beneath the Virden Formation, however, yielded a date of 34.7 m.y., which suggests the volcanic sequence is of Oligocene age, similar to the Datil Formation, and that the Virden Formation is a local fanglomerate unit of even younger age.

Thus in the Hidalgo County region of southwesternmost New Mexico and adjoining areas, there appear to be minor andesitic units of Early Cretaceous age; several centers of Late Cretaccous-early Tertiary volcanism from which were erupted thick, local sequences of andesitic-basaltic materials; local areas of thick, early Tertiary andesitic eruptions; and the widespread, thick Oligocene eruptives, beginning with andesite, and followed by latite and rhyolite masses.

The Cretaceous sedimentary rocks along the northern border of the region, in central Grant County and northern Luna County, consist of a basal arenaceous, conglomeratic facies, probably mostly of Early Cretaceous age, the Beartooth and Sarten sandstones, overlain by Late Cretaceous black shale, sandstone, and calcareous elastics.

In central and southern Hidalgo County, southern Luna County, and southern Cochise County, the tripartite sequence of the Big Hatchet Mountains (lower Hell-to-Finish red beds and conglomerate, middle U-Bar limestone, and upper Mojado sandstone) and of the Bisbee area (lower Glance Conglomerate and Morita red beds, middle Lowell and Mural limestones, and upper Cintura shale and sandstone) represent the Early Cretaceous sequence. Where Late Cretaceous strata are preserved, they are units like the Ringbone Formation and Hidalgo volcanics. In southeast Cochise County, in both the Pedregosa (Epis, 1956) and Chiricahua (Sabins, 1957) Mountains, units similar to the Ringbone and Hidalgo strata are unconformable on the Early Cretaceous Bisbee Group.

To the south and southeast in northwestern Chihuahua, Early Cretaceous strata crop out in many of the mountain ranges, and consist of a tripartite sequence, the lower Las Vegas Formation of sandstone and shale, the middle and prominent Cuchillo limestone, and upper units assigned to the Chihuahua Group, a sequence of limestone and calcareous shale. From the Santa Rita area southward to the Big Hatchet Mountains, and then southward into Mexico, the Early Cretaceous sequence generally thickens and contains more marine strata.

East of Hidalgo County, the identity of some Cretaceous beds is involved in the problem of the Lobo Formation. The type Lobo (Darton, 1917) in the Florida Mountains of central Luna County is an enigma, but lithologically it resembles the Early Cretaceous strata of the Victorio, Cedar, and Tres Hermanas Mountains, except the type Lobo has only a few carbonate-rock beds. In the Florida Mountains, above local lenses of nodular impure limestone, the Lobo Formation consists of interbedded gray to pinkish-gray calcareous siltstone and very silty limestone, pale-red, gray, and purplish-gray shale, and yellowish-brown to light-gray calcareous conglomeratic sandstone and con glomerate. This Lobo unit is in various places unconformable on the Permian Hueco Formation, Ordovician Montoya Dolomite, and Precambrian rocks in the northern and southeast Florida Mountains. It is overlain by Tertiary (?) andesites and associated sedimentary rocks, similar to the volcanic sequence that is above the Lobo of the Victorio Mountains.

North of the Florida Mountains in Cooks Range, an erosionally thinned Pennsylvanian sequence is overlain by red beds called the Lobo by Darton, but these strata are the Permian Abo Formation. Above the Abo, which is of variable thickness owing to differential post-Permian erosion, is the Early Cretaceous Sarten Sandstone, which appears to grade upward into the Late Cretaceous Colorado Shale. Unconformably above the Colorado Shale is the Macho andesite, tuff, and associated sedimentary rocks, which are considered to be of Tertiary age.

South of the Florida Mountains, in the Tres Hermanas Mountains, the lower 375 feet of Early Cretaceous beds are chert conglomerate, arkosic sandstone, pale-red siltstone, and gray siliceous limestone. This is overlain by 395 feet of massive limestone, which is beneath 425 feet of chert-limestone cobble conglomerate with interbeds of red, arkosic sandstone and gray, calcareous sandstone. The exposed upper 340 feet is sparsely fossiliferous, gray limestone. Both the upper and lower contacts of this Cretaceous section are faults; however, the Permian Hueco Formation does crop out in the Tres Hermanas Mountains, thus the Cretaceous probably overlies the Permian in the subsurface.

Thick limestone sequences of Early Cretaceous rocks crop out in the East Potrillo Mountains and in several places in and near the West Potrillo Mountains of southwest Dona Ana County and southeast Luna County. Parts of these sequences are similar to the Tres Hermanas Mountains section. To the northeast of the Florida Mountains in northwest and central Dona Ana County, the Cretaceous is absent in most areas, with Tertiary conglomerates and volcanic rocks unconformable on Wolfcampian strata. In the southeast Sierra de las Uvas area, however, huge blocks of Cretaceous limestone occur in the lower part of the basal volcanic sequence, and suggest that Early Cretaceous marine beds were deposited at least as far north as T. 21 S.

The positive area in southwest New Mexico that was eroded to provide the detritus of the Cretaceous sequences has been called the Burro uplift. It appears to have been a west-northwest-trending area with its highest parts in the Burro Mountains area of southwest Grant County, where the Beartooth sandstone and conglomerate rests on Precambrian rocks. Southward to the Victorio Mountains, the erosional unconformity below the Cretaceous rests on younger rocks, the Lower Ordovician El Paso Limestone northwest of the Victorios, and the Upper Ordovician Montoya Dolomite through Silurian Fusselman Dolomite in the Victorio Mountains. About 15 miles south of the Victorios in the Cedar Mountains, Cretaceous conglomerates overlie Mississippian and Pennsylvanian strata.

The southern edge of this uplifted area is of critical importance to the finding of oil and gas in southwestern New Mexico. An almost complete Permian section is preserved beneath the Cretaceous in the Big Hatchet Mountains and in the central Peloncillo Mountains. Blocks of late Pennsylvanian limestone occur with rounded boulders of Precambrian granite in lower andesites, believed by Flcge (1959) to be of early Tertiary age, in the Pyramid Mountains. Fusulinid-bearing Horquilla limestones crop out on a small hill in sec. 26, T. 25 S., R. 17 W., a few miles northwest of the Brockman Hills. However, faulting occurred in many areas prior to deposition of the Cretaceous sequence; thus, as in the Florida Mountains, the basal Cretaceous may rest on Ordovician dolomites on one side of a fault, and on Precambrian granite on the upthrown side of the fault.

If the Burro uplift trends east-southeastward from the Burro Mountains area into northern Chihuahua, passing under the West Potrillo Mountains area and through the Florida Mountains, it may intersect the southern continuation of the Orogrande basin south of Juarez. Or the Burro uplift may be merely the culminating stage of the small local uplifts of the late Pennsylvanian and Wolfcampian Florida Islands. The late Paleozoic Orogrande basin to the east and the late Paleozoic Pedregosa basin to the southwest may have been influenced by a latest Paleozoic and early Mesozoic expansion of this uplifted, eroded feature. Perhaps the enigmatic rocks of the central Sierra de Samalayuca are part of the core of this extended Burro uplift.

REFERENCES

Adams, J. E., and Rhodes, M. L., 1960, Dolomitization by seepage refluxion : Am. Assoc. Petroleum Geologists Bull., v. 44, p. 1912-1920.

Armstrong, A. K., 1958, The Mississippian of west-central New Mexico: N. Mex. Bureau Mines and Min. Res. Mem. 5, 32 p.

________ 1962, Stratigraphy and paleontology of the Mississippian System in southwestern New Mexico and adjacent southeastern Arizona : N. Mex. Bureau Mines and Min. Res. Mem. 8, 95 p.

1963, Biostratigraphy and paleontology of the Mississippian System, west-central New Mexico: N. Mex. Geol. Soc. Guidebook of the Socorro Region, 14th Field Conf., p. 112-122.

_ 1967, Biostratigraphy and carbonate facies of the Mississippian Arroyo Peñasco Formation, north-central New Mexico: N. Mex. Bureau Mines and Min. Res. Mem. 20, 79 p.

Bowshcr, A. L., 1961, The stratigraphic occurrence of some Lower Mississippian corals from New Mexico and Missouri: Jour. Paleont., v. 35,p. 955-962.

Bryant, Donald L., 1955, Stratigraphy of the Permian System in southern Arizona: unpub. Ph.D. thesis, Univ. Ariz., 209 p.

________ 1959, Marker zones in Permian formations of southern Arizona: Ariz. Geol. Soc. Digest, 2nd. Ann., p. 38-42.

__ and McClymonds, Neal E., 1961, Permian Concha Limestone and Rainvalley Formation, southeastern Arizona: Am. Assoc. Petroleum Geologists Bull., v. 45, p. 1324-1333.

Darton, N. H., 1917, Description of the Deming quadrangle: U.S. Geol. Surv., Geol. Atlas, Folio 207, 15 p.

Diaz, Teodoro, and Navarro, Arsenio, 1964, Lithology and stratigraphic correlation of the upper Paleozoic in the region of Palomas, Chihuahua: West Tex. Geol. Soc. Pub. No. 64-50, p. 65-84.

Dunham, R. J., 1962, Classification of carbonate rocks according to depositional texture, in Classication of Carbonate Rocks: Am. Assoc. Petroleum Geologists Mem. 1, p. 108-112.

Elston, W. E., 1960, Reconnaissance geologic map of Virden thirty-minute quadrangle: N. Mex. Bureau Mines and Min. Res. Geol. Map. 15.

Epis, R. C., 1956, Geology of the Pedregosa Mountains, Cochise County, Arizona: unpub. Ph.D. thesis, Univ. Calif., 181 p.

Flege, R. F., 1959, Geology of the Lordsburg quadrangle, Hidalgo County, New Mexico: N. Mex. Bureau Mines and Min. Res. Bull. 62, 36p.

Gillerman, Elliot, 1958, Geology of the central Peloncillo Mountains, Hidalgo County, New Mexico, and Cochise County, Arizona: N. Mex. Bureau Mines and Min. Res. Bull. 57, 152 p.

Gilluly, James, Cooper, J. R., and Williams, J. S., 1954, Late Paleozoic stratigraphy of central Cochise County, Arizona: U.S. Geol. Surv. Prof. Paper 266, 49 p.

Hayes, P. T., Simons, F. S., and Raup, R. B., 1965, Lower Mesozoic extrusive rocks in southeastern Arizona-the Canelo Hills Volcanics : U.S. Geol. Surv. Bull. 1194-M, 9 p.

Hernon, R. M., 1935, The Paradise Formation and its fauna: Jour. Paleont., v. 9, p. 653-696.

Jicha, H. L., 1954, Geology and mineral resources of the Lake Valley quadrangle, Grant, Luna, and Sierra Counties, New Mexico: N. Mex. Bureau Mines and Min. Res. Bull. 37, 93 p.

Kottlowski, F. E., 1962, Pennsylvanian rocks of southwestern New Mexico and southeastern Arizona, *in* Pennsylvanian System in the United States: Am. Assoc. Petroleum Geologists, p. 331-371.

1963, Paleozoic and Mesozoic strata of southwestern and south-central New Mexico: N. Mex. Bureau Mines and Min. Res. Bull. 79, 100 p.

Flower, R. H., Thompson, M. L., and Foster, R. W., 1956, Stratigraphic studies of the San Andres Mountains, New Mexico: N. Mex. Bureau Mines and Min. Res. Mem. 1, 132 p.

Foster, R. W., and Wengerd, S. A., 1969, Key oil tests and stratigraphic sections in southwestern New Mexico: N. Mex. Geol. Soc. Guidebook of the Border Region, Chihuahua and the United States, 20th Field Conf., p. 186-196.

Lasky, S. G., 1947, Geology and ore deposits of the Little Hatchet Mountains, Hidalgo County, New Mexico: U.S. Geol. Surv. Prof. Paper 208, 101 p.

Laudon, L. R., and Bowsher, A. L., 1949, Mississippian formations of southwestern New Mexico: Geol. Soc. America Bull., v. 60, p. 1-87.

Nations, J. D., 1963, Evidence for a Morrowan age for the Black Prince Limestone of southeastern Arizona: Jour. Paleont., v. 37, p. 1252-1264.

Packard, F. A., 1955, The stratigraphy of the Upper Mississippian Paradise Formation of southeastern Arizona and southwestern New Mexico: unpub. M.S. thesis, Univ. Wis., 103 p.

Ransome, F. L., 1904, The geology and ore deposits of the Bisbee quadrangle, Arizona: U.S. Geol. Surv. Prof. Paper 21, 168 p.

Ross, C. A., 1963, Standard Wolfcampian Series, Glass Mountains. Texas: Geol. Soc. America Mem. 88, 205 p.

Sabins, F. F., Jr., 1957, Stratigraphic relations in Chiricahua and Dos Cabezas Mountains, Arizona: Am. Assoc. Petroleum Geologists Bull., v.41, p. 466-510.

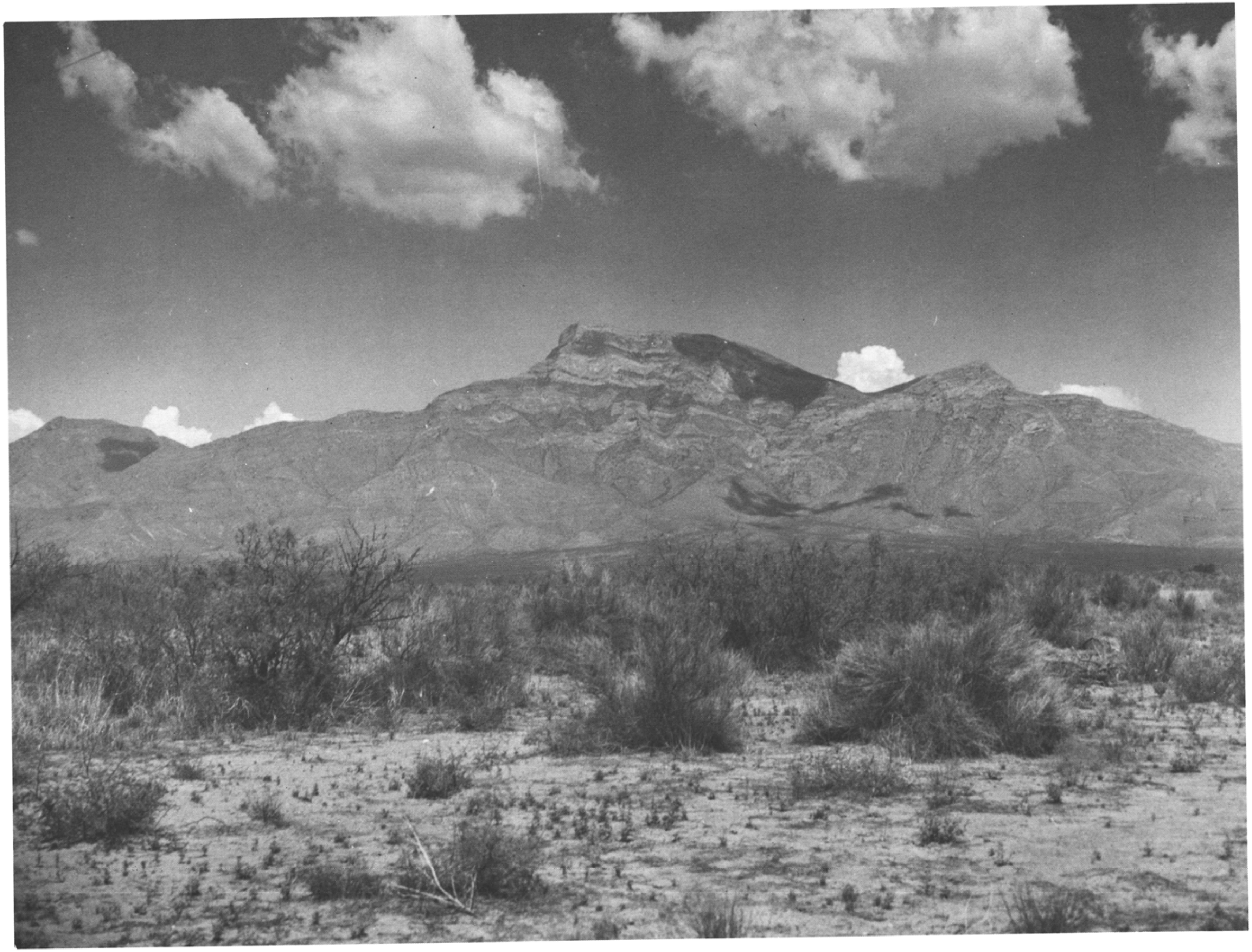
Stoyanow, A. A., 1926, Notes on recent stratigraphic work in Arizona, especially Upper Mississippian in southeastern : Am. Jour. Sci., 5th series, v. 12,p. 311-324.

1949, Lower Cretaceous stratigraphy in southeastern Arizona: Geol. Soc. America Mem. 38, 169 p.

Sando, W. J., 1969, Corals, *in* History of the Rcdwall Limestone of northern Arizona: Geol. Soc. America Mem. 114, p. 257-344.

Zeller, E. J., 1957, Mississippian endothyroid Foraminifera from the Cordilleran geosynclinc: Jour. Paleont., v. 31, p. 679-704.

Zeller, R. A., Jr., 1965, Stratigraphy of the Big Hatchet Mountains area, New Mexico: N. Mcx. Bureau Mines and Min. Res. Mem. 16, 128 p.



Big Hatchet Peak. View east-northeast from Playas Valley. *(Photograph by Zeller)*