# Geology of the Northern Franklin Mountains, Texas and New Mexico

GEOLOGICAL SURVEY BULLETIN 1298

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*By* R. L. HARBOUR

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*The geology of a complex fault-block range with emphasis on stratigraphy of Paleozoic rocks*

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1972

UNITED STATES DEPARTMENT OF THE INTERIOR

ROGERS C. B. MORTON, *Secretary*

GEOLOGICAL SURVEY

V. E. McKelvey, *Director*

Library of Congress catalog-card No. 70-187909

**For sale by the Superintendent of Documents, U.S. Government Printing Office**
**Washington, D.C. 20402**
**Stock Number 2401-2052**

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# GEOLOGY OF THE NORTHERN FRANKLIN MOUNTAINS, TEXAS AND NEW MEXICO

By R. L. HARBOUR


## ABSTRACT

The area described, about 160 square miles, lies in El Paso County, Tex., and Dona Ana County, N. Mex. It consists of the northern part of the Franklin Mountains and adjacent detrital terraces.

Rocks present in the area range in age from Precambrian to Holocene. Precambrian rocks exposed include nearly 5,000 feet of metamorphosed sedimentary and volcanic rocks that have been intruded by granite. The metamorphosed rocks are divided, in ascending order, into the Castner Limestone, about 1,100 feet thick; the Mundy Breccia, as much as 250 feet thick; and the Lanoria Quartzite, about 2,600 feet thick. A red rhyolite, about 1,400 feet thick, overlies the metamorphosed sequence and is also intruded by granite. The intruded granite is about 1,000 million years old. The granite is intruded by diabase that is provisionally assigned to the Precambrian.

Paleozoic rocks form the major part of the Franklin Mountains and range in age from Late Cambrian to Permian. They include the Bliss Sandstone at the base of Late Cambrian and Early Ordovician age; it ranges in thickness from 0 to about 250 feet. The Bliss is overlain by the El Paso Limestone of Early Ordovician age, about 1,500 feet thick, and the Montoya Dolomite of Middle and Late Ordovician age, about 400 feet thick. The next formation above is the Fusselman Dolomite of Middle Silurian age and is more than 600 feet thick. Devonian rocks, which are more than 200 feet thick, are mainly of Middle Devonian age, but include the Percha Shale of Late Devonian age. Mississippian rocks include the Las Cruces Limestone, the Rancheria Formation, and the Helms Formation, all of Laudon and Bowsher (1949), and have a combined thickness of about 640 feet. Pennsylvanian rocks are about 2,700 feet thick and are assigned to the Magdalena Formation. Permian rocks are about 2,300 feet thick, and all are assigned to the Hueco Limestone.

Rocks of Triassic and Jurassic ages are apparently absent. Unnamed rocks of Cretaceous age are exposed as outliers in the area and are more than 3,000 feet thick in adjacent areas. Tertiary and Quaternary rocks consist of felsite, gravel, sand, and caliche.

Although the Franklin Mountains may be regarded as mainly a north-trending fault block that has been tilted westward, in detail it is structurally complex and includes low-angle normal faults and local thrusts. Landslide blocks, related to Holocene topography, are significant local features along the eastern front of the mountains.

# INTRODUCTION

Publication of this report was delayed because of the tragic death of the author, R. L. Harbour, on November 10, 1966. The report, which was in an advanced stage of preparation at that time, was completed by his U.S. Geological Survey friends, who hope that they have not seriously modified his intended meaning in any part of the report.

The Franklin Mountains furnish excellent exposures of Paleozoic rocks. The mountains are structurally complex, and in assembling a complete section of Paleozoic rocks, geologic mapping was necessary. Aerial photographs of the Soil Conservation Service were used in the field mapping which continued intermittently from 1955 to 1959. The map (pl. 1) was originally designed to illustrate the stratigraphy but may also be of use in the search for natural resources in the area.

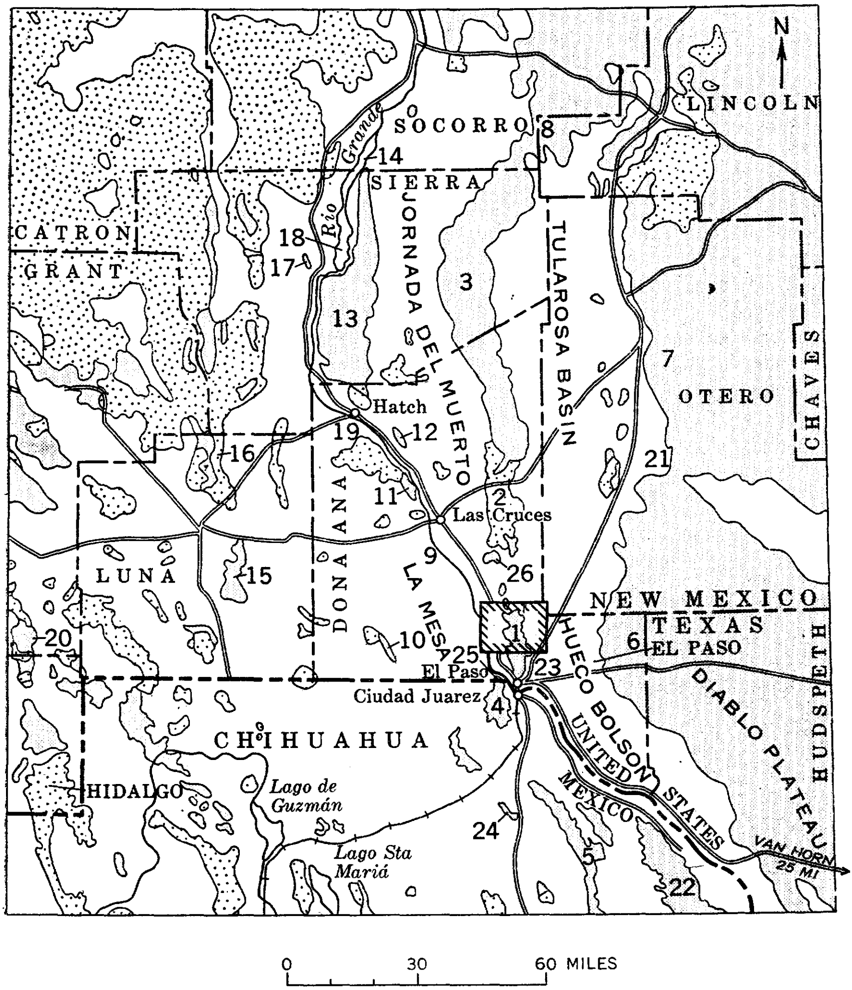
Special acknowledgment is made to several geologists for their assistance to the project. H. Ugalde Villarreal, of Petroleos Mexicanos, helped measure some of the stratigraphic sections and provided data on the geology of northern Chihuahua. Dr. P. T. Flawn, of the Texas Bureau of Economic Geology, examined the Precambrian rocks and helped fit them into the regional framework. The late Dr. L. A. Nelson, of Texas Western College (now the University of Texas at El Paso), and Dr. F. E. Kottlowski, of the New Mexico Bureau of Mines and Mineral Resources, furnished information on Pennsylvanian and Permian rocks of the area and the surrounding region.

## GEOGRAPHY

### REGIONAL SETTING

The Franklin Mountains lie in the extreme western tip of Texas and extend northward into New Mexico 23 miles from the city of El Paso which is built around their southern end. This is a southern part of the Basin and Range province, a region of vast desert basins filled with sand and gravel and flanked by mountain ranges of bedrock that generally trend north or northwestward. The historic Rio Grande flows southeastward through the region in a valley carved capriciously from basin to basin between the mountain ranges.

The mountains of the region are shown in figure 1. Most of them can be likened to islands of bedrock rising above a sea of their detritus. The Franklin Mountains form part of a north-south chain of isolated bedrock ranges that extends from the San Andres and Organ Mountains in New Mexico through Sierra del Paso del Norte and Sierra del Presidio in Chihuahua. In general, the moun-




***Bedrock mountain ranges***

1. Franklin Mountains
2. Organ Mountains
3. San Andres Mountains
4. Sierra del Paso del Norte
5. Sierra del Presidio
6. Hueco Mountains
7. Sacramento Mountains
8. Oscura Mountains
9. Mesilla Valley
10. East Potrillo Mountains
11. Robledo Mountain
12. Tonuco Mountain
13. Caballo Mountains
14. Elephant Butte Lake
15. Florida Mountains
16. Cooks Range
17. Mud Springs Mountains
18. Caballo Lake
19. Rincon Valley
20. Little Hatchet Mountains
21. Sand Canyon
22. Sierra Madre Oriental
23. El Paso Valley
24. Sierra de Samalayuca
25. Cerro de Muleros
26. Bishop Cap

FIGURE 1.—Index to area of geologic map (shaded boundary). Solid pattern represents pre-Tertiary rocks; the dotted pattern, lower Tertiary rocks (mostly volcanic); and the unpatterned areas, upper Tertiary and Quaternary rocks. Geology from Stose and Ljungstedt (1932) and International Geological Congress (1956).

tains of this chain are formed by westward-tilted bedrock with steep scarps of eroded strata facing eastward. Mirroring the chain 30 miles to the east is a series of eastwardly tilted blocks with steep western faces: the Oscura, Sacramento, and Hueco Mountains.

Flat, poorly drained topographic depressions, or bolsons, surface the waste-filled basins surrounding the mountains. These were interconnected on one great inland plain during Pleistocene time, but development of through drainage by the Rio Grande has partly dissected them. Tularosa Basin and the Lake Region (Cuenca Interior) of Chihuahua still have no drainage outlets and are dotted with inland lakes and playas. Hueco Bolson, La Mesa, and Jornada del Muerto drain partly into Rio Grande but have many ephemeral lakes.

The Rio Grande has carved broad valleys across the desert basins and narrow channels where constricted by mountains. Constrictions at El Paso and near Hatch divide the river course into the Rincon, Mesilla, and El Paso Valleys. The flood plains of the valleys are about 5 miles wide and have been irrigated since colonization by Spain. The waterflow is now controlled at dams impounding Elephant Butte and Caballo Lakes. It is on the Rio Grande's fertile flood plains that the population of the region is concentrated; cotton, alfalfa, and vegetables are its chief commerce.

## PHYSIOGRAPHY

The Franklin Mountains dominate the surrounding deserts from which they abruptly rise more than 3,000 feet. They are a linear range 23 miles long and less than 5 miles wide. The rock layers that form the mountains are tilted to the west and present a steep frontal scarp to the east below a knifelike crest that culminates in seven named peaks that range in altitude from 5,400 to 7,200 feet. Deep rugged canyons, all of them normally dry, lead eastward to the Hueco Bolson and westward to the Rio Grande. Transverse gaps eroded to the level of the desert waste break the mountains into three distinct, nearly alined segments; two minor segments are in New Mexico and the major segment is in Texas. The major topographic features of the mountains are shown in figure 2.

The northern segment of the Franklin Mountains is a limestone ridge that extends from Fillmore Pass between the Franklin and Organ Mountains to Webb Gap, 3½ miles to the south. It is less than a mile wide, slightly sinuous in plan, and nearly symmetrical in cross section. The crest is unbroken by sharp peaks, and rises 700 feet above the desert surface.

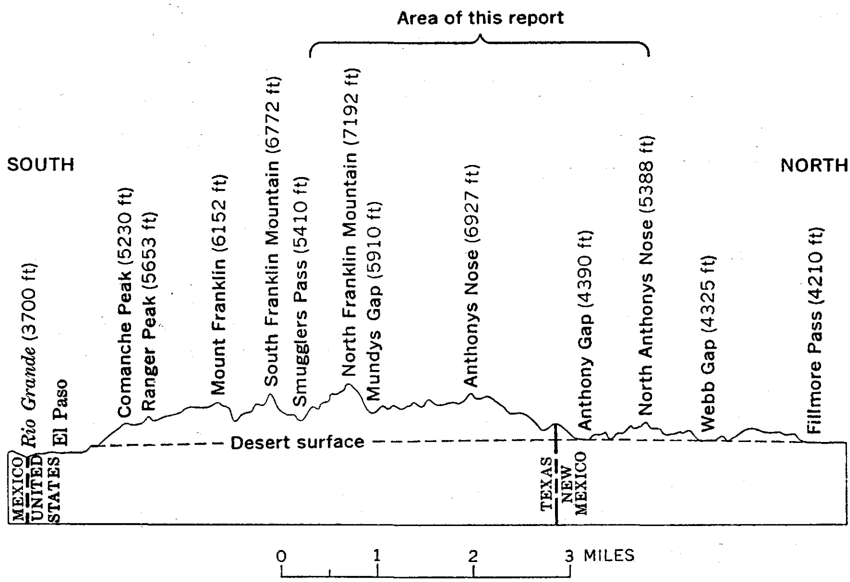



FIGURE 2.—Longitudinal profile of the Franklin Mountains, showing major topographic features and their altitudes. Vertical scale is exaggerated.

The other minor segment of the Franklin Mountains is a limestone ridge that extends 4 miles south-southeast from Webb Gap to Anthony Gap less than a mile north of the New Mexico-Texas boundary. The ridge attains a mile in width in the southern part where it culminates at the peak called North Anthonys Nose. The east slope is steeper than the west slope.

The major segment of the Franklin Mountains is an imposing serrated ridge that extends from Anthony Gap 16 miles due south to end abruptly at El Paso. The ridge is 2–5 miles wide, and its eastern face is very steep. Limestone forms the crest of the ridge except for a 3-mile section of red rhyolite which extends from Mundys Gap to South Franklin Mountain.

The area of geologic map (pl. 1) extends from North Anthonys Nose on the north to Smugglers Pass on the south and from Hueco Bolson on the east to Rio Grande on the west. It comprises 10 minutes of latitude (31°52½′ to 32°02½′) and 15 minutes of longitude (106°22½′ to 106°37½′), an area of 169 square miles lying in El Paso County, Tex., and Dona Ana and Otero Counties, N. Mex. The boundary between Texas and New Mexico (Douglas, 1930, p. 169–177, 226–231) follows a slightly errant 1859 survey of the 32d parallel to the west edge of the area where it swings southward in a meandering course along the channel of the Rio Grande as it was located in 1850. The Rio Grande flood plain, whose altitude is 3,750–3.790 feet, is the lowest part of the area, but the broad surface of Hueco Bolson east of the mountains is only 100–300 feet higher. North Franklin Mountain in the south-central part of the mapped area rises nearly 7,200 feet above sea level and is the summit of the Franklin Mountains.

## CLIMATE, FLORA, AND FAUNA

The climate of the area is that of the arid Southwest; the days are hot and sunny and the nights are cool because of the high altitude. The humidity is low and precipitation at nearby El Paso averages only 9 inches a year, more than half of it falling in July, August, and September. The prevailing wind is from the west and occasional duststorms arise in February, March, and April. The highest and lowest temperatures recorded at El Paso are 106°F and −5°F. June, July, and August, with an average temperature near 80°F, are the hottest months, and December and January, at 45°F, are the coldest.

Above the green fields and dense thickets of the Rio Grande flood plain, vegetation is sparse, and from a distance the bedrock mountains appear totally barren of plants. The appearance is misleading. Many plants have adapted to the scanty moisture and soil; the following observations are based on a description of the local flora by Walter Ammon (in West Texas Geological Society, 1958, p. 85–91). In the mountains, scattered stunted alligator juniper trees are found on ridgetops, and several large cottonwood trees are clustered high on the west slope at Cottonwood Spring. Yuccas, sotols, agaves, cactuses, and ocotillo occur everywhere in the mountains, and the canyons are choked with perennial shrubs, most of them thorny. On the desert basins surrounding the mountains, creosote bush is abundant, and saltbush, dwarf mesquite, and parthenium are also common. The Rio Grande flood basin, now largely drained and cleared for agriculture, once supported cottonwood forests, willow thickets, and swamps.

## POPULATION

The population and commerce of the mapped area are concentrated along the Rio Grande at Anthony (formerly La Tuna), Canutillo, Vinton, and Borderland, the only towns in the area (pl. 1). The largest of these is Anthony (population 1,500), which lies in both Texas and New Mexico; the other communities are in Texas. East of the Franklin Mountains, the northern limits of El Paso now (1960) extend into the mapped area, where several residential districts have been built since the topographic base of the geologic map was prepared in 1955. Outside the communities, many people reside on farms on the Rio Grande flood plain, and a few live on ranches on Hueco Bolson. Several families live on a natural-gas pumping station in the eastern part of the mapped area. Industry and services are largely centered in El Paso and in the neighboring Mexican city of Ciudad Juarez, Chihuahua. According to the 1960 census, the population of El Paso was 273,912 and the population of Ciudad Juarez was estimated at 294,000 by the El Paso Chamber of Commerce.

## PREVIOUS GEOLOGIC ACCOUNTS

The first scientific account of the geology of the region was by Wislizenus (1848), a physician who made a botanical and geological survey down the Rio Grande to El Paso del Norte and Chihuahua in 1846. Wislizenus (1848, p. 42, 137) identified fossils he collected from the mountains southwest of El Paso del Norte as Silurian in age. The identification seems to be in error, for only Cretaceous rocks are known in these mountains (Sierra del Paso del Norte).

Parry (1857), who was with the Mexican Boundary Survey in 1853–54, sketched the structure of the Franklin Mountains as seen from El Paso, reported the presence of Cretaceous rocks in El Paso Gorge, and collected Silurian and Carboniferous fossils in the Franklin Mountains as well as a specimen of the rhyolite that caps the highest peak.

Antisell (1856, p. 161–162, 166–167, pl. 14, geologic map), with a Pacific Railway survey in 1854–55, described the Organ Mountains (including the present Franklin Mountains), and prepared a geologic map and cross section which showed granite at the east base of the mountains overlain by Carboniferous limestone.

Shumard (1858, 1886,[1] p. 46, 103), a geologist, accompanied Capt. John Pope in 1855 on a railway survey expedition that passed by the south end of the Franklin Mountains. Shumard noted the granite beneath the sedimentary rocks, collected Lower Silurian (now Upper Ordovician) fossils from the mountains, and described the occurrence of similar rocks overlain by Carboniferous limestone in the Organ Mountains.

Jenney (1874) reported thick lower Paleozoic rocks in the Franklin Mountains. He described the sandstone (Bliss) at the base of the sedimentary rocks, and collected fossils in the overlying limestone that established the presence of Lower Ordovician, Upper Ordovi-

[1] Final publication of the results of the expedition was delayed by the resignation of B. F. Shumard and G. G. Shumard as State Geologist and Assistant State Geologist of Texas at the approach of the Civil War.

cian, and Middle Silurian rocks in a single section 2 miles north of El Paso.

Stanton and Vaughan (1896) measured and described the Lower Cretaceous rocks in El Paso Gorge.

Richardson first visited the area in 1903 and described the geology in a series of papers that culminated in 1909 with his definitive El Paso folio, the most important single publication on the geology of the Franklin Mountains. Richardson described the great Precambrian succession, and he subdivided the lower Paleozoic rocks into formations that have since been recognized over large areas of southern New Mexico and western Texas. On the folio's geologic map he sketched the structure of the mountains at a scale of 1:125,000 and contributed to the knowledge of basin-and-range evolution (Richardson, 1904, 1908a, 1909).

Darton (1918, 1922, 1928a, b) extended the lower Paleozoic formations of Richardson into southern New Mexico in his remarkable descriptions of the geology of the State. On his reconnaissance maps he outlined the structure of the desert mountain ranges and showed the geology of the New Mexico part of the Franklin Mountains.

King and King (1929, p. 910, 920) and Darton (1929) reported the presence of Devonian and Mississippian rocks in the Franklin Mountains.

Kirk (1934) described a section of the El Paso Limestone near El Paso and related its fauna to other Ordovician formations.

Nelson (1940) described the stratigraphy of the Franklin Mountains and measured a section of the Magdalena Formation. He divided the Magdalena into members and recorded a large Pennsylvanian fauna.

Sayre and Livingston (1945) described the ground-water resources of El Paso. Their descriptions of unconsolidated deposits that surround the Franklin Mountains are of special value to geologists.

Cloud and Barnes (1946, p. 72–75, 361–369, figs. 5, 6, pl. 16) described a section of the El Paso Limestone and established the type locality of the formation near the south end of the Franklin Mountains. They divided the El Paso into lithic and faunal units which they compared with formations of the Ellenburger Group of central Texas.

Laudon and Bowsher (1949, p. 34–37) described the Mississippian rocks of the Franklin Mountains in a study of southwestern New Mexico.

Pray (1958) and Howe (1959) measured sections of the Montoya and Fusselman Dolomites in the northern part of the Franklin Mountains.

The structural setting of the Franklin Mountains is described in papers on the part of Texas west of the Pecos River by Baker (1928, 1934) and King (1935).

Additional reports describe the geology of specific resources found in and near the Franklin Mountains. The tin deposits of the Franklin Mountains were described by Weed (1901), Richardson (1906), and Chauvenet (1910, 1911). The possibility of producing metallic magnesium from dolomite was explored by Kottlowski (1957). A specific mineral suite from limestone now known to be of Precambrian age was described by Lonsdale (1929). Cement materials were examined by Richardson (1908b, 1913) before and after a large cement plant was established at El Paso.

The geology of the debris-filled troughs surrounding the Franklin Mountains and the occurrence of ground water in them are the subject of water-supply papers that describe the following areas: The Rio Grande Valley of Texas (Slichter, 1905), the Rio Grande Valley of New Mexico (Lee, 1907a), the Tularosa Basin (Meinzer and Hare, 1915), the El Paso area (Sayre and Livingston, 1945), and the Hueco Bolson (Knowles and Kennedy, 1958).

The Franklin Mountains have been visited on field trips by the West Texas Geological Society (1946, 1950, 1958), the New Mexico Geological Society (1953), and the Roswell Geological Society (1960). The field-trip guidebooks contain road logs and special articles on the geology of the region.

## DESCRIPTION OF THE ROCKS

Rocks exposed in the Franklin Mountains and vicinity range in age from Precambrian to Holocene. All the systems are represented except the Triassic and Jurassic, and the interval that they would occupy does not crop out. Most of the rocks older than Tertiary are of marine origin, and in the rocks older than Cretaceous, limestone and dolomite predominate. The aggregate thickness of the formations in the Franklin Mountains, the neighboring Mexican ranges, and the basins that surround them is more than 22,000 feet, as shown in table 1.

In addition to the rocks shown on table 1, granite, granite porphyry, and diabase of Precambrian age and felsite of probable Tertiary age are present in the northern Franklin Mountains, and Cretaceous rocks are domed by an intrusion of andesite porphyry at Cerro de Muleros.

The sedimentary rocks that are exposed in the mapped area are illustrated graphically on plate 2.

TABLE 1.—*Layered rock units in the Franklin Mountains and vicinity*

| Age | Rock unit | Thickness (*feet*) | Thickness (feet) |
|---|---|---|---|
| Quaternary | Alluvium | | 0–50 |
| | Caliche and gravel rimrock | | 4–50 |
| Quaternary and Tertiary. | Basin deposits | | 0–4, 910 |
| Cretaceous | Unnamed deposits in Cerro de Muleros (Böse, 1910) and Sierra del Paso del Norte (Strain, 1958). | | 3, 000+ |
| Permian | Hueco Limestone: | | |
| | Upper unit | 386+ | |
| | Middle unit | 1, 171 | |
| | Lower unit | 658–742 | |
| | Total of Hueco Limestone | | 2, 300± |
| Pennsylvanian | Magdalena Formation: | | |
| | Upper member | 1, 180± | |
| | Bishop Cap Member | 636 | |
| | Berino Member | 448 | |
| | La Tuna Member | 423 | |
| | Total of Magdalena Formation | | 2, 700± |
| Mississippian | Helms Formation as used by Laudon and Bowsher (1949). | | 150–231 |
| | Rancheria Formation of Laudon and Bowsher (1949): | | |
| | Upper member | 202–230 | |
| | Middle member | 28–42 | |
| | Lower member | 123–136 | |
| | Total of Rancheria Formation of Laudon and Bowsher. | | 370± |
| | Las Cruces Limestone of Laudon and Bowsher (1949). | | 50–90 |
| Devonian | Percha Shale | | 0–99 |
| | Middle Devonian rocks: | | |
| | Upper part | | 7–45 |
| | Lower part | | 68–90 |
| Silurian | Fusselman Dolomite | | 532–640+ |
| Ordovician | Montoya Dolomite: | | |
| | Cutter Member | 128–166 | |
| | Aleman Member | 141–160 | |
| | Upham Member | 90–104 | |
| | Total of Montoya Dolomite | | 380–405 |
| | El Paso Limestone: | | |
| | Upper member | *211–335 | |
| | Middle member | *935–1, 080 | |
| | Lower member | *84–175 | |
| | Total of El Paso Limestone | | *1, 310–1, 590 |
| Ordovician and Cambrian. | Bliss Sandstone | | *0–250 |
| Precambrian | Rhyolite (extrusive) | | 0–1, 400 |
| | Lanoria Quartzite: | | |
| | Upper member | 550–700 | |
| | Middle member | 575–800 | |
| | Lower member | 1, 025–1, 100 | |
| | Total of Lanoria Quartzite | | 2, 600± |
| | Mundy Breccia | | 0–190 |
| | Castner Limestone | | 1, 112+ |

*Data from Cloud and Barnes (1946).

## PRECAMBRIAN ROCKS

Precambrian rocks crop out along the east front of the Franklin Mountains from El Paso 14 miles northward to near the Texas-New Mexico boundary. The oldest rocks are 5,000 feet of metamorphosed sedimentary and volcanic rocks that are obliterated, by intrusive granite, from Mundys Spring to Anthonys Nose in the central part of the mapped area (pl. 1).

The metamorphosed sedimentary and volcanic rocks are assigned to the Precambrian System because they lie unconformably beneath the Bliss Sandstone of Late Cambrian and Ordovician age and because no earlier Cambrian fossils have been found here or anywhere in the region. The granite is probably Precambrian in age, for the Bliss Sandstone appears to have been deposited on it. Determinations of the age of the granite (Wasserburg and others, 1962) indicate that it is about 1,000 million years.

The basement on which the oldest sedimentary rocks were deposited is not known, but at two localities, remnants of crossbedding are dimly outlined in granite at a level that apparently is stratigraphically below the metasedimentary rocks. These localities are (1) 0.9 mile north and 1.3 miles east of a peak called Anthonys Nose and (2) 1.2 miles south and 1.5 miles east of the same peak.

### CASTNER LIMESTONE

The oldest rocks exposed in the Franklin Mountains are 1,100 feet of limestone, hornfels, and diabase that rest on intrusive granite and which were designated the Castner Limestone (Harbour, 1960) at exposures in Castner Range, Fort Bliss Military Reservation, near the east base of North Franklin Mountain. The Castner is hidden from view by unconsolidated deposits south of Fusselman Canyon. North of Fusselman Canyon, granite intrusion has obliterated the formation except for isolated outcrops at the east base of the mountains in (1) Castner Range, (2) the eastward-projecting mountain spur 1.8 miles south of the Texas-New Mexico boundary, and (3) Hitt Canyon 0.6 mile south of the Texas-New Mexico boundary.

The type locality of the Castner Limestone is at Castner Range (pl. 2, graphic section I), where two blocks have survived assimilation by surrounding granite. Here, the limestone is slightly metamorphosed and is thinly and evenly bedded, light gray, green, and blue, and fine to coarsely crystalline. Thin layers of dark-gray hornfels and lenses of light-gray chert project from the weathered surfaces and give the outcrop a typical ribbed appearance. About one-third of the formation is dark-greenish-gray diabase sills which form slopes and are poorly exposed.

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Metamorphic minerals such as serpentine, tremolite, and dark-brown garnet are concentrated along bedding planes in the limestone. No clay was found in limestone samples that were dissolved in hydrochloric acid, and original clay minerals apparently were converted into stable silicate minerals by heat. A mineral suite from the Castner Limestone was described by Lonsdale (1929).

Peculiar bedding features are abundant in the upper part of the Castner Limestone at Castner Range. Small thrust faults and recumbent folds occur within single limestone beds and appear to reflect disturbance of the sea bottom during deposition. Edgewise breccia of chert and hornfels "shingles" are common and may be associated with the thrust faults and recumbent folds. Superimposed upon these features are gentle folds which occur only in the upper beds and which have more relief toward the top of the formation.

From bottom to top, terrigenous material in the Castner Limestone increases, and the dolomite content decreases. The basal bed at Castner Range is friable white dolomite that resembles unconsolidated sandstone, and the upper beds contain numerous layers of laminated hornfels or baked siltstone. The magnesium content of three relatively unmetamorphosed carbonate samples is shown in table 2.

Well-preserved algal structures are abundant in a bed 4 feet thick near the base of the Castner Limestone in the two blocks surrounded by granite at Castner Range. These structures are finely laminated hemispherical masses, about a foot in diameter that are convex upward. Two specimens examined by Richard Rezak (written commun., 1958) were identified as *Collenia frequens* Walcott. The species is common in upper Precambrian rocks, but it apparently has no value in correlation. It indicates shallow-water environment, and its growth habit can be used to establish the top and bottom of the beds.

In the eastward-projecting mountain spur 1.8 miles south of the Texas-New Mexico boundary, the Castner Limestone is dark gray and breaks down easily on weathering. The limestone is altered to

TABLE 2.—*Magnesium content, in percent, in the Castner Limestone*

[J. A. Thomas, analyst]

| Sample | Stratigraphic position | Carbonate content | Magnesium (mineral dolomite equals 13.1 percent) |
|---|---|---|---|
| F42c | 855 ft above base of formation | 84.5 | Trace |
| F26 | 320 ft above base of formation | 91.8 | 5.9 |
| F3a | Basal carbonate bed | 97.3 | 12.1 |

siderite and, except for a patch of unaltered limestone atop the spur, alteration has nearly erased the bedding planes.

In Hitt Canyon 0.6 mile south of the Texas-New Mexico boundary, the upper beds of the Castner Limestone are sharply folded and overturned. The limestone becomes increasingly sandy toward the top of the formation, and this is the only place where quartz sand was seen in the Castner.

Eight layers of diabase were found in the Castner Limestone at Castner Range (Harbour, 1960, p. 1789), and the thicker ones are shown in graphic section I (pl. 2). They are sills injected between the limestone beds; limestone above and below them appears altered, and no lava flow-structures are present. The sills may be the intrusive equivalent of basalt in the Mundy Breccia and are probably older than the Lanoria Quartzite. They are definitely older than the granite, which contains stoped blocks of the diabase where they are in contact in the eastern exposure at Castner Range.

The Castner Limestone with its diabase sills and algal structures is probably correlative with part of the Allamoore Formation near Van Horn, Tex., to the southeast (King, 1940; Harbour, 1960). The Allamoore is mostly limestone and exhibits similar structural features.

### MUNDY BRECCIA

Resting unconformably on the Castner Limestone is a black unit containing basalt boulders designated the Mundy Breccia (Harbour, 1960) at exposures in Castner Range. The Mundy, which is mapped with the Castner Limestone on the geologic map (pl. 1), also crops out at the eastern base of the Franklin Mountains on the north side of Hitt Canyon 0.6 mile south of the Texas-New Mexico boundary.

At Castner Range the Mundy Breccia is 190 feet thick in the western exposure, but it pinches out eastward between the Castner Limestone and the Lanoria Quartzite and is not present in the eastern exposure. The Mundy forms a dark-gray slope strewn with boulders of fine-grained black basalt. The boulders are unbedded and randomly oriented in place and are separated by a fine, dark-gray matrix resembling baked mudstone. The corners of the boulders appear slightly rounded, and the volume of the boulders is greater than that of the matrix. Flecks of chalcopyrite are common.

The Mundy Breccia probably accumulated as a surface deposit after a period of erosion inasmuch as it appears to fill channels in the Castner Limestone. The boulders are altered basalt, but the origin of the matrix has not been determined. If the matrix is volcanic debris, the Mundy may be an agglomerate that resulted from volcanic explosion. If the matrix is mudstone, the Mundy may be a deeply weathered flow or sill.

On the north side of Hitt Canyon 0.6 mile south of the Texas-New Mexico boundary, the Mundy Breccia is vertical to overturned and is exposed in a bulldozed prospect pit. Chunks of cellular carbon stained by copper carbonate occur between the basalt boulders. The carbon ignites by match and burns with a green flame, but it shows no vestige of organic structure.

The Mundy Breccia may represent the same period of uplift and erosion that separates the Allamoore and Hazel Formations in the Van Horn area to the southeast (King, 1940).

## LANORIA QUARTZITE

Resting on the Castner Limestone and Mundy Breccia is 2,600 feet of metamorphosed sandstone, siltstone, and shale termed the Lanoria Quartzite by Richardson (1909, p. 3). The Lanoria is the most conspicuous formation displayed along the east front of the Franklin Mountains, and it crops out from Sugarloaf Mountain in the northern suburbs of El Paso (about 3 miles south of the mapped area) to Mundys Gap in the southern part of the mapped area (pl. 1) where it is replaced northward by intrusive granite. The Lanoria reappears in the eastward-projecting mountain spur 1.8 miles south of the Texas-New Mexico boundary and at Hitt Canyon 0.6 mile south of the boundary.

The Lanoria is fine grained throughout, and no beds coarser than medium-grained sandstone are present. Ripple marks and bedding structures are clearly preserved, but organic remains are lacking.

The Lanoria is separated from the underlying formations by an unconformity, and it truncates the Mundy Breccia to rest on the Castner Limestone at places in Castner Range. No identifiable fragments of the Mundy or Castner were seen in the Lanoria, but a few rounded quartzite pebbles are present in the basal 4 feet.

A middle unit of massive quartzite permits division of the Lanoria into three members which can be distinguished wherever the Lanoria crops out (Harbour, 1960, p. 1790). Table 3 shows the approximate thickness of the members as measured on the geologic map.

### LOWER MEMBER

The lower member of the Lanoria Quartzite is about 1,100 feet of fine-grained quartzite, quartzitic siltstone, and baked shale that forms a slope beneath cliffs formed by the middle member. The bottom and top of the lower member are exposed only at Castner

TABLE 3.—*Thickness, in feet, of members of the Lanoria Quartzite*

| Member | South side of Fusselman Canyon | North Franklin Mountain (pl. 2, graphic section I) | 1.8 miles south of Texas-New Mexico State line | Hitt Canyon, 0.6 mile south of Texas-New Mexico State line |
|---|---|---|---|---|
| Upper | 550 | 700 | Poorly exposed | Poorly exposed. |
| Middle | 650 | 800 | 575 | 600. |
| Lower | 1, 050+ | 1, 100 | 1,025 | Poorly exposed. |

Range and in the eastward-projecting spur 1.8 miles south of the Texas-New Mexico boundary.

At columnar section I (pl. 2), the lower member of the Lanoria Quartzite is split by a granite sill about 2,000 feet thick. Below the sill is 260 feet of medium-grained crossbedded quartzite that is light gray in fresh fracture and weathers mottled red and gray. Above the sill, thin-bedded quartzite and quartzitic siltstone form about 60 percent of the lower member; the intervening beds are covered. The quartzite and quartzitic siltstone are finely laminated and micaceous and weather dark greenish gray and red. The covered intervals are probably baked shale and none are more than 20 feet thick.

### MIDDLE MEMBER

The middle member of the Lanoria Quartzite is 575–800 feet of massive quartzite that forms imposing cliffs along the east front of the Franklin Mountains. The member is crossbedded throughout, and the rock is very dense and mostly medium grained. At graphic section I (pl. 2), the middle part of the member forms a dark band between white ledges at the bottom and top of the member. This middle part is fine grained and weathers green and red.

### UPPER MEMBER

The upper member of the Lanoria Quartzite is 550–700 feet of fine-grained quartzite, siltstone, and baked shale that forms a brown-weathering slope between the middle member and the overlying rhyolite. The quartzite and quartzitic siltstone are finely laminated and weather dark greenish gray and red. Interbeds of shale are dark gray and are mostly covered.

In the eastward-projecting spur 1.8 miles south of the Texas–New Mexico boundary the upper member of the Lanoria is directly overlain by the Bliss Sandstone and is intruded by two sills of granite porphyry.

The Lanoria Quartzite may be a more distinctly bedded facies of the Hazel Formation, a thick red sandstone in the Van Horn area to the east (King, 1940).

## GRANITE PORPHYRY

Intruded as sills between beds of the Lanoria Quartzite is granite porphyry that in turn is intruded by the great granite mass of the east front of the Franklin Mountains. The sills occur at two localities in the mapped area (pl. 1)—on the east front of the mountains at Mundys Gap and in the eastward-projecting spur 1.8 miles south of the Texas-New Mexico boundary.

The granite porphyry is reddish brown and consists of phenocrysts of pink and white feldspar (20 percent), black ferromagnesian minerals (20 percent), and clear quartz (10 percent) in a fine-grained pink and black matrix (50 percent). The phenocrysts are as much as 12 mm long and tend to sphericity at places.

The granite porphyry may be the intrusive equivalent of the rhyolite at the top of the Precambrian sequence. They are similar in lithology and each is younger than the Lanoria Quartzite and older than the main granite mass.

## RHYOLITE

At the top of the Precambrian sequence is red rhyolite that forms the crest and west slope of the Franklin Mountains from Mundys Gap on the north to Smugglers Pass near the south boundary of the mapped area (pl. 1). The rhyolite is about 1,400 feet thick at North Franklin Mountain, but it is missing at the north and south ends of the mountains. North of Mundys Gap, the rhyolite is intruded by granite, and on the eastward-projecting spur 1.8 miles south of the Texas-New Mexico State line it is missing, presumably by erosion before deposition of the Bliss Sandstone. Near Sugarloaf Mountain 3 miles south of the mapped area, the rhyolite is truncated by an angular unconformity beneath the Bliss.

The rhyolite has widely spaced but distinct layers. It is resistant to erosion, and the Bliss Sandstone is commonly thin or absent where it is underlain by the rhyolite. The basal 100 feet of the rhyolite contains layers of rounded quartzite pebbles cemented by rhyolite, and the upper part contains randomly oriented blocks of quartzite at a few places.

The rhyolite is red to black and varies in composition. All varieties are porphyritic and contain feldspar phenocrysts in a red or black, aphanitic or fine-grained matrix. In many varieties, quartz or ferromagnesian phenocrysts are as common as feldspars. The phenocrysts, which make up 35–50 percent of the rock, average 5 mm in length, but some as long as 15 mm were noted by Richardson (1909, p. 6). At places the feldspar phenocrysts tend to sphericity, and the rock resembles intrusive sills of granite porphyry in the Lanoria Quartzite. A partial analysis of the rhyolite is reproduced on page 65.

The rhyolite is of volcanic origin. The rounded quartzite pebbles trapped in the basal part also suggest that the rhyolite is unconformable with the Lanoria Quartzite, from which the pebbles were doubtless derived. The absence of flow structures suggests that the rhyolite accumulated as volcanic debris rather than as molten lava. Occasional large blocks of quartzite in the upper part may be ejecta from a violent volcanic explosion.

## GRANITE

Massive pink granite intrudes all the Precambrian formations and is the most widely distributed rock along the east front of the Franklin Mountains in the mapped area (pl. 1). The granite completely obliterates the older Precambrian rocks for 4 miles between Mundys Gap on the south and the eastward-projecting spur 1.8 miles south of the Texas-New Mexico boundary. At Mundys Gap, a narrow strip of granite is exposed on the crest of the mountains. To the northwest, granite forms the west slope of the mountains in a small area and is faulted against Paleozoic rocks.

The granite appears red or pink from a distance and weathers into rounded forms that contrast with the angular topography carved on the other rocks in the mountains. It decomposes readily on weathering to grus that blankets the slopes. The granite is so deeply weathered at all outcrops that fresh samples can only be obtained from excavations. As noted by Richardson (1909, p. 6), the granite is complexly jointed. A conspicucous set of closely spaced joints trends northward and dips eastward at an angle that is nearly perpendicular to the bedding in the sedimentary rocks of the mountains.

The granite is composed of feldspar and quartz in nearly equal proportions. Minor quantities of biotite, hornblende, magnetite, and zircon are present. The feldspar is orthoclase and perthitic microline.

The texture of the granite varies from place to place. At Castner Range, it is generally even grained and coarse and has feldspar phenocrysts as large as 25 mm. Near contact with Precambrian formations at Castner Range, the granite is porphyritic, and a fine matrix (50 percent) contains coarse feldspar phenocrysts. In the tin-mine district between Mundys Gap and the eastward-projecting spur 1.8 miles south of the Texas-New Mexico boundary, the granite is medium grained (3 mm) and of even texture. Near the east tip of the spur, the granite is very coarse at one outcrop. A partial analysis of the granite is reproduced on page 65.

The granite is younger than the Precambrian formations described above, for it intrudes all of them. At Castner Range, the granite completely surrounds large blocks of Castner Limestone, Mundy Breccia, and Lanoria Quartzite. At Mundys Gap, the rhyolite is replaced northward by granite along an indistinct contact that is clearly intrusive. In the eastward-facing spur 1.8 miles south of the State line, the granite is bordered on the north by the Castner Limestone, Mundy Breccia, and Lanoria Quartzite along a contact that is sharp but very ragged. Granite tongues extend into the Lanoria along bedding planes and replaces the quartzite without inflating the section. At nearly all localities, progressive chilling in the granite and baking in the invaded rock increases toward the contact.

The granite appears older than the Bliss Sandstone. For a distance of 4 miles between Mundys Gap and the eastward-projecting spur 1.8 miles south of the State line, the Bliss rests on the granite with a probable sedimentary contact. The upper foot of the granite is discolored as if from weathering, and the Bliss contains detrital feldspar and quartz fragments that are the size of crystals in the granite. Richardson (1909, p. 7) stated that "in part at least, the granite is post-Carboniferous." Localities that Richardson (1909, p. 7) described as granite intruding Paleozoic rocks include (1) the west end of the eastward-projecting spur 1.8 miles south of the State line, and (2) Mundys Gap, where the granite crossed the range and extends northwestward. At the first locality, the Bliss Sandstone is brought against the granite by a fault that is younger than the granite, as shown by relationships on the geologic map (pl. 1). At the second locality, steeply dipping Paleozoic limestone abuts downward against granite along a horizontal plane (Avispa fault). The chemically unstable limestone is not metamorphosed or recrystallized within inches of the granite and the contact seems to be a fault that post dates the granite. Richardson (1909, p. 7) also described apophyses of the granite extending into the Bliss Sandstone a short distance north of El Paso; this locality is south of the mapped area and was not examined during this study. However, published age determinations (Wasserburg and others, 1962, p. 4025) indicate that the granite was intruded about 1,000 million years ago, long before Cambrian time.

## DIABASE DIKES

Intruded into the granite are vertical dikes and irregular bodies of mafic rock with diabasic texture. The dikes are most numerous in the tin-mine district at the east base of the mountains. Irregularly shaped bodies of diabase are common in the granite of the west slope near Mundys Gap, and a large patch of diabase appears to intrude the Precambrian rhyolite southwest of Mundys Gap.

The diabase is dark gray and dark green and decomposes so readily on weathering that dikes of it commonly form trenches in the more resistant granite. The rock is a mixture of lath-shaped ferromagnesian minerals and white feldspar and has a mottled fine-grained texture typical of diabase.

The diabase may vary in age, but it is provisionally assigned to the Precambrian. It is later than the granite in which it fills vertical fissures. Diabase dikes in the tin-mine district cannot be traced into the Bliss Sandstone, but recent rubble in the fissures masks the relationship. East and west of Mundys Gap, diabase bodies are in contact with fault planes between the granite and Paleozoic limestone. The faults are probably later than the diabase for no metamorphic effects appear in the limestone. The diabase bodies are relatively incompetent and may have been planes of weakness along faults.

## CAMBRIAN AND ORDOVICIAN ROCKS—BLISS SANDSTONE

After the Precambrian rocks were uplifted and deeply eroded, a sea advanced upon the area from the west or southwest, and the Bliss Sandstone was deposited, probably beginning in Late Cambrian time. The Bliss, which takes its name (Richardson, 1904, p. 27) from Fort Bliss near El Paso, appears to be a basal sandy phase of the El Paso Limestone of Early Ordovician age. It forms a brown slope above the Precambrian rocks for it is thinly bedded and jointed so that it readily weathers into talus blocks. From near the Texas-New Mexico boundary to Mundys Gap, the Bliss crops out high on the east front of the mountains. Between Mundys Gap and Smugglers Pass, the Bliss crops out near the base of the west slope of the mountains because of faulting, and south of Smugglers Pass it is exposed high on the east face of the mountains. From north to south in the mapped area (pl. 1), the Bliss overlies granite porphyry, Lanoria Quartzite, granite, and rhyolite. Normal thickness of the Bliss is 210 feet (pl. 2, measured sections 1 and 5), but south of Mundys Gap the topography of the basal contact is irregular, the Bliss thins out, and the El Paso Limestone locally rests directly on the rhyolite and contains rounded rhyolite pebbles.

The Bliss consists of sandstone, quartzite, and siltstone of various colors that combine to lend a dark effect. The sandstone and quartzite are composed of fine to medium quartz grains cemented by clay and silica; they are finely laminated throughout and cross laminated at places. The siltstone is dark green and maroon, micaceous, and finely laminated. The grains are mostly quartz, and the cement is clay, silica, and glauconite. Feldspar and quartz granules are common throughout the Bliss, and hematite occurs on joints and bedding planes. Fossils include borings and trails, and, at a few places, remnants of snails and inarticulate brachiopods.

Individual beds in the Bliss are lenticular, but the formation exhibits a twofold division at most places. Generally, the lower part is resistant light-gray quartzite, and the upper part is nonresistant dark-green and gray sandstone and siltstone.

The contact of the Bliss with the Precambrian rocks is an angular unconformity beneath which the rhyolite was removed by erosion at the north and south ends of the mountains. Total relief of the surface on which the Bliss was deposited was about 300 feet.

The Bliss is probably a beach and nearshore deposit of the sea in which the younger El Paso Limestone accumulated. The contact with the El Paso appears conformable, and the Bliss is finely laminated as if by current and wave action. Modern descendants of lingulid brachiopods common in the Bliss are found in tropical intertidal and shallow-water areas on bottoms rich in organic matter. Northward in New Mexico, iron accumulated with the Bliss Sandstone, and an easterly trending phase containing oolitic hematite is present in the Caballo and San Andres Mountains (Kelley, 1949, 1951).

The age of the Bliss Sandstone has not been determined exactly; no diagnostic fossils have been found in the Franklin Mountains. *Lingulepis accuminata*, *Obolus matinalis*?, and *Lingulella* sp. were reported from the lower part of the Bliss in the Franklin Mountains by Richardson (1909, p. 3), *Lingulepis* aff. *L. walcotti* Resser, and *Lingulepis* cf. *L. accuminata* (Conrad) have been found in the upper part of the Bliss in the Franklin Mountains (Cloud and Barnes, 1946, p. 369; this report, p. 102). All the fossils are inarticulate brachiopods found elsewhere in both Cambrian and Ordovician rocks, but in absence of other fossils, they suggest a Late Cambrian age (P. E. Cloud, Jr., written commun., 1958).

At other places, fossils diagnostic of both Late Cambrian and Early Ordovician age have been reported from the Bliss. The lower part has yielded diagnostic Late Cambrian trilobites at Tonuco Mountain and Caballo Mountains 50 and 80 miles northwest of the Franklin Mountains (Flower, 1953). The upper part has yielded diagnostic Early Ordovician fossils in the Mud Springs Mountains 90 miles to the northwest (Flower, 1953) and at Beach Mountain 110 miles to the southeast (King, 1940, p. 154–155; Cloud and Barnes, 1946, p. 66–69). The Bliss may vary in age from place to place if the shallow near-shore waters in which it was deposited advanced slowly over the land. It may be both Late Cambrian and Early Ordovician in age at places; the presence of glauconite suggests that deposition was slow and intermittent.

## ORDOVICIAN ROCKS

Ordovician rocks include the El Paso Limestone (Lower Ordovician) and the Montoya Dolomite (Middle and Upper Ordovician). Although the sea withdrew in Middle Ordovician time, conditions in the El Paso and Montoya Seas were somewhat similar; both formations are made up of persistent carbonate beds that are remarkably free from detritus derived from the land. The El Paso shows more evidence of current action than the Montoya.

### EL PASO LIMESTONE

Overlying the Bliss Sandstone is the El Paso Limestone which was named by Richardson (1904, p. 29) from exposures in the Franklin and Hueco Mountains. The El Paso crops out in light-gray thinly layered cliffs along the east front of the Franklin Mountains from El Paso to Smugglers Pass and from Mundys Gap to near the Texas-New Mexico boundary. The El Paso is 1,590 feet thick at its type locality near El Paso (Cloud and Barnes, 1946, p. 361–369). In the mapped area (pl. 1) it is 1,341 feet thick near Anthonys Nose (pl. 2, measured section 1) and 1,313 feet thick near the Texas-New Mexico boundary (measured section 5). The basal contact is sharp but parallel to bedding in the Bliss Sandstone, and the thinning northward appears to be largely due to pre-Montoya erosion.

The El Paso is gray limestone and dolomite with numerous layers and nodules of compact gray chert as well as internal structures of dolomitic chert peculiar to the formation. Quartz sand grains are concentrated at two horizons above the sandy lower member, and clay and silt are present in all the carbonate rocks. No layers of clay or shale are present in the mapped area (pl. 1), but the carbonate beds are laminated at intervals of 3 feet or less. The limestone, which typically weathers light-bluish gray, is fine grained, and many layers contain recemented angular fragments broken off by wave or current action. The dolomite is medium grained and slightly porous. It is more homogeneous than the limestone, for recrystallization tends to obscure primary features.

Chert in the El Paso occurs in compact gray nodules, lenses, and replacement of brachiopods and cephalopods, as well as in an internal network of dolomitic chert that weathers as raised tan mottles averaging one-fourth inch across. The dolomitic chert, which is not present in the sandy phases of the El Paso, makes up 30–40 percent of the rock, and on leaching by acid, the resulting mass is light to dark gray, finely crystalline, and is honeycombed by rhomb-shaped voids that probably are casts of dolomite crystals. The shape of the dolomitic chert masses is irregular, and the outer boundaries tend to be convex. They may have been localized by mud-ingesting organisms, for definite trails, burrows, and pellets of similar material are common throughout the formation. All the chert in the El Paso appears to have originated during or immediately after deposition of the limestone (Cloud and Barnes, 1946, p. 95–96).

The El Paso Limestone appears to have been deposited far offshore in a shallow turbulent sea. The fossils are marine, the formation is laminated as if by wave and current action, and the nearest land, as shown by the distribution of the formation, was distant. Cloud and Barnes (1946, p. 79–106) described conditions in the El Paso Sea and suggested that the water was warm and that sand grains high in the formation were swept out to sea by windstorms.

The El Paso Limestone is Early Ordovician in age as suggested by Jenney (1874), established by Richardson (1904, 1908a, 1909), and since confirmed in numerous reports. The uppermost beds at El Paso contain Early Ordovician fossils, but these high beds have been removed by pre-Montoya erosion in the northern part of the Franklin Mountains (Howe, 1959, p. 2,289). The El Paso is equivalent to part of the Ellenburger Group of Texas and is commonly referred to the Ellenburger in wells in southeastern New Mexico. Fossils collected during this investigation include snails, brachiopods, trilobites, and conodonts that are listed on pages 103–105. Distribution of the conodonts is shown on table 4. They add little to the El Paso fauna of more comprehensive reports (Kirk, 1934; Cloud and Barnes, 1946). Worthy of note, perhaps, is the Early Ordovician occurrence of *Trochonema* sp., a snail that is found in later rocks elsewhere, according to E. L. Yochelson (written commun., 1956), which occurs in the highest part of the El Paso Limestone (USGS colln. 2239CO).

The El Paso is divided into three distinctive members, but more subtle division can be made, for the beds are very persistent. Although the beds appear discontinuous because of lateral replacement of limestone by dolomite, such features as chert type, sand content, and color have resisted replacement. Some of these features are shown in the graphic sections (pl. 2), and the variations in thickness of the major units northward to Bishop Cap are shown in figure 3.

### LOWER MEMBER

The lower member of the El Paso is 84–175 feet of tan dolomite that is finely laminated and sandy throughout. The sand grains are welded by secondary silica, and the carbonate content is about 50 percent. The fine lamination is caused by varying carbonate content, and the rock is very dense and tough. Most of the sand grains are fine to silt-size quartz, but some are larger flakes of muscovite. The sandy dolomite is sharply separated from the underlying Bliss Sandstone, but there is no evidence of unconformity. The lower member grades into the overlying middle member by a decrease in sand content and is an environmental unit that varies in age from place to place. At measured section 5, plate 2, the lower member is 84 feet thick, and at measured section 1, it is 160 feet thick. At the west base of the Franklin Mountains between Mundys Gap and Smugglers Pass, the member rests directly on Precambrian rhyolite and contains rounded pebbles of the rhyolite.

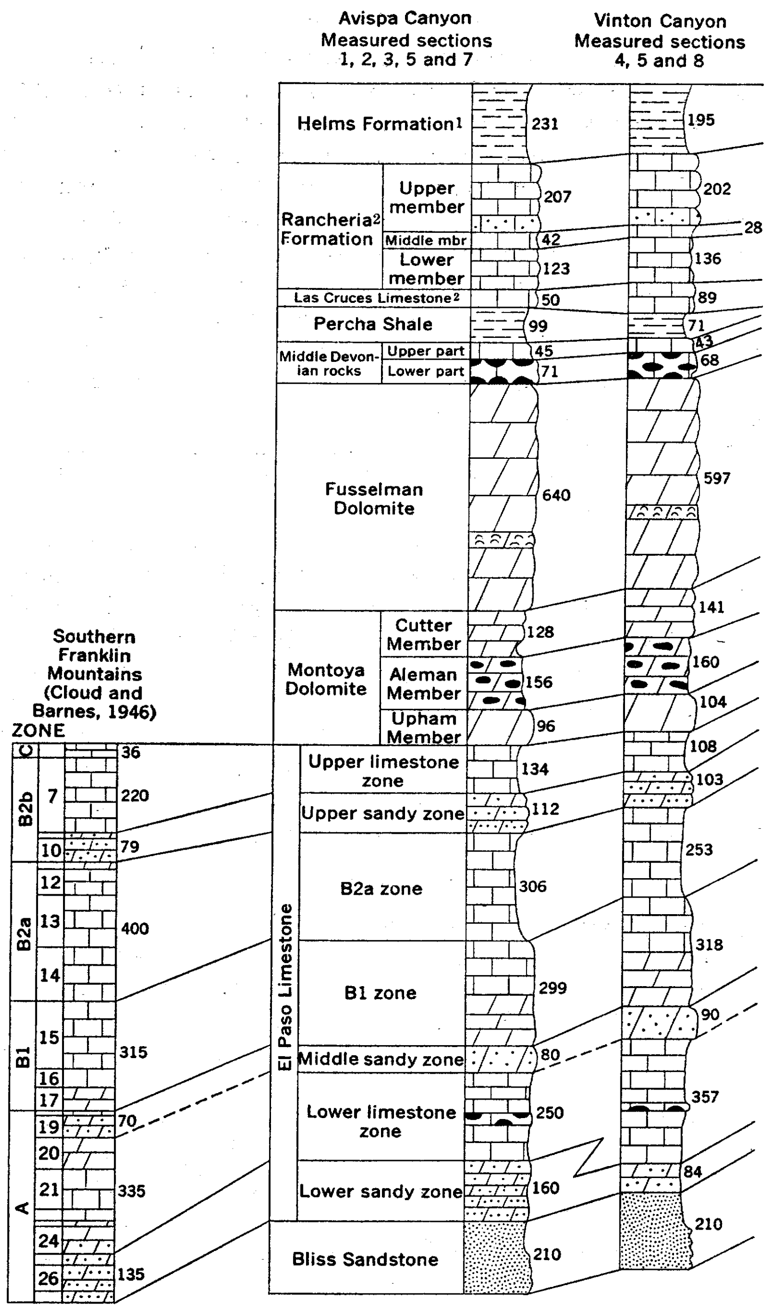
The sandy dolomite at the base of the El Paso appears to be a homogeneous unit only in the Franklin Mountains. At the south end of the mountains, the member is about 175 feet thick as described by Cloud and Barnes (1946, p. 367–368). At Beach Mountain 110 miles to the southeast, the lower member of the El Paso contains beds of siltstone and shale and may lie disconformably on the Bliss Sandstone (Cloud and Barnes, 1946, p. 359–360). In the San Andres, Sacramento, and Caballo Mountains to the north, the lower member contains interbedded sandstone and is difficult to distinguish from the Bliss, which contains thin limestone beds.

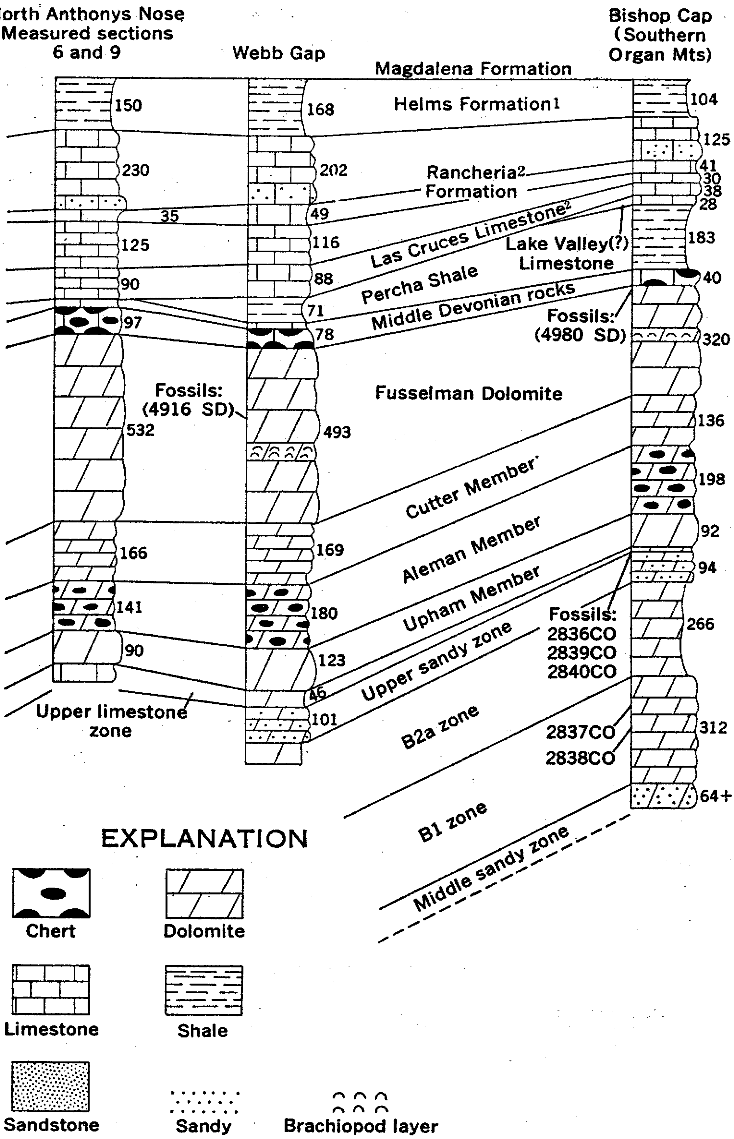
### MIDDLE MEMBER

The middle member is about 1,000 feet of limestone, dolomite, and chert that make up the major part of the El Paso Limestone. Lateral transition of limestone to dolomite is common, but the member is readily separable into three parts by a sandy zone about 600 feet below the top. More refined subdivision by chert type and silicified fossils probably can be made.

The lower part of the middle member is nonsandy gray limestone in beds 2–3 feet thick that weather light-bluish gray and tend to form a slope below cliffs formed by the rest of the member. The limestone is mottled by an internal network of dolomitic chert, and near the base of the member, layers of solid gray chert are concentrated in a distinctive zone that weathers to a rusty color (pl. 2).

A sandy zone in the middle member, which contains fine to coarse, rounded and frosted quartz grains suspended in limestone and dolomite, occurs throughout the Franklin Mountains and in the southern


Avispa Canyon
Measured sections
1, 2, 3, 5 and 7
Vinton Canyon
Measured sections
4, 5 and 8
Helms Formation1
231
195
Rancheria2 Formation
Upper member
207
202
Middle mbr
42
28
Lower member
123
136
Las Cruces Limestone2
50
89
Percha Shale
99
71
Middle Devonian rocks
Upper part
45
43
Lower part
71
68
Fusselman Dolomite
640
597
Montoya Dolomite
Cutter Member
128
141
Aleman Member
156
160
Upham Member
96
104
El Paso Limestone
Upper limestone zone
134
108
Upper sandy zone
112
103
B2a zone
306
253
B1 zone
299
318
Middle sandy zone
80
90
Lower limestone zone
250
357
Lower sandy zone
160
84
Bliss Sandstone
210
210
Southern Franklin Mountains (Cloud and Barnes, 1946)
ZONE
C
36
B2b
7
220
10
79
B2a
12
13
14
400
B1
15
16
17
315
A
19
70
20
21
335
24
26
135




[1]As used by Laudon and Bowsher (1949)
[2]Of Laudon and Bowsher (1949)

FIGURE 3.—Graphic sections of lower Paleozoic rocks in the Franklin and Organ Mountains, Texas and New Mexico. (Locations of sections are shown on plate 1.) Thicknesses are in feet.

Organ Mountains (fig. 3). In the northern part of the Franklin Mountains, the sandy zone is 90 feet thick, but the base is not sharply defined. The sand is concentrated at two places within the zone (pl. 2), and layers of calcareous sandstone 6 inches thick are locally present.

Above the sandy zone, the middle member consists of cliff-forming limestone and dolomite that contain abundant chert in layers, lenses, internal networks, and replacement of fossils, particularly cephalopod siphuncles. Near Anthonys Nose (measured section 1), the beds are discontinuous and contain low stromatolitic mounds.

### UPPER MEMBER

The upper member, which is marked by a conspicuous sandy zone at the base, thins northward in the Franklin Mountains beneath an unconformity. The member is divisible into two major parts in the mapped area (pl. 1).

The lower part of the upper member is fine-grained light-gray dolomite that is finely laminated throughout. The dolomite is very sandy at the base, where it contains frosted fine to coarse grains of quartz. Small cavities lined with quartz crystals are common in the dolomite, but no chert or fossils are present. The dolomite is lighter in color than the rest of the El Paso Limestone (pl. 2).

The upper part of the lower member in the mapped area is nonsandy dark-gray limestone and dolomitic limestone that resemble the middle member of the El Paso. The beds weather light-bluish gray and contain an internal network of dolomitic chert that weathers as light-tan mottling. The thinning of this part of the member northward (fig. 3) shows the truncation of the El Paso Limestone by the Montoya Dolomite.

## MONTOYA DOLOMITE

Above the El Paso Limestone in the Franklin Mountains is the Montoya Dolomite which Richardson (1908a, p. 476, 478–479) defined and differentiated from the El Paso Limestone of his report of 1904. The basal member of the Montoya forms a smooth dark cliff above the ledges of the El Paso that weather light gray. The base of the Montoya is sharply defined and appears parallel to beds in the El Paso at single outcrops, but as the formations are traced northward, the Montoya rests on progressively lower beds in the El Paso, and the contact is probably an angular unconformity of low degree. Howe (1959, p. 2289) estimated that 245 feet of El Paso present at the south end of the Franklin Mountains was removed by pre-Montoya erosion in the southern Organ Mountains, 30 miles to the north. The rate of truncation from Anthonys Nose (pl. 2, graphic section 1) to the southern Organ Mountains (Bishop Cap) is about 128 feet in 18 miles (fig. 3).

The Montoya Dolomite is nearly 400 feet thick in the Franklin Mountains and is made up of three distinctive members that are conformable with each other and are uniform in thickness and lithology over a large region (Howe, 1959, p. 2330). The Upham Member at the base is medium-grained gray dolomite that appears to be a single bed with indistinct and widely separated laminae. The Aleman Member in the middle is fine-grained dark-gray dolomite with numerous layers, lenses, and nodules of dark-gray chert. The Cutter Member at the top is fine-grained dark-gray dolomite that is evenly bedded and contains a few chert lenses and nodules. No sandstone or shale beds are present, but quartz sand grains occur at the base of the lower member, and clay is present in dolomite throughout the formation. Silicified fossils are abundant in the two upper members, and shadowy fossil remnants are present in the lower member.

A review of Montoya terminology shows that the definition of the formation has varied since it was differentiated from the El Paso Limestone by Richardson (1908a). In extending the Montoya and Fusselman into southern New Mexico, Darton (1918, 1928a) designated the Cutter Member of this report as the lower member of the Fusselman Limestone, for Richardson's definition of the Montoya-Fusselman contact was vague. In the Sacramento Mountains, Pray and Bowsher (1952) followed Darton's terminology although they reported a disconformity between Darton's members of the Fusselman and found Ordovician fossils in the lower member. In the Caballo Mountains, Kelley and Silver (1952) found the same relationships and placed Darton's lower member in the Montoya. At about the same time, Pray (1953) redefined rocks in the Sacramento Mountains as the Montoya, Valmont, and Fusselman Dolomites. The Valmont is the same unit as the Cutter Member of this report. Kelley and Silver (1952) suggested a group status for the Montoya and named and defined the Cable Canyon, Upham, Aleman, and Cutter Formations. The three later formations are synonymous with the members of this report, and the Cable Canyon is not present in the Franklin Mountains. Although Richardson did not designate a type locality, Kelley and Silver (1952) suggested one in the Caballo Mountains, and both Pray (1958) and Howe (1959) suggested a type locality (pl. 2, measured section 5 of present report) in the northern Franklin Mountains.

The Montoya Dolomite probably accumulated far offshore in a calm shallow tropical sea. The wide distribution of the formation

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shows that the shoreline was distant, and the abundant fossils suggest a shallow sunlit bottom. The fossils, particularly the corals, suggest that the water was warm, and the thick bedding and presence of delicate unbroken fossils show that the sea was calm, although layers of broken brachiopod shells are present. As suggested by Howe (1959, p. 2330), accumulation of chert, silicification of fossils, and dolomitization occurred during or very shortly after deposition.

The Upham Member of the Montoya Dolomite is Middle Ordovician in age, and the Aleman and Cutter Members are Late Ordovician (Kottlowski and others, 1956, p. 24–26; Howe, 1959, p. 2287). Shumard (1886, p. 103) collected "lower Silurian" fossils from the Montoya as early as 1855. Fossils collected during the present investigation are listed on pages 105–109. The distribution of the fossils is shown in tables 4 and 5.

In addition to the fossils shown on table 5, the Upham Member contains *Receptaculites oweni* and species of *Calapoecia*, *Favosites*, *Streptelasma*, and *Maclurites?*, which were identified in the field by R. J. Ross, Jr. (written commun., 1957). Ross, who identified the brachiopods in this report and compared them with other Montoya collections, believes that the Aleman and Cutter Members cannot be differentiated on the basis of their fossils. A comparison of the lists on tables 4 and 5 with regional lists by Howe (1959, p. 2302, 2314, 2324) shows that he reported more brachiopod forms in the Upham and Aleman Members and fewer in the Cutter.

Of particular interest is the occurrence, very near the top of the Montoya Dolomite, of fossils (colln. D404CO, p. 105) that are definitely Late Ordovician in aspect according to R. J. Ross, Jr. (written commun., 1957). The locality lies near the crest of the mountains and is difficult to reach; it is the only place at which fossils were seen in the uppermost part of the Cutter Member.

### UPHAM MEMBER

The Upham Member is about 100 feet of gray dolomite so massive that it resembles a single poorly laminated bed. The dolomite is even grained (about 0.3 mm) and slightly porous and is finely mottled by light-gray crystalline fossil detritus, particularly crinoid stems. The fossils are randomly oriented, and large disklike snails (*Maclurites?* sp.) rest perpendicular to the bedding at places. Chert is scarce and silica occurs as crystalline cavity filling and sparse fossil replacement. The dolomite yields traces of clay on leaching by acid. The lower 30 feet of the Upham (pl. 2) yields rounded and frosted fine to coarse quartz sand grains that are effectively hidden

TABLE 4.—*Distribution of conodonts collected in the El Paso and Montoya Formations in the northern Franklin Mountains*

[Collections shown in descending stratigraphic sequence (no collections from units and members not shown). Identifications by W. H. Hass, October 1958]

| | | | USGS collection [1] | *Acodus* sp. A | *A.* sp. B | *Acontiodus* sp. A | *A.* sp. B | *Aphelognathus gracilis* | *A. grandis* | *Belodus compressus* | *Drepanodus* cf. *D. curvatus* | *D.* cf. *D. inclinatus* | *D. lineatus* | *D. subarcuatus* | *D.* cf. *D. subrectus* | *D. triangularis* | *D.* sp. A | *D.* sp. B | *Lonchodina* sp. A | *L.* sp. B | *Lonchodus* sp. A | *Neoprioniodus* sp. A | *Oistodus* sp. A | *O.* sp. B | *O.* sp. C | *Paltodus ? variabilis* | *Plectodina* sp. A | *?Rhipidognathus?* sp. A | *Roundya* sp. A | *?Scolopodus quadruplicatus* | *S.* sp. A | *S.* sp. B | *?S.* sp. C | *S.* sp. D | *Trichonodella* sp. A | *T.* sp. B | *Zygognathus* sp. A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Montoya Dolomite | Cutter Member | Dolomite unit | D417CO, D426CO | -- | -- | -- | -- | X | -- | X | X | X | -- | -- | X | -- | -- | -- | X | -- | -- | X | -- | -- | -- | -- | -- | X | X | -- | -- | -- | X | -- | X | -- | X |
| | | | D427CO | -- | -- | -- | -- | X | -- | X | X | -- | -- | -- | -- | -- | -- | -- | -- | -- | X | X | -- | -- | -- | -- | -- | -- | X | -- | -- | -- | X | -- | X | -- | X |
| | | Marl unit | D428CO, D430CO | -- | -- | -- | -- | X | X | X | X | X | -- | -- | X | -- | -- | -- | X | X | -- | X | -- | -- | -- | -- | X | X | X | -- | -- | -- | -- | -- | X | X | X |
| | Aleman Member [2] | | D431CO | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | X | -- | -- | -- | -- | -- | -- | -- | -- | |
| El Paso Limestone | Upper member | Dark-gray limestone. | D429CO | -- | -- | -- | -- | X | -- | X | X | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | X | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | X | -- | -- | -- | |
| | | | D413CO | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | X | X | -- | -- | -- | X | -- | -- | -- | -- | -- | -- | |
| | | | D408CO | X | -- | X | -- | -- | -- | -- | -- | -- | -- | X | -- | -- | X | -- | -- | -- | -- | -- | X | X | -- | -- | -- | -- | -- | X | X | X | -- | -- | -- | -- | |
| | Middle member [3] | | D424CO | -- | -- | -- | -- | -- | -- | -- | -- | -- | X | -- | -- | X | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | X | -- | -- | -- | -- | -- | -- | |
| | | | D425CO | -- | -- | -- | X | -- | -- | -- | -- | -- | X | -- | -- | X | -- | -- | -- | -- | -- | -- | -- | -- | -- | X | -- | -- | -- | -- | -- | X | -- | -- | -- | -- | |
| | | | D407CO, D433CO | -- | X | -- | -- | -- | -- | -- | -- | -- | X | X | -- | X | -- | X | -- | -- | -- | -- | -- | -- | -- | X | -- | -- | -- | -- | -- | X | -- | X | -- | -- | |

[1] See plate 2 for exact stratigraphic position, except collns. D431CO and D408CO which are not shown on plate 2 but are on plate 1.

[2] Colln. D431CO from above coral bed, colln. D429CO from below.

[3] All collections from below top of sandy zone.

TABLE 5.—*Distribution of fossils collected in the Montoya Dolomite in the northern Franklin Mountains*

[Collections shown in descending stratigraphic sequence. Identifications by W. A. Oliver, J. M. Berdan, and R. J. Ross, Jr. Query (?) indicates indefinite identification]

| | | USGS collection[1] | *Bighornia* sp. | *Palaeophyllum thomi* | *Saffordophyllum* sp. | "*Streptelasma*" sp. | *Grewingkia?* sp. | "*Streptelasma*" *trilobatum* | *Tollina* [*Manipora*] sp. | *Sceptropora* sp. | *S.* cf. *S. facula* | *Diceromyonia* sp. | *D.* cf. *D. tersa* | *Dinorthis* sp. | *Hebertella* sp. | *H.* cf. *H. sinuata* | *Hypsiptycha* sp. | *H.* cf. *H. hybrida* | *H. neenah* | *H.* cf. *H. neenah* | *H.* aff. *H. neenah* | *Isotelus* sp. | *Lepidocyclus* sp. | *Onniella* sp. | *Plaesiomys* sp. | *Platystrophia* sp. | *P.* cf. *P. equiconvexa* | *Rafinesquina* sp. | *Resserella* (or *Diceromyonia*) sp. | *Sowerbyella* sp. | *Strophomena* sp. | *Thaerodonta* sp. | *T.* cf. *T. aspera* | *T.* aff. *T. aspera* | *T.* cf. *T. recedens* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cutter Member | Dolomite unit | D404CO | | | | | | | | | | X | | ? | | | | | | | | X | ? | | | | | | | | | | | | |
| | | D415CO | | | | | | | | | | | | | | | ? | | | | | | ? | | | | | | X | X | | | | | |
| | | D416CO | X | | | X | | X | | | | | | | | | X | | | | | | | | | X | | | X | | | | | | |
| | | D417CO, D426CO | | | | X | X | | | | X | X | X | X | | | | X | | X | | | ? | | | | X | ? | | | X | X | | X | X |
| | | D418CO, D427CO | | | | | | | | | X | X | | | | | | | | | X | | | | | | | | | | | X | X | | |
| | | D419CO, D622CO | | | | | | | | | | | | | X | X | | | | | | | | | | X | | | | | | | | | |
| | Marl unit | D402CO, D403CO, D428CO, D430CO | | | | | | | | | X | | | X | X | X | X | | X | | | | | X | X | X | | | | | X | X | | | |
| Aleman Member | | D431CO | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 2370CO[2], D411CO[2] | | X | ? | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | D414CO, D429CO | | | | | | | | | | | | | X | X | | | | | | | | | | | | | | | | | | | |
| Upham Member | | 3868CO | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | |

[1] See plate 2 for exact stratigraphic position, except collns. D430CO and D431CO which are not shown on plate 2 but are on plate 1.

[2] Collection from coral bed.

by the granular texture. At places dolomitic sandstone layers one-half inch thick mark the base of the member.

Large-scale mottling of weathered surfaces in the dolomite of the Upham is produced by a projecting network of light-tan interconnected nodules at places. The lateral distribution of this nodular weathering phase is freakishly irregular, and its origin is not known. It was noted by Cloud and Barnes (1946, p. 362), and was described and illustrated by Howe (1959, p. 2297–2298), who attributed it to irregular dolomitization.

### ALEMAN MEMBER

The Aleman Member is about 150 feet of dark-gray dolomite (60 percent) with numerous layers, lenses, and nodules of dark-gray chert. Weathering produces a mottled effect, for the dolomite weathers light gray. The dolomite is dense and very fine grained, but the grains are visible to the naked eye. It is argillaceous and yields 1–2 percent of black clay on dissolving in acid. The boundaries of the chert bodies are sharp and generally irregular, and most layers appear to be formed of coalescing lenses. At places, some of the chert in the Aleman is white. The basal contact of the Aleman is sharp, but there is no evidence of unconformity.

A layer of colonial corals, *Palaeophyllum thomi* (Hall), occurs 32–43 feet below the top of the Aleman Member throughout the northern Franklin Mountains. The bed is 2–5 feet thick, and the corals, which form about half the rock, are mostly silicified. The bed of corals can be traced at least 140 miles to the east (Howe, 1959, p. 2311).

### CUTTER MEMBER

The Cutter Member of the Montoya Dolomite is 128–166 feet thick in the northern Franklin Mountains. It consists of a persistently covered marl unit about 30 feet thick, overlain by a dolomite unit. The marl unit crops out on the crest of the mountains 100 yards south of measured section 2, where it consists of nodular marl, dolomite, limestone, and shale with abundant silicified brachiopods. The dolomite unit, which forms a layered light-gray cliff capped by the massive brown-weathering Fusselman Dolomite, is in even beds 2–6 feet thick that are probably separated by shale partings. The beds are finely laminated and contain lenses and nodules of chert and sparse silicified brachiopods. The dolomite is dark gray and dense; the grains are about the size of silt. It closely resembles dolomite in the Aleman Member and yields as much as 7 percent black clay on dissolving in acid.

Variations in thickness of the Cutter are probably depositional variations, and where the member is thickest it seems to be more thickly bedded. The base appears conformable, and the top is interpreted as a disconformity of slight relief.

## SILURIAN ROCKS—FUSSELMAN DOLOMITE

The sea withdrew in Late Ordovician time and returned with the deposition of the Fusselman Dolomite in Middle Silurian time. The Silurian sea was remarkably free from terrigenous material as were the Ordovician seas, and the limestone and dolomite of the Fusselman, Montoya, and El Paso Formations contrast with the overlying shaly rocks of late Paleozoic age.

The Fusselman Dolomite overlies the Montoya Dolomite and was named by Richardson (1908a, p. 476, 479–480; 1909, p. 4) from exposures in the El Paso quadrangle. The Fusselman crops out as imposing serrated cliffs in the Franklin Mountains, where it is thick, massive, and complexly jointed. It forms the mountain crest at Anthonys Nose 2.8 miles south of the Texas-New Mexico boundary and at South Franklin Mountain 1 mile south of the area of the geologic map (pl. 1). Thickness of the Fusselman ranges from 640 feet near Anthonys Nose to 320 feet at Bishop Cap (fig. 3). Richardson did not designate a type locality, and Pray (1958, p. 30) suggested a type locality (pl. 2, graphic section 4) in the northern Franklin Mountains. The suggestion is logical because the most accessible complete exposure of the formation in the mountains is at this locality.

The northward thinning of the Fusselman Dolomite it attributed to pre-Middle Devonian erosion. The basal contact of the Fusselman is a disconformity that is virtually parallel to the underlying Cutter Member of the Montoya Dolomite, but the upper contact appears to be an angular unconformity. At measured section 3, plate 2, the overlying Devonian strata fill sinkholes or channels in the Fusselman Dolomite. On the north side of Vinton Cayon, truncation of the Fusselman by the Devonian beds has produced a southward convergence between beds in the formation that is visible in single outcrops.

The Fusselman, which is almost pure dolomite, occurs in thick beds that are remarkably free of terrigenous material. The color of the formation ranges from nearly white to dark gray and averages about medium-light gray (pl. 2). The dolomite grains are 0.2–1.0 mm in size, but most samples are even grained. The coarse varieties are generally porous. Examination of insoluble residues from columnar section 3 suggests that no quartz sand is present in the

Fusselman; two rounded orange sand grains from unit 6 of that section probably resulted from contamination of the sample. All dolomite samples yield at least a trace of clay, and dark varieties yield as much as 2 percent. Brown-weathering veinlike networks of chert are common in the dolomite, and at places they are concentrated into chert nodules which grade outward into dolomite. The chert is clear crystalline quartz in finely disseminated to clustered grains that are rhombic and similar in size to the dolomite grains; the chert is clearly of secondary origin. Insoluble residues from measured section 3 average about 1 percent, and the weight ratio of chert to clay is about 2:1. At Bishop Cap, six samples from the Fusselman averaged 0.9 percent insoluble residue (Kottlowski, 1957, p. 25–28).

Gray limestone patches surrounded by dolomite are common in the upper 100 feet of the Fusselman at most localities. The limestone is dense, aphanitic, massive, and noncherty. The patches may be undolomitized remnants of original Fusselman Limestone.

Color changes can be used to subdivide the Fusselman Dolomite locally (pl. 2). The basal 115 feet is very light gray dolomite that weathers tan at measured section 3 (p. 87–88), but the contrast with the overlying dark-gray dolomite fades northward at graphic section 4 (pl. 2), and the basal beds are dark to medium gray at graphic section 6 (pl. 2). The most persistent color band in the Fusselman is a light-gray band that is 250–370 feet above the base at measured section 3, and 243–340 feet above the base at graphic section 4, where Pray (1958, p. 36) designated it an informal middle member of the Fusselman. This light-gray band is present, but not so sharply defined, at graphic section 6, but it cannot be recognized at Webb Gap 3 miles to the north. Layers of dolomitized brachiopods occur slightly below this light-gray band at most, if not all, localities.

The Fusselman Dolomite was deposited far offshore in a shallow sea, as shown by its wide distribution and its contents of marine fossils including corals that probably grew in warm shallow water. The massive character of the dolomite and the scarcity of land-derived detritus suggest that the sea was calm or that circulation was restricted by reefs such as are common in Silurian rocks elsewhere. Pray (1958, p. 36) reported small bioherms or stromatolitic masses in the upper 100 feet of the Fusselman in the northern Franklin Mountains (pl. 2, graphic section 4, of this report). At Webb Gap and Bishop Cap, stromatoporoids are common in the Fusselman.

The Fusselman Dolomite was assigned a Middle Silurian age by Richardson (1909, p. 4) on the basis of two brachiopod types and a coral from unspecified levels in the formation. Pray (1958, p. 37) found a coral of Middle Silurian aspect near the top of the Fusselman at his suggested type locality (pl. 2, graphic section 4, of the present report).

Fossils were collected north of the mapped area (pl. 1) in an attempt to further establish the age of the Fusselman Dolomite. Near Webb Gap (SW¼ sec. 33, T. 25 S., R. 4 E., Dona Ana County, N. Mex.), where the Fusselman is 490 feet thick, the following fossils were collected from 285 to 291 feet above the base (USGS collns. 4916–SD, 4735–SD): *Favosites*, 3 spp., *Catenipora* cf. *C. simplex* (Lambe), *Halysites*, 5 spp., *Syringaxon* sp., *Tryplasma* sp., *Pentamerus* sp., *Platystrophia* sp., *Coelospira* sp., and indeterminate genera of auloporid, cyathophylloid, and streptelasmatid corals, and a gastropod. The corals, which are crudely silicified, were identified by W. A. Oliver, Jr., who regards them as definitely Silurian. P. E. Cloud, Jr., identified the brachiopods and classified them as definitely Middle Silurian.

Near Bishop Cap (NW¼NE¼ sec. 25, T. 24 S., R. 3 E., Dona Ana County, N. Mex.) the Fusselman is 320 feet thick, and the following fossils were collected 10 feet below the top (USGS colln. 4980–SD): *Favosites* sp., *Syringaxon* sp., *Pentamerus* cf. *P. oblongus* Sowerby, and an indeterminate cyathophylloid coral that is probably an undescribed genus. The corals, which are crudely silicified, were identified by W. A. Oliver, Jr., who classified them as Silurian or Devonian. The brachiopod is common in the Early and Middle Silurian ($C_3$-Wenlock), according to J. M. Berdan, who identified it.

The fossils from Webb Gap and Bishop Cap tend to confirm the Middle Silurian age of the upper half of the Fusselman Dolomite. An Early Silurian age for the lower part cannot be ruled out; fossils of that age from the Fusselman in the Sacramento Mountains were reported by Pray (1953, p. 1913–1915).

## DEVONIAN ROCKS

Beginning in late Middle Devonian time and continuing into Late Devonian time a sequence of rocks was deposited upon the Fusselman Dolomite after the Fusselman had been tilted gently southward and eroded. These were the first deposits since Late Cambrian time that contained a large percentage of clastic fragments and were largely derived from the land.

Devonian rocks were thought to be missing in the Franklin Mountains by Richardson (1909, p. 4), and their presence was first reported by King and King (1929, p. 910) and by Darton (1929). All the Devonian rocks of the Franklin Mountains were named the Canutillo Formation by Nelson (1940). Later, Laudon and Bowsher

(1949) recognized that the upper part of Nelson's Canutillo represented the Percha Shale, and they restricted the name Canutillo to only a fraction of Nelson's Canutillo. In the present report, all Devonian rocks are mapped together as a unit, but the Middle Devonian rocks are described separately from the Percha Shale of Late Devonian age. Names for Devonian units in the Franklin Mountains that have been used and those used in the present report are shown in table 6.

TABLE 6.—*Classification of the Devonian rocks in the Franklin Mountains*

<table>
<tr><th>Nelson (1940, p. 164)</th><th>Laudon and Bowsher (1949)</th><th colspan="2">Present report</th><th>Age</th></tr>
<tr><td rowspan="3">Canutillo Formation</td><td>Percha Shale</td><td colspan="2">Percha Shale</td><td>Late Devonian</td></tr>
<tr><td>Canutillo Formation</td><td>Upper part</td><td rowspan="2">Middle Devonian rocks</td><td rowspan="2">Middle Devonian</td></tr>
<tr><td>Unnamed</td><td>Lower part</td></tr>
</table>

## MIDDLE DEVONIAN ROCKS

North of Vinton Canyon, Middle Devonian rocks are exposed on the east front of the Franklin Mountains. From Vinton Canyon south to Avispa Canyon, the Middle Devonian crops out on the west slope of the mountains. South of Avispa Canyon, it is missing at the surface because of the Avispa fault. In the mapped area (pl. 1), the Middle Devonian ranges in thickness from 116 feet at Avispa Canyon (pl. 2, graphic section 7) to 97 feet at North Anthonys Nose (measured section 9) where the uppermost part is missing due to post-Devonian erosion.

The Middle Devonian is thin-bedded dark-gray marl, chert, and shale that is divisible into a cherty lower part and a shaly upper part. Although the parts are distinctive, apparently the boundary between them is gradational, and the upper part grades into the overlying Percha Shale.

Middle Devonian rocks were probably deposited near the shore in a muddy sea that transgressed northward across the Fusselman Dolomite. Unfossiliferous dark-gray chert and marl give way upward to alternating black shale and fossiliferous marl. The fossils are mostly phosphatic types that are common in black stagnant water sediments: inarticulate brachiopods, conodonts, and conulariids; calcareous brachiopods are also present.

All the Devonian rocks beneath the Percha Shale in the Franklin Mountains are probably late Middle Devonian in age, according to J. T. Dutro, Jr., and W. H. Hass, who identified the fossils listed on page 109. At Vinton Canyon, the upper part yielded brachiopods and conodonts (USGS locs. 5821 SD, 5823 SD) in an assemblage that is regarded by Dutro and Hass (written commun., 1956) as late Middle Devonian. Above the Fusselman Dolomite at Avispa Canyon, the base of the lower part yielded a similar association of fossils (USGS locs. 4696–SD and 4697–SD) as well as a productellid brachiopod that effectively rules out a pre-Middle Devonian age (J. T. Dutro, Jr., written commun., 1957). Stratigraphically lower beds between Vinton and Avispa Canyons are unfossiliferous.

As indicated by King, King, and Knight (1945, sheet 2), Devonian rocks in the Franklin Mountains are identical with those in the Hueco Mountains to the east, where a similar division of cherty beds overlain by shale is present. The cherty beds may also correspond in part to the Caballos Novaculite of the Marathon region, about 200 miles southeast of the Franklin Mountains. Northward, Middle Devonian rocks diminish in thickness to 40 feet at Bishop Cap (fig. 3), where the upper part is either absent or cannot be separated from the Percha Shale. The cherty lower part evidently pinches out in the Organ Mountains, but the fossiliferous upper part may be of the same age as the Onate Formation of the San Andres Mountains (Stevenson, 1945, p. 221–222; Laudon and Bowsher, 1949, p. 34–36).

### LOWER PART

The cherty lower part is interlensed dark-gray chert and marl overlying a few feet of persistently covered shale, limestone, and dolomite breccia derived from the Fusselman Dolomite. Chert in lenses ½–2 feet thick makes up about half the lower part. Bedding in the enclosing marl curves around the chert lenses, and the marl is intricately fractured as if the chert was emplaced after the marl was deposited. On weathering, the marl is light gray and the chert is limonite stained. The lower part is 68–90 feet thick in the mapped area (pl. 1).

The oldest beds in the lower part are confined to ancient pot holes or channels in the Fusselman Dolomite 0.6 of a mile southwest of Anthonys Nose (pl. 2, graphic section 3). The depressions are filled by a maximum of about 25 feet of thin-bedded unfossiliferous limestone and shale that appears to be older than the basal beds that yielded fossils at Avispa Canyon (USGS colls. 4696–SD, 4697–SD).

### UPPER PART

The shaly upper part of the Middle Devonian sequence is calcareous dark-gray shale with thinner beds of dark-gray marl and limestone. The shale is identical with the Percha Shale. The marl and limestone are in unfossiliferous beds that are generally less than a foot thick. A single unlaminated bed of black sandy limestone weathers brown and marks the top of the Middle Devonian. Laudon and Bowsher (1949, fig. 17) showed an unconformity beneath the Percha Shale, but the contact appears conformable and the upper part of the Middle Devonian closely resembles a transition zone between the cherty lower part and the Percha.

### PERCHA SHALE

Overlying the Middle Devonian rocks in the Franklin Mountains is black shale that was correlated with the Percha Shale of southwestern New Mexico by Laudon and Bowsher (1949, p. 36) because of its lithology and stratigraphic position. The Percha occurs only in the north half of the the Franklin Mountains; it is missing south of Avispa Canyon because of the Avispa fault at the west base of the mountains. From Avispa Canyon to Vinton Cayon, the Percha is on the west slope of the mountains; from Vinton Cayon northward, it is on the east front. The Percha is 99 feet thick at Avispa Canyon (pl. 2, graphic section 7) and 71 feet thick at Vinton Canyon (pl. 2, graphic section 8). It is locally missing beneath an unconformity at North Anthonys Nose (pl. 2, measured section 9).

The Percha consists of calcareous black shale that is persistently covered by talus in the Franklin Mountains. No fossils were seen in it.

The Percha Shale in the Franklin Mountains is assigned a Late Devonian age because it overlies upper Middle Devonian rocks and is separated from Mississippian rocks by an unconformity. Thickness variations in the Percha northward to the southern Organ Mountains are shown in figure 3. Truncation of the Percha by the Las Cruces Limestone at North Anthonys Nose is local, for the Percha reappears at Webb Gap and thickens to 183 feet at Bishop Cap. To the east, the Percha of the Hueco Mountains is about 100 feet of unfossiliferous shale that is lighter in color than in the Franklin Mountains (King and others, 1945, sheet 2). Regional distribution of the Percha in southern New Mexico was described by Kelley and Silver (1952, p. 75–78), who suggested that the Percha includes both Upper Devonian and Lower Mississippian rocks at places and that it may be younger in southwestern New Mexico than in southeastern New Mexico.

## MISSISSIPPIAN ROCKS

Mississippian rocks in the Franklin Mountains include the Upper Mississippian Las Cruces, Rancheria, and Helms Formations of Laudon and Bowsher (1949). They are thinly alternating marine limestone and shale that were deposited without major interruption after the Percha Shale had been folded at North Anthonys Nose. The Mississippian rocks are like the Devonian rocks in that thin units persist for miles; they contrast with the irregularly bedded Pennsylvanian limestone and shale. The lower Mississippian Lake Valley Limestone, which is present in the Sacramento, San Andres, and northern Organ Mountains of New Mexico, is missing by erosion or nondeposition in the Franklin Mountains. The Las Cruces, Rancheria, and Helms Formations were deposited in a single basin that lay south of lat 32° 30′ and included the Franklin, Hueco, and southern Organ Mountains. The shaly Upper Mississippian rocks at Bishop Cap (fig. 3) are so unlike the massive Lake Valley Limestone 15 miles to the north that Dunham (1935, p. 46–47) erroneously reported that Mississippian (and Devonian) rocks were absent in the southern Organ Mountains.

Although Richardson (1909, p. 4) thought that Mississippian rocks, like those of Devonian age, were missing in the Franklin Mountains, their presence was reported by King and King (1929) and by Darton (1929). Formation names that have been proposed for Mississippian rocks in the Franklin Mountains and those used in the present report are shown in table 7.

### LAS CRUCES LIMESTONE OF LAUDON AND BOWSHER (1949)

Unconformably overlying Devonian rocks in the Franklin Mountains is the Las Cruces Limestone, which was named by Laudon and Bowsher (1949, p. 17) from exposures at Vinton Canyon. On weathering, the Las Cruces forms a characteristic light-gray band at the base of cliffs capped by cherty brown-weathering limestone of the Rancheria Formation. Like the other Devonian and Mississippian rocks, outcrops of the Las Cruces are limited by faulting to the north half of the mountains, where it is 50–90 feet thick. It was mapped with the Rancheria Formation on the geologic map (pl. 1).

The Las Cruces is a fine-grained black limestone in even beds about 1 foot thick that are probably separated by shale partings. The limestone weathers white and is so dense and brittle that it shatters much like glass when broken. Upon dissolving in acid, the limestone yields 10 percent black clay, tiny pyrite cubes, and sparse silicified ostracode valves. At most places the Las Cruces is chert free, but at

TABLE 7.—*Classification of the Mississippian rocks in the Franklin Mountains*

<table>
<tr><th colspan="2">King, King, and Knight (1945)</th><th>Laudon and Bowsher (1949)</th><th colspan="2">Present report</th><th>Midcontinent provincial series</th></tr>
<tr><td rowspan="5">Helms Formation</td><td>Upper member</td><td>Helms Formation</td><td colspan="2">Helms Formation [1]</td><td>Chester</td></tr>
<tr><td rowspan="4">Lower member</td><td rowspan="3">Rancheria Formation</td><td>Upper member</td><td rowspan="3">Rancheria Formation [2]</td><td rowspan="4">Meramec</td></tr>
<tr><td>Middle member</td></tr>
<tr><td>Lower member</td></tr>
<tr><td>Las Cruces Formation</td><td colspan="2">Las Cruces Limestone [2]</td></tr>
</table>

[1] As used by Laudon and Bowsher (1949).
[2] Of Laudon and Bowsher (1949).

North Anthonys Nose (measured section 9), layers of black chert a few inches thick are present in the basal 20 feet.

Fossils are scarce in the Las Cruces Limestone, and Laudon and Bowsher (1949, p. 17, 37–38) considered it Meramec in age on the basis of a meager fauna and a lithologic resemblance to the overlying Rancheria Formation. The Las Cruces and Rancheria Formations are confined to the same depositional basin, and appear to be conformable although Laudon and Bowsher (1949, p. 17) reported a "conspicuous unconformity."

Northward, the Las Cruces Limestone persists at least as far as Bishop Cap (fig. 3) in the southern Organ Mountains. About 7 feet of limestone in the southern San Andres Mountains has been correlated with the Las Cruces by Laudon and Bowsher (1949, p. 42). To the east, the Las Cruces has not been identified in the Sacramento Mountains, but graphic sections by King, King, and Knight (1945, sheet 2) suggest that it is present in the Hueco Mountains, where it contains varying amounts of shale and thins southward toward Rancheria Mountain.

### RANCHERIA FORMATION OF LAUDON AND BOWSHER (1949)

The Rancheria Formation overlies the Las Cruces Limestone and was named by Laudon and Bowsher (1949, p. 17), who chose Vinton Canyon in the Franklin Mountains as the type locality although they derived the name from a Hueco Mountain locality where the formation is well exposed. Outcrops of the Rancheria, which occur only in the north half of the Franklin Mountains, are characterized by thin beds of laminated nearly black cherty limestone that weather brown. The Rancheria is 362–390 feet thick in the mapped area (pl. 1).

Most limestone beds in the Rancheria are partly silicified by secondary chert, but chert-free limestone near the middle of the formation weathers nearly white and divides it into three members throughout the Franklin Mountains and at Bishop Cap in the southern Organ Mountains (fig. 3 and pl. 2). Limestone beds in both the lower and upper members are separated by poorly exposed gray shale or siltstone; fine quartz sand is present in limestone of the upper member. Thin porous beds of coarse crinoidal limestone occur in the lower and upper members at most places.

As established by Laudon and Bowsher (1949, p. 17), the Rancheria Formation is of Meramec age, and its fauna resembles that of the Moorefield Shale of Arkansas. Fossils in the Rancheria are numerous but difficult to extract; the new collections listed on page 110 of the present report do not add materially to the lists of Laudon and Bowsher (1949).

Northward, the lower and upper members of the Rancheria diminish in thickness, and the formation is 196 feet thick at Bishop Cap in the southern Organ Mountains. Farther north the Rancheria is 200 feet thick at Bear Canyon in the southern San Andres Mountains, where it rests unconformably on the Lake Valley Limestone, and a few miles still farther north it wedges out (Laudon and Bowsher, 1949, p. 42; Kottlowski and others, 1956, p. 35). To the northeast in the southern Sacramento Mountains, the Rancheria also wedges out northward above the Lake Valley Limestone (Laudon and Bowsher, 1949, p. 31). In the Hueco Mountains to the east, the Rancheria ranges erratically in thickness from 200 to 400 feet (King and others, 1945, sheet 2).

### LOWER MEMBER

The lower member of the Rancheria Formation is brown-weathering cherty limestone and poorly exposed siltstone and shale. The limestone, which is dense, fine grained, and nearly black, yields 20 percent black clay when it is dissolved in acid. The limestone beds are finely laminated and average 1–2 feet in thickness. The tops and the bottoms of many beds are silicified by dark-gray chert, like the chert in the upper member that grades into limestone in the interior of the beds. Bedding lamination is preserved in the chert, which is clearly secondary in origin. The siltstone and shale beds, which are persistently covered, make up about 25 percent of the member although some beds are as thick as 7 feet. The lower member averages about 130 feet in thickness in the mapped area (pl. 1), and, except that it contains no sand, it is identical with the upper member of the Rancheria.

Uncemented crinoid debris in beds less than 10 feet thick occurs in the lower member of the Rancheria at Vinton Canyon (pl. 2, graphic section 8) and at Webb Gap north of the mapped area. The beds are unlaminated and their upper surfaces swell slightly at the expense of the overlying limestone. The rock is almost entirely composed of broken crinoid stems ⅛–¼ inch in diameter. Despite the clastic appearance, fragile brachiopods are unbroken. Only traces of clay and silicified fossil fragments remain when the rock is dissolved in acid.

Fossils are sparse in the lower member of the Rancheria.

### MIDDLE MEMBER

The middle member of the Rancheria is fine-grained black limestone that forms a white band in weathered hillsides and resembles the Las Cruces Limestone. It is in unlaminated even beds about 1 foot thick that are probably separated by shale partings. The limestone contains neither sand nor the secondary chert that characterizes the lower and upper members of the Rancheria Formation, but it yields 10 percent black clay on dissolving in acid. The middle member is 28–42 feet thick in the mapped area (pl. 1), and it is 41 feet thick at Bishop Cap (fig. 3).

A shale bed 1–2 feet thick that contains abundant calcareous brachiopods (*Torynifer?* sp., USGS colln. 16673–PC) is at the top of the member at most places. Silicified brachiopods and black chert nodules occur in the member at Bishop Cap.

### UPPER MEMBER

The upper member of the Rancheria Formation is brown-weathering limestone with siltstone or shale in the upper part. The limestone is dense, fine grained, and nearly black. It is delicately laminated and contains 1–10 percent fine quartz sand and 15–20 percent black clay. Many beds are silicified along the bedding planes by chert that grades outward into the limestone through a limonite-stained rind that is finely granular calcite and silica. The centers of the chert lenses are dense dark-gray chert in which sand grains, laminations, and fossils are dimly visible. The upper member of the Rancheria is 202–230 feet thick in the mapped area (pl. 1).

The basal 50 feet of the member has no shale partings and is finely cross-laminated sandy and cherty limestone that forms the most prominent cliff between the Fusselman Dolomite and the Magdalena Formation. The limestone is unfossiliferous and caps the lower member of the Helms Formation as used by King, King, and Knight (1945, sheet 2).

The upper part of the member contains poorly exposed siltstone or shale beds separating thin beds of cherty, sandy, fine-grained fossiliferous limestone. The siltstone or shale beds compose about 30 percent of the thickness. They are more numerous toward the top of the formation. This fact suggests that the Rancheria lithology grades into the Helms because there was a decreasing lime supply in the sea.

At most localities the member contains thin porous beds of crinoid debris identical with those in the lower member.

### HELMS FORMATION AS USED BY LAUDON AND BOWSHER (1949)

Overlying the Rancheria Formation in the Franklin Mountains is the Helms Formation. It is identical with the Helms Formation as restricted by Laudon and Bowsher (1949, p. 19) and with the upper part of the Helms Group of Beede (1920, p. 8). The Helms typically forms talus-covered slopes beneath massive cliffs of Pennsylvanian limestone. It is limited to the north half of the Franklin Mountains by faulting, where it is 231 feet thick at Avispa Canyon (pl. 2, graphic section 7), 195 feet thick at Vinton Canyon (pl. 2, graphic section 8), and 150 feet thick at North Anthonys Nose (pl. 2; measured section 9, p. 92).

The Helms is composed of calcareous gray shale and a few beds of marly olive-drab limestone that probably make up less than 10 percent of the thickness. The limestone is dense and fine grained, and at places it is oolitic; it yields 15–50 percent clay and traces of fine quartz sand on dissolving in acid. Except at the top, the limestone beds are less than 1 foot thick and form rectangular blocks on weathering.

At the top of the Helms is thinly interbedded limestone and shale in a zone that is arbitrarily included with the formation. The limestone is identical with limestone in the overlying Magdalena Formation; it is dark gray, cherty, and contains crinoid fragments, brachiopods, and snails. The zone is thickest (47 ft) at Avispa Canyon (pl. 2, graphic section 7), where the limestone beds are as thick as 3 feet.

A lens of fine-grained quartzite crops out at the top of the Helms immediately below the Magdalena Formation 0.75 mile south of the peak North Anthonys Nose (NW1/4 sec. 27, T. 26 S., R. 4 E.). The lens is about 20 feet thick, and a tree-trunk impression in it was identified from photographs as *Lepidodendron* sp. by C. B. Read (oral commun., 1960).

Fossils from the upper part of the Helms indicate a Chester age, according to Laudon and Bowsher (1949, p. 19–20). Additional brachiopods, snails, and ostracodes from the middle and upper parts of the Helms are listed on pages 110–111 of the present report. They support the age assignment of Laudon and Bowsher, according to J. T. Dutro, Jr., and I. G. Sohn (written commun., 1956).

Outcrops of the Helms occurs only in the Franklin, Organ, Sacramento, and Hueco Mountains, although rocks of like age occur in wells in southeastern New Mexico and in mountain ranges of southeastern Arizona. The Helms thins gradually and regularly northward to 104 feet in the southern Organ Mountains (fig. 3) and is missing in the San Andres Mountains. It is 60 feet thick in the southern Sacramento Mountains (Pray, 1954, p. 99) and wedges out northward, apparently because of pre-Pennsylvanian erosion. In the Hueco Mountains to the east, it is 35–110 feet thick (King and others, 1945, sheet 2).

## PENNSYLVANIAN ROCKS

The Pennsylvanian System is represented in the Franklin Mountains by the Magdalena Formation, which accumulated without perceptible erosion of the soft shale of the Helms Formation. Throughout Pennsylvanian time, the area probably lay beneath the sea near the axis of a north-treading trough, the Orogrande basin (Kottlowski, 1959). The trough sank continuously as the shallow sea received the Magdalena sediments, and the nearest imposing landmass was northeast of the present Sacramento Mountains. If the area emerged from the sea at the end of Pennsylvanian time, no physical evidence remains, for the Magdalena Formation appears to grade into the overlying Hueco Limestone in the Franklin Mountains.

### MAGDALENA FORMATION

Pennsylvanian rocks in the Franklin Mountains were called the Magdalena Formation by Nelson (1940, p. 165). They were part of the Hueco Formation (Richardson, 1904, 1908a, 1909) which included all strata between the Silurian and Cretaceous Systems. The Magdalena is about 2,700 feet thick and forms a series of cliffs and slopes on the west side of the Franklin Mountains from their northern tip southward (pl. 1). To the south, Cretaceous rocks are in contact with lower Paleozoic rocks along Avispa fault at the west base of the mountains, and exposures of the Magdalena Formation are limited to slices in the fault zone.

The Magdalena of the Franklin Mountains was deposited in the same sea as Pennsylvanian rocks throughout southern New Mexico, but because the beds are discontinuous, many local names have been used (Kelley and Silver, 1952, fig. 11). The Pennsylvanian rocks have been termed the Magdalena Series in the Organ Mountains (Dunham, 1935), the Magdalena Limestone in the Hueco Mountains (King and others, 1945), and the Magdalena Group (with local formations) in the Caballo and Sacramento Mountains (Kelley and Silver, 1952; Pray, 1954). In southern New Mexico, 15 formations proposed by Thompson (1942) are not now in use because they are based on fusulinid zones and because their lithologic boundaries are vaguely defined. Midcontinent series names based on fusulinids have formed the basis of classification in the San Andres Mountains and Robledo Mountain (Kottlowski and others, 1956; Kottlowski, 1960). Division of the Pennsylvanian into mappable genetic units, such as Read and Wood (1947) established in central and northern New Mexico, is needed here. In their classification, Pennsylvanian rocks were termed the Magdalena Group with formations representing a basal transgressive clastic phase, a middle widespread marine phase, and an upper regressive clastic phase. In the Franklin and southern Organ Mountains, transgressive and regressive phases have not been recognized, and the term Magdalena Formation is retained here.

The Magdalena Formation consists of limestone overlain by progressively increasing amounts of shale or siltstone and is characterized by discontinuity of beds and bedding planes. A fourfold division is present in the mapped area: (1) cliff-forming limestone at the base (La Tuna Member); (2) a unit of limestone and shale (Berino Member); (3) a unit of shale with thin limestone beds (Bishop Cap Member); and (4) a unit of silty shale which contains gypsum and a few thin limestone beds (upper member). These members, which were defined by Nelson (1940, p. 166–167), can be recognized throughout the Franklin Mountains and at Bishop Cap in the southern Organ Mountains (pls. 1, 2).

Limestone in the Magdalena ranges in type from dark gray, cherty, massive, and fossiliferous in the two lower members to light gray, noncherty, finely laminated, and unfossiliferous in the upper member. The siltstone or shale beds, which make up more than half the formation, are persistently covered by talus in all members. At the few exposures of the Magdalena, light-gray silty shale with poor fissility is the most common type, but the fresh color may be dark gray. Chert-pebble conglomerate marks the base of the upper member, and a lens of it is present in the Bishop Cap Member. Sparse sand grains occur in limestone beds in all members, but only a few thin sandstone beds are present. Fossils are abundant in all but the upper member, and they were described by Nelson (1940, p. 167–171). A few supplementary collections are listed on pages 111–112.

The Magdalena Formation in the Franklin Mountains may span all Pennsylvanian time, but because much of it is barren of fossils, the actual age limits are obscure. The upper and lower contacts, which resemble transition zones, are difficult to define. Regional fusulinid studies (Needham, 1940; Thompson, 1942) show that correlatives of all the midcontinent series except possibly the Morrow are present in most southern New Mexico mountain ranges. Although Thompson (1942, p. 28) concluded that the oldest Pennsylvanian in New Mexico occurred in the Franklin Mountains, he postulated statewide breaks at the base and at the top of the Pennsylvanian System. Rocks that are probably equivalent to Morrow, Missouri, and Virgil rocks appear to be barren of fusulinids in the Franklin Mountains. Fusulinid distribution in the Magdalena Formation of the Franklin Mountains is shown in table 8.

The members of the Magdalena used here cannot be recognized beyond some neighboring ranges. The La Tuna and Berino Members extend northward to Bishop Cap in the southern Organ Mountains, where they are 280 and 483 feet thick respectively. The La Tuna contains thin sandstone lenses at Bishop Cap, but the Berino is very

TABLE 8.—*Fusulinid distribution in the Magdalena Formation of the Franklin Mountains*

[All identifications and age determinations by L. G. Henbest except that the identification of *Triticites* sp. is from information supplied by F. E. Kottlowski of New Mexico Bureau of Mines and Mineral Resources from a specimen collected at Anthony Gap in the northern part of the mapped area (pl. 1)]

| | |
|---|---|
| Upper member (1,180± ft thick) | *Triticites* sp. (Virgil or Wolfcamp equivalent) |
| | Barren? |
| Bishop Cap Member (636 ft thick) | *Fusulina* sp. (Des Moines equivalent) |
| Berino Member (448 ft thick) | *Fusulinella* sp. (Atoka equivalent) |
| La Tuna Member (423 ft thick) | Barren? |
| | *Millerella* sp. (Morrow equivalent) |

like the Berino of the Franklin Mountains, and the overlying rocks are concealed by Quaternary gravel. In the northern Organ Mountains, Mississippian rocks are unconformably overlain by conglomeratic brown shale (Dunham, 1935, p. 46), and therefore the members of the Franklin Mountains probably cannot be recognized. To the east in the Hueco Mountains, 500 feet of limestone that makes up the lower division of the Magdalena of King, King, and Knight (1945) may be the same unit as the La Tuna Member; the other Franklin Mountains members cannot be identified, but the distribution of shale and chert-pebble conglomerate is similar. In the Sacramento Mountains to the northeast, the Pennsylvanian rocks vary erratically from place to place (Pray, 1954) and are best related to the Magdalena of the Franklin Mountains on the basis of fusulinids.

A widespread feature in Pennsylvanian rocks in the region is gypsum in the uppermost part. It is present in the Franklin Mountains (pl. 2, measured section 12) and is reported in the San Andres Mountains (Kottlowski and others, 1956) and the northern Hueco Mountains (Hardie, 1958) as well as in oil tests in the Hueco Bolson.

### LA TUNA MEMBER

The La Tuna Member was named for La Tuna, Tex. (pl. 1), and has its type area on the west side of the Franklin Mountains east of Vinton, Tex. (Nelson, 1940, p. 166–167). The member is 423 feet thick at Vinton Canyon (pl. 2, graphic section 11), where it forms imposing cliffs above the shaly Mississippian and Devonian rocks. The member is made up of dense crinoidal dark-gray limestone with abundant lenses of aphanitic black chert. The bedding planes appear to be parallel, but individual beds are discontinuous. The beds thin progressively from about 10 feet near the base to 1 foot at the top. The chert lenses are sharply bound and contain fossils. Although the La Tuna is generally thought to be a cherty limestone, thin lenses of shale are common near the top. The upper contact is indefinite and the boundary is arbitrarily drawn.

Brachiopods, silicified corals, mollusks, and bryozoa, in addition to the ever-present crinoid debris, occur throughout the La Tuna. Vertebrate remains (bones and shark teeth) occur sparsely in the upper part, as well as silicified fusulinids that are externally like species of *Fusulinella* collected from the overlying Berino Member. As noted by Nelson (1940, p. 170), brachiopods outnumber the mollusks in the La Tuna.

The La Tuna is a shallow-water accumulation of broken and unbroken fossils cemented by clayey lime mud. Discrete lenses of silica gel gathered on the sea floor during deposition and hardened to black chert. The thinning of beds toward the top of the member was probably due to increasing sea currents. At a distance, the massive outcrops of the La Tuna resemble reefs, but no swelling of the beds is apparent.

### BERINO MEMBER

The Berino Member was named for Berino, N. Mex., about 4 miles north of Anthony (pl. 1), and has its type area on the west side of the Franklin Mountains east of Vinton, Tex. (Nelson, 1940, p. 166–167). A greater amount of shale marks the base of the Berino, and the member, which is 448 feet thick at Vinton Canyon (pl. 2, graphic section 11), is characterized by a brown-banded outcrop. The member consists of shale and limestone in alternating units about 20 feet thick. At the top of the member at Vinton Canyon is 70 feet of massive limestone that persists throughout the Franklin Mountains as far north as Bishop Cap, where it occurs at the summit. Limestone beds in the Berino are identical to those in the La Tuna; they are dark gray, fine grained, and crinoidal, and contain black chert lenses. The shale is persistently covered, but where it is exposed it is silty and only partly fissile. Brown carbonaceous shale containing silicified wood fragments crops out at the base of the member, and lenses of quartz sandstone are present in limestone near the top.

Myriads of fossils occur in the Berino, and the tops of the limestone beds are marked by trails and pellets of organisms. Mollusks dominate the fauna (Nelson, 1940, p. 169–170), and brachiopods, corals, and bryozoa are common. Fusulinids are also abundant. A species of *Fusulinella* from the lower part of the Berino (USGS loc. f2429, p. 112) was identified by L. G. Henbest (written commun. May 23, 1958), and *Fusulina euryteines* occurs near the middle of the member (Nelson, 1940, p. 169, bed 71). Therefore, the Berino contains rocks equivalent to parts of both the Atoka and Des Moines Series of the midcontinent region.

Deposition of the Berino was characterized by rhythmically alternating lime and clay in a sea that must have been shallow, for life was abundant. The lime was probably accumulated by organisms during periods of clear water, but the clay was derived from the land. The fluctuating clay supply may have been caused by intermittent uplift of the land, or it may have been swept out to sea by periodic floods. Early during Berino deposition, tree trunks drifted out to sea from an unknown shore.

### BISHOP CAP MEMBER

The Bishop Cap Member was named for Bishop Cap, a peak in New Mexico 14 miles north of Anthony, and has its type area on the west side of the Franklin Mountains east of Vinton, Tex. (Nelson, 1940, p. 166–167). Originally published as Bishops Cap, the geologic name is changed in this report to agree with the spelling of the place name Bishop Cap. The member at Vinton Canyon is 636 feet thick (pl. 2, graphic section 11), and consists of poorly exposed shale (75 percent) and thin beds of cliff-forming limestone. The shale units are as thick as 100 feet and are extensively masked by a weathering veneer of puffy yellow clay which yields unbroken mollusks and brachiopods. The limestone is dark gray, dense, fine grained, and fossiliferous. Some beds are unlaminated and contain delicate leaf-like algae that suggest quiet-water deposition, but other beds are laminated and sandy. Chert occurs in sparse lenses and as nodules, pellets, and fossil replacement. The tops of many limestone beds contain lenses of limestone breccia that suggest current scour, and the section as a whole contains a few chert pebbles. The change from the more resistant Berino Member is abrupt: at Vinton Canyon 50 feet of persistently covered shale marks the base of the Bishop Cap; in New Mexico, the topmost Berino limestone bed forms a lengthy scarp along the west side of the Franklin Mountains.

Fossils are abundant in the Bishop Cap Member. The species are fewer than in the Berino, and snails, brachiopods, and clams dominate the fauna (Nelson, 1940, p. 167–168). Fusulinids are common in the limestone, and, with the possible exception of the upper quarter of the Bishop Cap, the member lies wholly within the zone of *Fusulina* (Des Moines equivalent). The fusulinids from the lower part of Bishop Cap (USGS loc. f12795, p. 112) consist of *Wedekindellina euthysepta* (Henbest) and *Fusulina distenta* Roth and Skinner which indicate middle Des Moines age according to L. G. Henbest (written commun., Dec. 12, 1959). He also recognized species of *Fusulina* of Des Moines age in a sample from 153 feet below the top of the member at Vinton Canyon (USGS loc. f12430) which are overlain by a zone that is apparently barren of fusulinids and which includes nearly all the upper member of the Magdalena Formation.

A continuing increase in the supply of clay featured deposition of the Bishop Cap, and currents became strong enough to disaggregate limestone beds and produce limestone breccia. Periods of clear-water limestone deposition decreased in frequency. The sea was probably shallow, for snails and brachiopods thrived on the muddy bottom.

### UPPER MEMBER

The upper member of the Magdalena consists of silty shale, minor limestone and gypsum, and a persistent bed of chert-pebble conglomerate which marks the base. The member is estimated to be 1,180 feet thick at Vinton Canyon, where it is mostly covered and where a hypothetical strike fault was shown in it by Richardson (1909). However, tracing of the member along the west side of the Franklin Mountains suggests that no such fault is present at Vinton Canyon. The lithology of the member must be pieced together from scattered outcrops.

The lower 159 feet of the member is partly exposed at Vinton Canyon (pl. 2, graphic section 11) where 21 feet of chert-pebble conglomerate marks the base. This bed was included in the upper part of the Bishop Cap Member by Nelson (1940, p. 167, bed 226). It consists of rounded to angular pebbles of light- and dark-gray chert in a matrix of quartz sand, and is imperfectly cemented by silica. Above the chert-pebble conglomerate are thin beds of limestone separated by poorly exposed shale. The limestone is identical with beds in the Bishop Cap Member.

The lower half of the member is partly exposed near Avispa Canyon (pl. 2, graphic section 10), where the basal conglomerate consists of 2–6 feet of sparsely conglomeratic sandstone. Limestone beds in the lower part at Vinton Canyon are not present here, and the basal sandstone is overlain by 691 feet of yellow-weathering silty shale and fissile silty limestone. The shale does not cleave as finely as pure shale and appears to grade into the limestone both laterally and vertically. The limestone is light gray, finely laminated, and noncherty; oolites and fragments of small clams were seen in one of the beds. The ratio of shale to limestone is estimated at 8:1.

The upper 480 feet of the member is partly exposed near the Texas-New Mexico boundary at graphic section 12 (pl. 2). The lower half (units 1–20) closely resembles the lower member at graphic section 10 (pl. 2): yellow silty shale (90 percent) separates thin beds of fissile light-gray limestone that is barren of chert and fossils. In the upper 223 feet of the member (units 21–42), limestone beds increase in frequency and thickness and total about half the rocks measured; toward the top of the member the limestone becomes darker, more massive, and contains chert nodules and a few fossils. The limestone beds are separated by yellow silty shale and gypsum. Only thin gypsum beds crop out at the locality of graphic section 10 (pl. 2), but 0.6 mile to the northwest (NW¼ sec. 33, T. 26 S., R. 4 E., Dona Ana County, N. Mex.) a thick bed is quarried 85–197 feet below the top of the member.

The upper member of the Magdalena Formation is virtually barren of fossils in the Franklin Mountains. Two collections of megafossils listed on page 111 are not definitive, according to E. L. Yochelson (written commun., 1956). Nearly all 18 mollusks and five brachiopod genera from the lower part of the upper member at Vinton Canyon (USGS loc. 16356–PC) were reported from the Berino and Bishop Cap Members by Nelson (1940, p. 167–170). Despite the scarcity of fossils, the upper member probably contains both Missouri and Virgil equivalents for they are present in the nearby Hueco Mountains and Robledo Mountain (King and others, 1945; Kottlowski, 1960).

The sea was probably shallow while the upper member of the Magdelena was being deposited, for the limestone beds are finely laminated as if by currents. As the gypsum was probably deposited in restricted seas, the lack of organisms may have been due to increasing mud and salt in the water.

## PERMIAN ROCKS

At the beginning of Permian time, the area of the Franklin Mountains remained beneath the sea, and therefore the supply of shaly land detritus that characterized the Magdalena Formation gradually decreased. As the sea became clear, organisms thrived in the warm shallow water and accumulated to form the unlaminated beds of the Hueco Limestone. Deposition in the sea continued without interruption well into Early Permian time, but the record is then lost, for Cretaceous rocks probably rest directly on the Lower Permian Hueco Limestone, although the contact is not exposed in the Franklin Mountains.

### HUECO LIMESTONE

Overlying and grading into the Magdalena Formation in the Franklin Mountains is the Hueco Limestone, a term now applied only to the upper or Permian part of the Hueco Formation of Richardson (1904, 1908a, 1909). The Hueco crops out intermittently in the western foothills of the mountains and in small outliers surrounded by basin deposits east of the mountains near Anthony Gap. Although the top is not exposed, more than 2,046 feet of Hueco Limestone occurs above the Magdalena Formation in a single fault block south of Avispa Canyon, and the total thickness is at least 2,300 feet (pl. 2, graphic sections 14a, 14b).

The Hueco is characterized by massive beds of gray cherty fossiliferous limestone and persistent beds of marly yellowish-gray siltstone. It is lighter in color and more evenly bedded and contains less shale than the Magdalena Formation. Although the beds lack variety, they are persistent, and the presence of two layers of yellow siltstone that contain abundant fusulinids permits separation of the Hueco into the three units shown on the geologic map (pl. 1). As shown in table 9, the units do not represent major lithologic changes

TABLE 9.—*Lithologic correlation of the Hueco Limestone in the Franklin and Hueco Mountains*

| Northern Franklin Mountains (Measured sections 1, 13, 14a, 14b, 14c) | | | | Hueco Mountains (King and others, 1945) | |
|---|---|---|---|---|---|
| Unit | Thickness (feet) | Dominant lithology | Thickness (feet) | Rock unit | Thickness (feet) |
| Upper | 455 | Cherty light-gray limestone | 70 | Deer Mountain Red Shale Member | 180 |
| | | Red siltstone | 106 | | |
| | | Thin-bedded cliff-forming cherty gray limestone | 193 | | |
| | | Siltstone marker bed | 17-86 | Upper division | 740 |
| Middle | 1,171-1,198 | Cliff-forming cherty gray limestone | 394 | | |
| | | Noncherty unfossiliferous dark-gray limestone interbedded with siltstone. | 486 | Middle division | 260-350 |
| | | Cherty gray limestone, thin-bedded at base, massive at top | 254 | | |
| | | Siltstone marker bed | 37-64 | | |
| Lower | 658-742 | Cherty gray limestone with siltstone beds as thick as 20 ft near base. | 428-480 | Lower division | 310-470 |
| | | Cherty limestone marker bed | 16-34 | | |
| | | Thinly interbedded limestone, gypsum, and shale or siltstone. | 214-228 | Powwow Conglomerate Member<br>Absent | |

in the Hueco nor do they correspond with the divisions established in the Hueco Mountains by King and others (1945).

Brachiopods, snails, corals, and fusulinids are abundant in the Hueco Limestone except for the middle part of the middle unit. Fossils collected from the Hueco are listed on pages 112–119. Only fusulinids were systematically collected, and their distribution, based on identification by L. G. Henbest, is shown in table 10.

Most of the Hueco Limestone is in the Wolfcamp Series, but the upper part is equivalent to the lower part of the Leonard Series. The fusulinids collected from the base of the Hueco to the upper part of the middle unit are characteristic of the Wolfcamp. According to L. G. Henbest (written commun., July 2, 1958), fusulinids collected from the base of the upper unit and from 130 feet below it near Avispa Canyon (pl. 2, graphic section 14c, units 129 and 122; USGS locs. f12417, f12418, f12435) appear to be Leonard species above the normal range of the Wolfcamp genus *Pseudoschwagerina*. However, several species of *Pseudoschwagerina* occur in beds assigned to the upper unit 4 miles to the south (pl. 2, measured section 13, unit 8; USGS loc. f12423), and they are of Wolfcamp aspect according to Henbest. The beds are assigned to the upper unit because (1) they underlie 270 feet of fusulinid-barren rocks including brown, red, and yellow siltstone that is not present ner Avispa Canyon, and (2) they contain brachiopods (USGS loc. 16656–PC) very similar to those in the siltstone marker bed at the base of the upper unit near Avispa Canyon (USGS loc. 16654–PC). The correlation between graphic sections 13 and 14c is shown on plate 2.

A Leonard age for the upper beds is suggested by the similarity of the variegated siltstone at measured section 13 (units 11, 12) with the Deer Mountain Red Shale Member, upper member of the Hueco in the Hueco Mountains. Although Thompson (1954, p. 19) included all the type Hueco Limestone in the Wolfcamp Series the Deer Mountain is generally assigned to the basal part of the Leonard Series (King and others, 1945; Bachman and Hayes, 1958).

Eastward, near the crest of the Hueco Mountains, the Hueco is thinner than it is in the Franklin Mountains. The thinning seems to be due to missing beds at the unconformity at the base, as well as to depositional thinning of all major units. The correlations shown on table 9 are based on lithologic comparisons and are reinforced by an examination of rocks in the western foothills of the Hueco Mountains, 4 miles west of Powwow Tank and 1 mile north of U.S. Highway 62. At this locality, the Hueco is underlain by a zone 600 feet thick of thin-bedded limestone and shale or siltstone that appears to be missing at the basal Hueco unconformity in Powwow Canyon

TABLE 10.—*Fusulinid distribution in the Hueco Limestone, northern Franklin Mountains, Tex.*

[Collections shown in descending stratigraphic sequence. Identifications by L. G. Henbest. Query (?) indicates indefinite identification]

| Unit in Hueco Limestone | USGS collection | | | *Ozawainella huecoensis* | *Parafusulina linearis* | *P. schucherti* | *Paraschwagerina* sp. | *P.? nelsoni* | *Pseudofusulina emaciata* | *P. huecoensis* | *P. powwowensis* | *Pseudoschwagerina* sp. | *P. beedei* | *P. convexa* | *P. gerontica* | *P. morsei* | *P. morsei* var. *needhami* | *P. uddeni* | *P.? laxissima* | *P.? texana* | *P.? texana* var. *ultima* | *Schubertella* sp. | *S. kingi* | *Schwagerina* sp. | *S. andresensis* | *S. bellula* | *S. diversiformis* | *S. eolata* | *S. franklinensis* | *S. hawkinsi* | *Triticites? coextenta* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Measured section[1] | | Other outcrops[2] | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 14a, 14b, 14c | 12, 13 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Upper | f12417 | f12423[3] | f12433, f12434 | | | | | X | | | | | | ? | X | X | | X | | X | X | | | X | | | X | X | X | | |
| Middle | f12418, f12435 | | | | X | | | | | | | | | | | | | | X | | | | | X | | | | X | | X | |
| | f12436 | | f12422 | | | ? | | X | | | | | | X | | | | | | X | | X | | | | | | | X | | |
| | f12437 | | f12419,[4] f12420, f12421 | | | | X | | | | | | | | | ? | | | | X | | | | | | ? | | | | | |
| | f12416 | | | | | | ? | | | | | | | | X | | | X | | X | X | | | | | | | | | | |
| Lower | f12438 | | | | | | | | | | | | | | | | | ? | | X | | | | X | | X | | | | | |
| | f12439 | f12431 | | | | | | | | | | | ? | | | | | | X | X | | | | | X | | | | | | |
| | f12440–f12443 | | | | | | ? | | X | | | | | | | | | | X | | | | | X | | | | | | | |
| | | f12514 | f12361, f12362, f12362a | X | | | | | ? | X | X | | | | | | | X | | X | | | X | ? | | | | | | | |
| | f12444–f12446 | | | | | | | | | | | X | | | | X | X | | | | | | | X | | | | | | | ? |
| | f12424, f12425, f12447–f12451 | | | | | | | | | | | X | | | | X | X | ? | | | | | | | | | | | | | ? |

[1] See plate 2 for exact stratigraphic position.
[2] See plate 1 for locality.
[3] Loc. 85 of Dunbar and Skinner (1937).
[4] These three collections are loc. 87 of Dunbar and Skinner (1937).

(King and others, 1945, sheet 2, sections M, N). The zone yields Permian fusulinids in at least the upper half, and if it is included with the overlying Hueco, the lower division of King, King, and Knight (1945) is more than 1,000 feet thick at this locality. Thus, only 5 miles west of the type locality of the Powwow Conglomerate Member, the Powwow is missing, Pennsylvanian and Permian rocks appear conformable, and the general succession resembles the Hueco of the Franklin Mountains 20 miles to the west. The Powwow may be a local conglomerate that marks the top of a narrow Pennsylvanian and Permian arch that extended northward through Sand Canyon (Bachman and Hayes, 1958) and the Sacramento Mountains (Pray, 1949).

Northward, the Hueco Limestone grades by intertonguing into a nonmarine red-bed equivalent, the Abo Formation of central New Mexico. In the Organ Mountains, most of the Hueco was removed by erosion during Cretaceous or Tertiary time; the Hueco remnant was mapped with Pennsylvanian rocks by Dunham (1935). The Hueco is present in Robledo Mountain (Kottlowski, 1960) and tongues out northward in the San Andres and Sacramento Mountains (Kottlowski and others, 1956; Pray, 1954). Tongues of Abo extend as far south as Robledo Mountain and the southernmost Sacramento Mountains (Kottlowski, 1960; Bachman and Hayes, 1958).

### LOWER UNIT

The lower unit of the Hueco consists of limestone separated by talus-covered intervals that are probably dominantly siltstone or shale, although gypsum may occur in the lower part. The unit is 742 feet thick near Avispa Canyon (pl. 2, graphic section 14a) and 658 feet thick at the Texas-New Mexico boundary (pl. 2, graphic section 12). The thinning appears to be depositional, and limestone constitutes 63 percent of the thickness at both localities. The lower unit is divided into three parts by a cherty limestone marker bed (pl. 2 and table 9).

The lower part of the lower unit is 214–228 feet thick and appears to be a transition zone between Magdalena and Hueco lithology. The base of the Hueco was arbitrarily placed at or near the stratigraphically lowest unlaminated crinoidal cherty limestone, a type that characterizes overlying Hueco beds. Other limestone beds resemble those in the upper member of the Magdalena Formation; they are light gray, laminated, silty, and contain no chert or fossils. The proportion of limestone of the Magdalena type decreases southward in the Franklin Mountains. Gypsum, sparse chert pebbles, and thin dolomite beds present at the Texas-New Mexico boundary (pl. 2, graphic section 12) are missing southward at Avispa Canyon (measured section 14a). About 115 feet of impure gypsum occurs at the top of the interval 0.8 of a mile northwest of graphic section 12 (NE¼ sec. 32, T. 26 S., R. 4 E.). The fusulinids listed in table 10 were loose specimens that apparently weathered from shale or siltstone near Avispa Canyon, and none were seen in the interval near the State line.

A light-gray limestone marker bed near the middle of the lower unit persists throughout the Franklin Mountains. Dark- and light-gray chert nodules, many of dumbbell shape, are concentrated toward the base and make up about half the rock. The limestone is crinoidal and forms a massive cliff that appears to be a single unlaminated bed 65 feet thick at measured section 14a (units 35, 36) and 26 feet thick at graphic section 12 (units 56, 57). The cherty limestone marker bed is the lowest Hueco bed exposed at Vinton Canyon.

Above the cherty limestone marker bed, the lower unit is gray to dark-gray crinoidal cherty limestone separated by talus-covered intervals. The limestone beds are generally unlaminated and average about 3 feet in thickness. Fossiliferous dark- and light-gray chert nodules are abundant in the limestone beds. No gypsum was seen in the talus, and the covered intervals are probably silty shale. Fusulinids are abundant in the limestone, but are sparse in talus derived from the covered intervals.

### MIDDLE UNIT

The middle unit of the Hueco Limestone is mostly limestone (67 percent), but persistent siltstone zones permit separation into the four parts shown in table 9. The unit is completely exposed only near Avispa Canyon (pl. 2, graphic sections 14a, 14b, 14c), where it is 1,171 feet thick.

At the base of the middle unit is fossiliferous yellow siltstone from which weather large obese species of *Pseudoschwagerina* that characterize the outcrop throughout the northern Franklin Mountains. Numerous brachiopods, mollusks, and corals also weather from the siltstone; species collected are listed on page 118. The siltstone zone contains lenses of fossiliferous marl, and it thickens northward from 37 to 64 feet (pl. 2, graphic sections 12, 14a).

Above the fossiliferous yellow siltstone near Avispa Canyon (pl. 2, graphic sections 14a, 14b, units 79–88) is 254 feet of limestone (90 percent) interbedded with poorly exposed talus-covered siltstone. The limestone is crinoidal throughout, and contains fossiliferous gray chert nodules; the beds are generally unlaminated and range from thin in the lower part to very massive in the upper part, where they form perhaps the most imposing cliffs in the Hueco Limestone.

The massive cliff-forming limestone is overlain by 486 feet of unfossiliferous siltstone (60 percent) and limestone near Avispa Canyon (pl. 2, graphic section 14b, units 90–108). In the intermittent exposures, the siltstone is yellowish gray and unlaminated; the grains are poorly cemented quartz. The limestone is dark gray, thin bedded, and noncherty, and it contains abundant crinoid debris. A few snails appear to be the only unbroken fossils. The interval is easily eroded and is correlated with the lithologically similar middle division of the Hueco Limestone of the Hueco Mountains (King and others, 1945).

At the top of the middle unit near Avispa Canyon (pl. 2, graphic section 14c, units 109–125) is 394 feet of cherty gray limestone (90 percent) and a few thin siltstone units. The limestone lacks variety; it is gray, thin bedded, and resistant. It contains abundant chert in gray nodules and as replacements of brachiopods and snails. Crinoid stems and echinoid spines are abundant, and fusulinids are sparse.

#### UPPER UNIT

The upper unit of the Hueco Limestone is partly exposed near Avispa Canyon (pl. 2, graphic section 14c), but the thickest exposure (386 ft) is in an outlier surrounded by Cenozoic deposits near the south boundary of the mapped area (measured section 13). The unit is divided into four parts by silty intervals (pl. 2 and table 9).

An interval of fossiliferous yellowish-gray siltstone marks the base of the upper unit. Numerous fossils, including a distinctive small brachiopod (*Chonetes* n. sp.?) and large fusulinids, weather from it. Near Avispa Canyon (pl. 2, graphic section 14c, units 126–131) limestone beds are interbedded with the siltstone, and the interval is 86 feet thick. At measured section 13 (units 7, 8), 17 feet of fossiliferous siltstone and thin limestone beds are correlated with the interval on the basis of lithology despite a difference in the fusulinid fauna (table 10).

Limestone overlies the fossiliferous siltstone interval. The limestone is fine grained, gray, and thin bedded (1–3 ft) and contains nodules and lenses of light- and dark-gray chert. At measured section 13 (units 9, 10), the limestone is 193 feet thick, and the bedding is distorted as if gypsum beds had been removed by solution; no other evidence of gypsum is present. No fusulinids were seen in the interval.

Variegated siltstone overlies the thin-bedded limestone at measured section 13 (units 11, 12). The siltstone is brown, purplish-red, and yellow, and the bedding is contorted as if by solution of gypsum. The interval, which is 106 feet thick, includes sandy mudstone and is unfossiliferous. It is tentatively correlated with the Deer Mountain Red Shale Member of the Hueco Limestone in the Hueco Mountains (King and others, 1945).

At least 70 feet of limestone overlies the Deer Mountain correlative at measured section 13 (unit 13), and it seems to be the stratigraphically highest exposure of Hueco Limestone in the Franklin Mountains. The limestone resembles beds in the underlying Hueco Limestone. It is light gray and fine grained and contains chert nodules. The beds are fractured, slumped, and cut by veins or iron gossan. Silicified brachiopods (*Composita*? sp. and *Wellerella*? sp.) appear to be the only fossils.

## CRETACEOUS ROCKS

Lower Cretaceous rocks are presumed to rest unconformably on the Hueco Limestone in the Franklin Mountains vicinity as they do 35 miles to the east (King and others, 1945). However, marine rocks of Jurassic age are reported in the Sierra de Samalayuca 30 miles to the south of El Paso (Diaz, 1956, p. 27–29). The interval that Jurassic strata would occupy in the Franklin Mountains area is missing at the surface because of faulting.

Lower Cretaceous rocks may prove to be very thick in the El Paso area. South of the San Andres Mountains and Cooks Range in New Mexico, either the bottom or the top is hidden at most localities. Lasky (1947, p. 12) reported more than 15,000 feet of rocks in the Little Hatchet Mountains of southwestern New Mexico equivalent to the Trinity Group. Trinity equivalents are not known in the El Paso area, but they may be missing because of faulting, for they crop out in the nearby Sierra del Paso del Norte or Juarez Mountains (Strain, 1958).

As noted by Richardson (1909, p. 5), Cretaceous rocks in the Franklin Mountains are limited to small outliers detached from the main mountain mass by faults and separated from each other by a cover of Cenozoic basin deposits. Immediately across the Rio Grande, about 2,000 feet of Lower and Upper Cretaceous rocks crop out in the Cerro de Muleros (Bose, 1910). These rocks include limestone and shale equivalent to the Cretaceous Fredericksburg and Washita Groups, unfossiliferous sandstone correlate with the Dakota Sandstone (Kottlowski and others, 1956, p. 65), thin-bedded sandstone, limestone, and shale equivalent to the Upper Cretaceous Eagle Ford Shale. Upper Cretaceous rocks in the Sierra del Paso del Norte are probably thicker, for they reportedly contain coal of probable post-Eagle Ford age (Strain, 1958).

Conglomeratic sandstone, shale, and limestone in steeply dipping beds are faulted against Ordovician rocks at the west base of the mountains near the south boundary of the mapped area (pl. 1). The bedding is lenticular. The sandstone is tan and pink and poorly cemented, and it contains pebbles and cobbles of limestone and chert that may have been derived from the Hueco Limestone. The shale is maroon, violet, and tan; it is sandy and is easily eroded. One 2-foot-thick bed of marly aphanitic light-gray limestone crops out near the base of the exposure and contains remnants of snails. About 400 feet of preseumed Cretaceous rocks is present at the locality, but most of the beds are covered by talus.

These rocks may be the oldest Cretaceous beds exposed in the vicinity of El Paso. Richardson (1909, p. 5) collected *Pecten texanum* Roemer at an outcrop 1 mile to the south. This clam may be limited to equivalents of the Washita and Fredericksburg Groups (Stanton, 1947, p. 46), but the relationship of these beds to those in the mapped area was not determined. No conglomerate is reported in Lower Cretaceous rocks elsewhere in the El Paso area.

## TERTIARY AND QUATERNARY ROCKS

The area that now includes the Franklin Mountains was one of low relief and was below or near sea level throughout Paleozoic and Mesozoic time. The mountain ranges were uplifted some time after retreat of the Late Cretaceous seas. In a regional study, King (1935) concluded that uplift of the mountain ranges and igneous activity began in early Tertiary time. The felsite sill in the El Paso Limestone may have been emplaced at this time.

If mountain building began in early Tertiary time, Oligocene and Miocene deposits derived from the rising mountain blocks may be present at depth in the surrounding basins. The basin deposits now exposed are Pliocene and Pleistocene in age.

Deposition of rock waste from the mountains virtually ceased by middle or late Pleistocene time. As the supply of detritus decreased, a thin veneer of caliche accumulated to form the gravel caliche and rimrock.

Mountain uplift and igneous activity continued in Pleistocene and Holocene time and may still be in process. Faults with scarps in different stages of erosion displace the gravel and caliche rimrock along the east front of the Franklin Mountains. Lava flows cap the rimrock west of the Rio Grande, and a well near Anthony penetrated an igneous layer in the basin deposits.

The last major event recorded in the area was downcutting by the Rio Grande through the resistant gravel and caliche rimrock. This downcutting exposed the upper part of the basin deposits. The basin deposits themselves have been partly or wholly attributed to deposits by a through-flowing river or ancestral Rio Grande (Lee, 1907a, p. 21–22; Bryan, 1938, p. 207; Sayre and Livingston, 1945, p. 41; Kottlowski, 1958, p. 46–48) which is supposed to have been diverted into various intermontane basins by lava or faulting and to have emptied into the Lake Guzman region of Chihuahua. The chief evidence of a river origin for the basin deposits is the presence of rounded pebbles that could have originated in local interior drainage systems. As noted by Kelley and Silver (1952, p. 184), the evidence seems unconvincing. Apparently, sufficient water for basin-to-basin drainage did not exist until late Pleistocene time, when the river course was determined by the low point in each intermontane basin (King, 1933, p. 256–261).

Terrace gravel and windblown sand that extensively mask the basin deposits are Quaternary in age and are not differentiated on the geologic map (pl. 1). At many places along the Rio Grande and its tributaries, two or more gravel-veneered terrace levels are present below the gravel and caliche rimrock. They are destructional terraces formed during entrenchment of the Rio Grande and its tributaries, but whether they record temporary halts in erosion by the river, or are river meanders abandoned at random was not determined. Windblown sand forms a thin layer over the caliche and gravel rimrock of Hueco Bolson and is present in dunes in Mesilla Valley. Virtually stabilized sand dunes as much as 100 feet high lie immediately east of the Rio Grande floodplain from which the dunes were cast up by the prevailing westerly winds.

## TERTIARY(?)—FELSITE SILL

A felsite sill about 5 feet thick forms a white band in the lower member of the El Paso Limestone on the west side of North Franklin Mountain. The felsite is ivory to white, dense, and aphanitic; scattered grains of quartz (1 mm) and weathered ferromagnesian minerals are visible. The boundaries of the sill crosscut the limestone at places. The same or a similar sill forms a white band near the El Paso–Bliss contact along the east front of the mountains at El Paso (Cloud and Barnes, 1946, p. 367, unit 24). The sill is probably of Tertiary age by analogy with similar intrusive rocks of known Tertiary age in the region.

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## TERTIARY AND QUATERNARY—BASIN DEPOSITS

Unconsolidated deposits fill deep basins east and west of the Franklin Mountains. The basin deposits are mostly clay, silt, and sand eroded from the mountains and deposited by stream and wind, probably in mudflats and lakes. Gravel is relatively scarce in the basin deposits, even where the mountains are nearby. On the east side of mountains, about 200 feet of the basin deposits beneath the gravel and caliche rimrock have been exhumed by erosion. On the west side of the mountains, the Rio Grande has eroded them to a depth of about 300 feet below the rimrock. The outcrop area is persistently masked by a veneer of mountain outwash, dune sand, and talus, so that fresh exposures of the basin deposits are limited to steep walls in arroyos and in excavations.

The use of the term "basin deposits" follows that of King (1935). The same sediments were termed "bolson deposits" by Richardson (1909) and Sayre and Livingston (1945). The term Santa Fe Formation has been used here for the deposits in the Rio Grande depression (Bryan, 1938, p. 205; Kottlowski, 1960). However, at the north and south ends of the Franklin Mountains the upper beds beneath the caliche and gravel rimrock pass into and cannot be distinguished from unconsolidated deposits of the Hueco Bolson. It seems preferable to use a general term for all the deposits than to extend the Santa Fe Formation into the Hueco Bolson.

East of the Franklin Mountains, the basin deposits of Hueco Bolson are very poorly exposed. In the northern part of the mapped area (pl. 1), friable white sand with rounded volcanic pebbles locally crops out beneath the gravel and caliche rimrock. The sand and gravel is at least 50 feet thick on the east boundary of the mapped area in a sandpit (SW¼ sec. 30, T. 26 S., R. 6 E. Dona Ana County, N. Mex.). The gravel pinches out westward toward the Franklin Mountains, but is present north of the State line on the east tips of the terraces capped by the gravel and caliche rimrock west of War Highway 11. Rounded and frosted pebbles of volcanic glass, which characterize the gravel, were found in an experimental groundwater recharge shaft 0.8 of a mile south of the State line on the west side of War Highway 11. Extent of sand and gravel outside the mapped area is not known. Foreset beds in the sandpit dip southeastward, and the sand and gravel is probably a stream deposit derived from the southern Organ Mountains. The composition of 110 pebbles from the uppermost basin deposits niear Quirke Lake (sec. 22, T. 26 S., R. 5 E.) follows:

| *Description* | *Number of pebbles* |
|---|---|
| Volcanic. The predominant type contains white feldspar crystals and sparser quartz phenocrysts in a fine purple groundmass. Purple characterizes the Soledad Rhyolite of Dunham (1935, p. 56–60) in the Organ Mountains | 67 |
| Chert, black to white | 25 |
| Quartzite | 9 |
| Granite, pegmatite, and quartz | 8 |
| Basalt, purple, vesicular | 1 |
| Unidentified | 8 |

West of the Franklin Mountains the basin deposits of the Mesilla Valley are best exposed in the west bank of the Rio Grande, where Sayre and Livingston (1945, p. 32–33) described 227.8 feet of gray sand and brown clay beneath the caliche rimrock. Within the mapped area the upper 100 feet partly crops out along the pipelines on the west side of Anthony Gap. Here, the upper basin deposits consist of mottled reddish-brown and white silty mudstone that is indistinctly layered in intervals several feet thick. The layers are marked by white caliche zones. About 250 feet below the gravel and caliche rimrock in the southern part of the mapped area, friable to dense white sandstone crops out in walls of arroyos leading westward to the Rio Grande. The sandstone is clay free and is cemented by lime. Sparse rounded pebbles of chert and igneous rock and nodules of caliche were seen in sandstones of similar topographic and stratigraphic position north of the mapped area (sec. 1, T. 26 S., R. 3 E.).

Water wells have probed the basin deposits both east and west of the Franklin Mountains; a few on the west side of the mountains reached bedrock.

In the wells drilled east of the mountains the basin deposits of Hueco Bolson are clay and sand with some gravel and caliche (Richardson, 1909, p. 5–6; Sayre and Livingston, 1945, p. 27–33; Knowles and Kennedy, 1958, p. 17–18). The clay is generally red to brown, the sand and gravel is clean and uncemented, and the larger fragments are principally quartzite, porphyry, and granite. The deposits are coarser near the Franklin Mountains, where they contain more sand than clay. Bedding is very lenticular. In the wells drilled west of the mountains, the basin deposits of Mesilla Valley are also sand, clay, gravel, and caliche. However, the clay is usually buff or gray, and the gravel contains basalt fragments (Sayre and Livingston, 1945, p. 29).

In summary, the basin deposits are known only from scattered exposures and drill holes limited to any upper fraction of the total thickness. The deposits are more than 4,920 feet thick in a well drilled about 2 miles south of Newman, 3 miles east of the mapped area (King, 1935,p. 253). Near the east base of the Franklin Mountains, wells as deep as 1,955 feet have failed to reach bedrock. The basin deposits do not thicken as abruptly on the west side of the mountains, where numerous bedrock outliers rise above the unconsolidated deposits, and three wells reached bedrock at depths between 320 and 820 feet. Westward, a well 1 mile southwest of Anthony bottomed in basin deposits at 1,705 feet and passed through an igneous layer from 1,270 to 1,418 feet beneath the surface. The stratigraphy of the deeply buried basin deposits may be very complex.

Fossil bones and teeth found in the exposed basin deposits suggest that the uppermost beds are Pleistocene in age and that the lower part is Pliocene. Richardson (1909, p. 5–6) reported that Pleistocene mammoth, horse, and tapir teeth were found "about 100 feet below the top of the mesa" in a gravel pit near downtown El Paso. The pit was probably in the block now defined by Virginia, St. Vrain, California, and River Streets (Sayre and Livingston, 1945, p. 37). Relatively recent terrace gravels are present at the locality, but the fossils probably were found in the fine-grained basin deposits. Mammoth bones and horse bones of Pleistocene age were collected in a railroad cut below the east rim of La Mesa about 12 miles west of El Paso (Lee, 1907b, p. 215). Kirk Bryan (in Sayre and Livingston, 1945, p. 39) reported, however, that a mammoth skull of Pliocene aspect was found just below the rim of La Mesa 1½ miles west of La Union, N. Mex. Analogy with the genetically similar Santa Fe Formation to the north suggests that most of the basin deposits accumulated in Pliocene time.

## QUATERNARY—GRAVEL AND CALICHE RIMROCK

A thin layer of caliche and calichified gravel forms a resistant rimrock atop the basin deposits both east and west of the Franklin Mountains in the mapped area (pl. 1). The rimrock of the east slope is displaced by faults near the mountains and extends over much of the surface of Hueco Bolson. The rimrock of the west slope appears unfaulted and is a remnant of the caliche and gravel that cap La Mesa west of the Rio Grande. The rimrock of the east and west slopes merge to form a single plain around the north end of the mountains at Fillmore Pass north of the mapped area. Therefore, the gravel and caliche atop both Hueco Bolson and La Mesa were deposited upon a single broad plain that sloped gently away from the protruding bedrock mountains and was later dissected by the Rio Grande and its tributaries.

The rimrock of Hueco Bolson as described by Sayre and Livingston (1945, p. 28, 31–33) is commonly 2–4 feet thick and is white sandy caliche with scattered rock pebbles. The caliche is typically fractured, broken, and faintly layered; vertical columns of sand resembling plant root structures are abundant. At most places the caliche is overlain by a few feet of red sandy soil.

In the high outward-facing benches on the east and west slopes of the mountains the rimrock is composed of angular fragments of bedrock derived from the mountains and cemented by white caliche. The benches steepen progressively toward the mountains, and the rimrock thickens to as much as 50 feet. At places such as the high benches on the north side of Castner Range (pl. 1), the rimrock falsely appears to be as thick as 150 feet because of secondary calichification on the bench faces.

The gravel and caliche rimrock is of Pleistocene age. Atop La Mesa on the west side of the Rio Grande several outpourings of lava have covered the rimrock since its formation, and two flows, one of them much older in appearance than the other, cap the caliche near Kilbourne and Hunts Holes. These interesting depressions are described as volcanic explosion craters by Lee (1907b) and Darton (1916, p. 424–425; 1933, p. 134), and, with less persuasion, as subsidence features by Reiche (1940). At Aden Crater, near the Southern Pacific Railroad 50 miles northwest of El Paso, remains of a ground sloth that fell and was trapped in an extinct lava vent atop the rimrock have been found (Lull, 1929; Darton, 1933, p. 135). The animal is the same type as mid-Pleistocene forms found in tar pits at Rancho La Brea, Calif. However, as Lull noted, the Aden sloth was amazingly well preserved, and no other animals so ancient in type were found.

## HOLOCENE ALLUVIUM

Holocene alluvium forms the flood plains of most of the stream courses in the mapped area (pl. 1), and the deposits can be regarded as transient deposits temporarily halted en route to the Gulf of Mexico. The alluvium consists of gravel derived from the bedrock of the mountains and sand derived from the basin deposits. The size and proportion of gravel decreases downstream from the mountains.

The alluvium of the Rio Grande flood plain is not exposed to view and is difficult to separate from the underlying basin deposits in well cuttings. The thickness, which probably records the depth of scour during a great flood, is probably less than 200 feet, and the flood plain is generally supposed to be rising (Bryan, 1938, p. 218).

The stream courses that lead westward from the Franklin Mountains to the Rio Grande flood plain are marked by linear deposits of alluvium that form a braided pattern as they flatten and approach the Rio Grande. The thickness of this alluvium is probably 10 feet or less, and the gravel ranges from boulders in the mountains to pebbles near the river.

On the east side of the Franklin Mountains, the alluvium is confined to narrow canyons near the mountain front and merges to form a broad apron on the east and downthrown side of a curvilinear fault in the basin deposits. The alluvium has buried the older fault. On the broad apron to the east the alluvium is locally cemented by caliche and is marked by fault scarps of recent origin. Thickness ranges from less than 10 feet to as much as 300 feet on the west side of the earlier fault. A large fan of boulders of Precambrian rocks is present at the mouth of Fusselman Canyon.

## STRUCTURE

The area of the present Franklin Mountains was folded and uplifted in Precambrian time, and slowly sank and rose intermittently during the Paleozoic and Mesozoic Eras. The present mountains were raised by Cenozoic deformation, and it is this deformation that has exposed the Paleozoic and Mesozoic rocks.

### PRECAMBRIAN DEFORMATION

Precambrian deformation of the Franklin Mountain area included granitic intrusion and folding; no faulting of Precambrian age can be definitely identified. Effects of the granite intrusion and folding are shown in a restored cross section of the area as it may have appeared immediately before the El Paso Limestone was deposited (fig. 4).

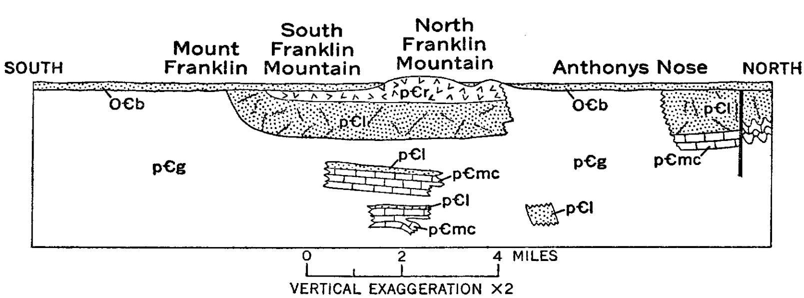


FIGURE 4.—Diagrammatic section of the Franklin Mountains area, from El Paso due north to the Texas-New Mexico boundary, at the beginning of El Paso (Ordovician) time. O€b Bliss Sandstone (Ordovician and Cambrian); p€g, granite; p€r, rhyolite; p€l, Lanoria Quartzite; p€mc, Mundy Breccia and Castner Limestone, all of Precambrian age.

Precambrian structural trends in the Franklin Mountains cannot be ascertained in the rather narrow outcrop belt. In the Van Horn region 120 miles to the southeast, Precambrian deformation trends west-northwest and involves rocks that may be equivalent to the Castner Limestone and Lanoria Quartzite. Folding there is confined to a narrow belt on the north side of a northward overthrust, and the rocks flatten northward beneath the Bliss Sandstone (King, 1940, p. 151–152).

## GRANITE INTRUSION

A large mass of granite invaded the Castner Limestone, Mundy Breccia, Lanoria Quartzite, and Precambrian rhyolite before folding, uplift, and erosion. Intrusion of the granite was not accomplished by force, for no folding in the host rock is attributed to it. The granite chemically assimilated and mechanically stoped the host rock.

The Lanoria Quartzite and the rhyolite appear to have been completely assimilated or replaced by the granite between Mundys Gap and the eastward-projecting spur of the Franklin Mountains 1.8 miles south of the Texas-New Mexico boundary. Where the granite intruded the rhyolite, the contact between them appears gradational. Where the granite intruded the quartzite, tongues of the granite extend into the quartzite without expanding the bedding. Assimilation of the rhyolite and quartzite by the granite probably enriched the magma only in silica.

The chemical compositions of the granite and rhyolite are very similar as shown by the following analyses from Richardson (1909, p. 6, 7):

| | *Granite (percent)* | *Rhyolite (percent)* |
|---|---|---|
| $SiO_2$ | 73.76 | 76.34 |
| $CaO$ | .81 | .77 |
| $K_2O$ | 5.66 | 5.76 |
| $Na_2O$ | 3.64 | 2.88 |

The Castner Limestone was probably deformed by mechanical settling and tilting of blocks into the granite. Two large blocks of the Castner are completely surrounded by granite at exposures near North Franklin Mountain (fig. 4). These blocks were torn loose from the overlying Lanoria Quartzite and appear to have sunk in the magma. Absence of the Castner in most of the mountain front may be due to such sinking of limestone blocks cut off by magmatic assimilation of the overlying Lanoria Quartzite.

## FOLDING AND FAULTING

Folding of the rocks in Precambrian time was probably associated with the uplift that preceded peneplanation of the region before the Bliss Sandstone was deposited. The folding left a broad asymmetrical synclinal depression (fig. 4) which was at least 4,000 feet deep near North Franklin Mountain; the southern limb was steeper than the northern.

One west-northwest-trending fault on the north side of Hitt Canyon could possibly be of Precambrian age. Here, the Castner Limestone on the north side is dropped against the Lanoria Quartzite (pl. 1). No Precambrian faults are apparent in the Lanoria Quartzite for a distance of 6 miles in the central part of the Franklin Mountains, nor were any recognized in the large areas underlain by the homogeneous granite.

## PALEOZOIC AND MESOZOIC DEFORMATION

In Paleozoic time the region was affected by intermittent epeirogenic subsidence and uplift. The thick sedimentary sequence accumulated on slowly sinking bottoms of shallow inland seas. Periodic retreat of the seas was caused by gentle uplift, for the formations are nearly parallel and the clastic sediments are generally fine.

In Cambrian through Mississippian time, deformation was especially gentle. A consistent pattern of regional uplift to the north and subsidence to the south was established, and all the formations except the Montoya thicken southward. As suggested in figure 3, the thickening is due both to depositional thickening and to regional angular unconformities at the bases of the Montoya Dolomite and Devonian rocks. The only suggestion of local structural deformation is a pre-Mississippian flexure at North Anthonys Nose where about 100 feet of Devonian rocks are missing beneath the Las Cruces Limestone of Laudon and Bowsher (1949). The flexure is probably an anticline, but the trend could not be established at the outcrop.

In Pennsylvanian and Permian time, deformation took the form of subsiding troughs flanked by north-trending anticlines. The area of the Franklin Mountains subsided rapidly and lay near the axis of a north-trending trough from Early Pennsylvanian through Early Permian time. East of the Franklin Mountains, linear folding culminated near the beginning of the Permian Period and produced a north-northwest-trending arch in the Hueco Mountains, Sand Canyon, and the Sacramento Mountains (King, 1935; Bachman and Hayes, 1958; Pray, 1949). Farther east, about 100 miles east of the Franklin Mountains, another northwest-trending arch formed at the site of Huapache monocline in the Guadalupe Mountains (Hayes and Koogle, 1958). A positive area also lay west of the Franklin Mountains near the present Florida and Robledo Mountains, but its form and trend are not clearly outlined.

In early Mesozoic time the area probably was structurally stable and may have been peneplaned (King, 1935, p. 236–237).

Deformation by subsidence began again in Late Jurassic time and probably continued throughout the Cretaceous Period. The regional study of King (1935, p. 236–241) suggests that El Paso lay near the north edge of a northwest-trending Late Jurassic and Early Cretaceous geosyncline in which the younger formations overlap northward onto the Paleozoic.

## CENOZOIC DEFORMATION

Cenozoic structural features in the Franklin Mountains trend north to northwest and are a result of both compression and tension, which culminated in uplift of the mountain block above the surrounding basins. Structural features caused by compression include thrust faults and, on the west slope of the mountains, anticlines and synclines. Structural features caused by tension include high- and low-angle normal faults and, probably, the Avispa fault. The pattern of the Cenozoic structural features suggests that compression preceded tension, for thrust faults and folds are cut off by the Avispa fault (fig. 5). All the features are most logically attributed to a single period of compression followed by relaxing tension at which time the mountains were uplifted along a normal fault near their eastern base.

Regional studies indicate that the pattern of early Cenozoic compressional structural features and later normal faults persists throughout the Basin and Range province in western Texas and southern New Mexico. In his description of New Mexico, Darton (1928a, p. 193, 210) suggested that the San Andres and Sacramento Mountains are anticlines outlined by the initial folding, then modified by relatively minor faulting. Baker (1928, p. 343) thought that erosion of the mountain ranges of western Texas had proceeded too far to determine whether the mountains were built by the earlier compression or the later tension. More recent descriptions of New Mexico's Organ Mountains (Dunham, 1935, p. 142–147), Caballo Mountains (Kelley and Silver, 1952, p. 135–172), Sacramento Mountains (Pray, 1954, p. 103–106), and Rio Grande depression (Bryan, 1938, p. 204, 209) tend to confirm the conclusions of King (1935, p. 244–251) that in western Texas and northern Mexico uplift of the present mountain ranges took place along normal faults after a period of compression.

The structural features can be dated only by examining the orogenically derived sediments that are buried beneath younger deposits in the El Paso region. The earlier compressional features of Trans-

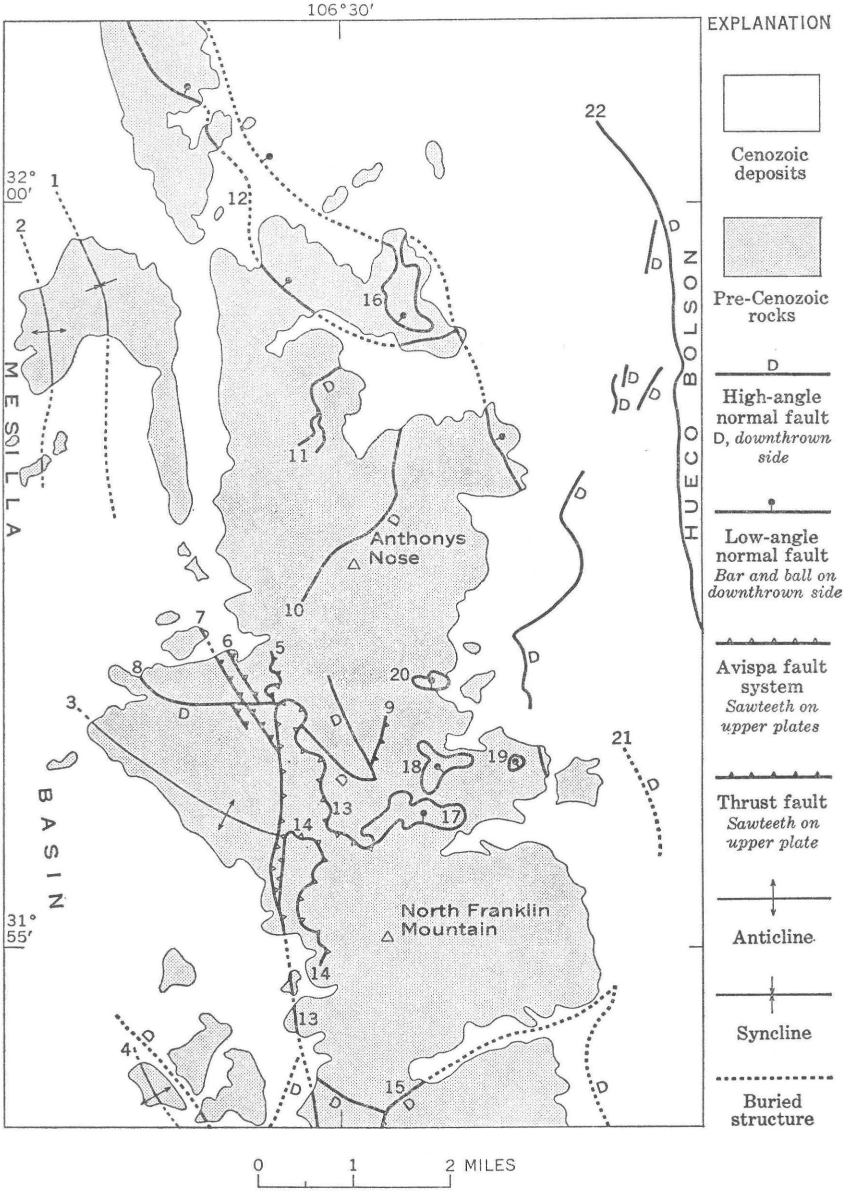


FIGURE 5.—Major Cenozoic structural features in the Franklin Mountains. Numbered features are described in text.

Pecos Texas were attributed to the first half of the Tertiary by King (1935, p. 244–245). In the Caballo Mountains of New Mexico, orogenically derived sediments are exposed, and the folding and thrust faulting is probably earliest Tertiary (Kelley and Silver, 1952, p. 136). Folding and thrusting in the Franklin Mountains appears to be a northward continuation of early Tertiary structure in the western branch of the Sierra Madre Oriental (King, 1935, fig. 7, p. 242; Kelley and Silver, 1952, p. 169). However, the overturning and overthrusting in the Franklin Mountains is westward, whereas in the Sierra Madre Oriental it is eastward.

The age of the normal faults that relatively depressed the basins and uplifted the ranges is uncertain because erosion has revealed only the upper beds of the basin deposits, and even in them faulting is difficult to detect because of poor exposure and lenticularity of the beds. The initial uplift of the mountains is generally placed in Miocene time (Baker, 1928, p. 341–342; King, 1935, p. 252; Bryan, 1938, p. 204; Kelley and Silver, 1952, p. 36). It is not known whether faulting has been a continuous process since it began, or if there was a distinct period of major uplift. Bryan (1938, p. 209) and Dunham (1935, p. 176) believed that much if not most of the mountain building occurred at the end of Pliocene time. However, proved displacement on faults involving the basin deposits is generally less than 400 feet in this region. Mountain building may still be continuing as shown by recent fault scarps along the fronts of the Franklin, East Potrillo, Organ, Sacramento, and Caballo Mountains.

Perhaps the most striking feature of the Franklin Mountains structures is the curvature of the fault planes (fig. 5; pl. 1). Recent fault scarps in the Cenozoic deposits are markedly sinuous and the Fusselman Canyon fault is a high-angle normal fault with a U-shaped trace. Other curving fault planes are the Avispa fault and the low-angle normal faults. Avispa fault is U-shaped in both plan and cross section, and the planes of the low-angle normal faults are decidedly irregular and include klippelike masses resembling landslide blocks far removed from the mountain front. The curvature may partly be due to irregularity in the basement rocks; it is not due to later folding of the fault planes. Drag folding is notably absent along most of the normal faults.

## FOLDS AND THRUST FAULTS

The folds and thrust faults in the northern Franklin Mountains that are attributed to early Tertiary compression trend northwest, and the overthrusting and overturning of folds are southwestward. All the features clearly due to compression are on the west slope of the mountains and lie west of a stable belt about 3 miles wide in which the beds may have been tilted westward at a later date. The numbers in parentheses in the following descriptions refer to features shown in figure 5 and on plate 3.

A syncline (1, fig. 5) and an anticline (2, fig. 5) lie south of the State line west of Anthony Gap (pls. 1 and 3, section *A–A′*). The axes of the structural features are slightly sinuous and parallel to the trend of the mountains; the general plunge is southward. The eastern limb of the syncline, as outlined by exposures of the resistant lower unit of the Hueco Limestone, is at least 4 miles long. The asymmetry and steeper west limbs of these folds may be products of postfold tilting of the main mountain block.

A northwest-trending anticline (3, fig. 5) in the Hueco Limestone is exposed south of Avispa Canyon (pls. 1 and 3, section *D–D′*). The anticline is decidedly asymmetric; the southwest limb is nearly vertical and the north limb dips about 20°. The anticline is cut off at the east by Avispa fault.

Near the south boundary of the mapped area (pls. 1 and 3, section *E–E′*) a narrow anticline (4, fig. 5) in the upper unit of the Hueco Limestone trends northwest. The southwest limb dips 71°, and the northeast limb dips 47°.

Three northwest-trending thrust faults are present at Avispa Canyon, and two of them (5 and 6, fig. 5) are cut off at the south by Avispa fault (pls. 1 and 3, sections *B–B′*, *C–C′*, *D–D′*, *E–E′*). At the easternmost fault (5), the massive La Tuna Member of the Magdalena Formation is thrust westward along a nearly horizontal plane over steeply dipping and overturned shale and limestone of the three overlying members of the Magdalena Formation. Maximum stratigraphic displacement is about 2,500 feet at a small klippe on the north side of Avispa Canyon, but is negligible half a mile to the north. The other two thrust faults (6 and 7, fig. 5) at Avispa Canyon (pls. 1 and 3, sections *B–B′* and *C–C′*) are high angle and have thrust the upper member of the Magdalena Formation over the lower and middle units of the Hueco Limestone. Maximum stratigraphic displacement is about 500 feet and both faults are offset along a later fault (8, fig. 5) that trends westward beneath gravel in Avispa Canyon (pls. 1 and 3, section *B–B′*).

## HIGH-ANGLE NORMAL FAULTS

High-angle normal faults in the northern Franklin Mountains include a set of northeast-trending faults that appear to be younger than the folds and thrusts and older than Avispa fault, the low-angle normal faults, and Fusselman Canyon fault. There are other high-angle bedrock faults of undetermined displacement.

Diversity of trends of these other faults suggests that they result from several periods of deformation.

The earliest normal faults trend northeastward across the mountains between North Anthonys Nose and Avispa fault (13, fig. 5). Along nine of 12 such faults, the basinward or southeast side is the downthrown side. Stratigraphic displacement along the fault (10, fig. 5) immediately south of Anthonys Nose is 800 feet where the trace crosses the Bliss Sandstone, but displacement along the other transverse faults is less than 300 feet, and they are not shown in figure 5.

A branching high-angle normal fault (11, fig. 5) north of Anthonys Nose trends north-northeastward oblique to the strike of the beds. The fault plane dips 50° E. and is almost perpendicular to the bedding.

On the east front of the mountains opposite Avispa Canyon (pls. 1 and 3, section *C–C′*) a north-northeast-trending fault (9, fig. 5) involves Precambrian granite, the Bliss Sandstone, and the El Paso Limestone, and it has a displacement of about 300 feet. The fault plane is nearly perpendicular to the beds, which dip 30° WNW. Because no folding or drag can be attributed to the fault, it may be a high-angle normal fault that has been tilted rather than a true reverse fault.

At North Anthonys Nose near the north boundary of the mapped area (pl. 1), a southeast-trending normal fault (12, fig. 5) roughly parallels the local trend of the mountains. The northeast or basinward side has been relatively downthrown. Stratigraphic displacement is negligible about 1 mile north of North Anthonys Nose but increases southeastward to more than 4,000 feet at Hitt Canyon where the El Paso Limestone on the northeast side is faulted against the Castner Limestone. The fault plane is curved and dips 20°–60° E. Its intersection with other faults near Hitt Canyon suggests that it is younger than other high-angle normal faults and older than a low-angle normal fault (16, fig. 5).

## AVISPA FAULT SYSTEM

Avispa fault (13, fig. 5) is shaped like a northward-plunging anticline in cross section (fig. 6). The west limb trends northward along the west base of the Franklin Mountains and is nearly vertical at the surface. At Avispa Canyon, the fault curves sharply eastward and doubles back in a south-southeastward direction to Mundys Gap. The fault can be traced from Mundys Gap to the eastern front of the range where it is obscured by a low-angle normal fault (17, fig. 5) that may be a landslide block (pls. 1 and 3, section *A–A′*). The

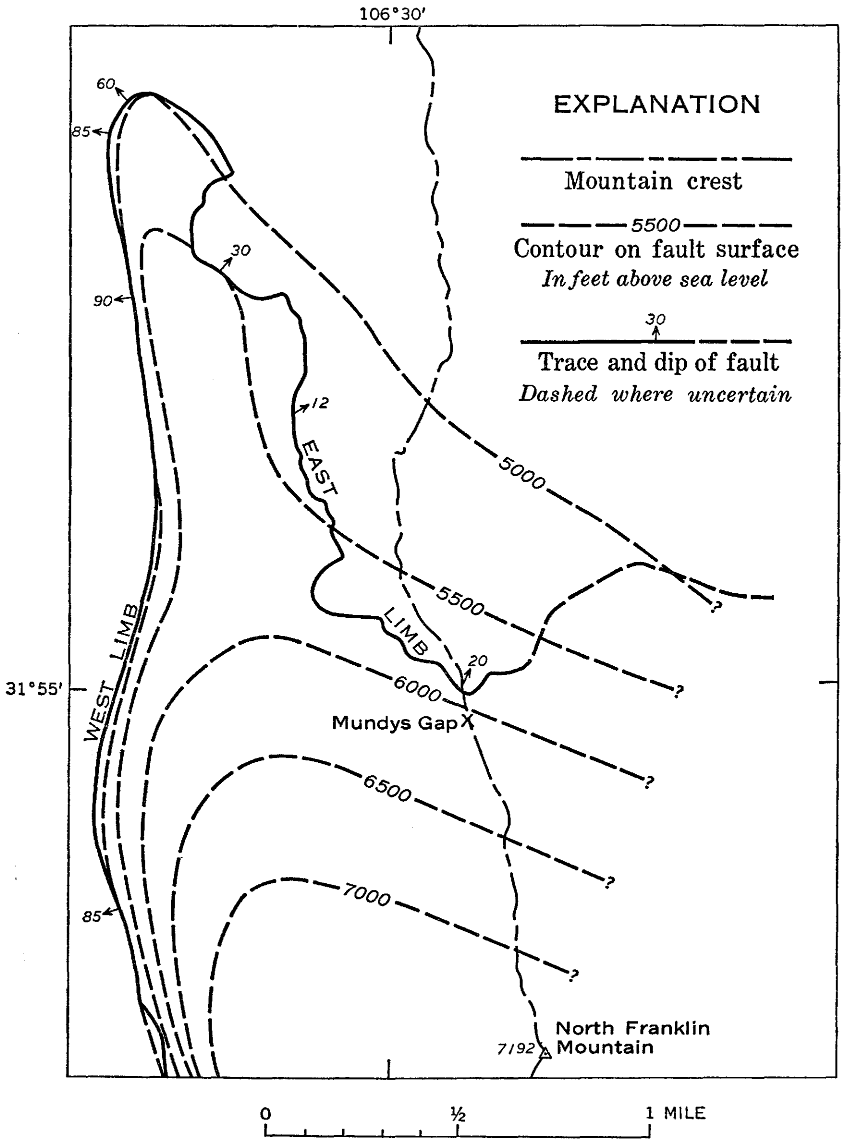


FIGURE 6.—Configuration of the Avispa fault surface.

east limb dips about 20° NE. but it may have dipped more steeply eastward before the mountains were uplifted. Thus, the trace of Avispa fault is U-shaped and is open toward the south.

The outer margin of the U-shaped Avispa fault system appears to be formed by a single great fault (13, fig. 5) which at many localities is closely paralleled on the inner side by one or two subsidiary faults. In all places the rocks in the inner plates are older than those in the next outer plate. The total apparent stratigraphic displacement along the fault system ranges from more than 7,800 feet where Cretaceous rocks are brought against the El Paso Limestone at the south boundary of the mapped area (pl. 1), to about 2,500 feet where the fault trace reverses its trend in Avispa Canyon. Northward along the west limb, a subsidiary U-shaped fault (14, fig. 5) curves into the inner block near Mundys Gap (pls. 1 and 3, sections *C–C′*, *D–D′*, and *E–E′*), and a similar one is present at McKelligon Canyon 2½ miles south of the mapped area. These two faults are the same in form and relative displacement as the main fault in Avispa Canyon, and they partly account for the northward decrease in apparent stratigraphic displacement along the fault system.

No consistent pattern of folding is associated with the faulting of the Avispa system. The large inner block, which is mostly competent Precambrian rhyolite, is nearly undeformed. The outer block, which is mostly Paleozoic limestone, shows drag folding along the western limbs of the faults, but along the eastern limb near the crest of the mountains the limestone is chaotically jumbled between faults that appear to be older than those of Avispa system. In what appears to be drag folding, the west limb of the main Avispa fault is virtually a vertical bedding plane fault at the surface, and the rocks to either side resume their normal westward dip in a short distance. On the southeast side of the fault "nose" in Avispa Canyon, older fault planes in the outer block change in attitude as they approach Avispa fault and may be drag folded by it.

Relative displacement along the Avispa fault system as well as the drag along the west limb and "nose" suggests that the outer block moved relatively downward and the inner block pierced upward. If the outer block moved either eastward or westward over the curved fault plane, the blocks probably would have been relatively twisted, yet the bedding attitude in the two blocks is similar. Conceivably the outer block moved northward or southward and the fault limbs are tear faults, but the movement would have to have been about 10 miles to bring Cretaceous rocks against the El Paso Limestone.

If the inner block pierced upward, however, it is difficult to imagine the mechanics of the movement. Locally, preexisting planes of weakness may have been selected by the fault: it is closely paralleled by a granite intrusive contact in the inner block at Mundys Gap, and incompetent diabase bodies are also common along the fault plane.

The age of the Avispa fault system is also uncertain. It does not appear to be a relatively recent mountain-building fault, but no other fault in the northern Franklin Mountains displaces it. It may have broken through to the surface near the present mountain front and in some way initiated landsliding.

### FUSSELMAN CANYON FAULT

Fusselman Canyon fault (15, fig. 5) is a long curved fault along the east front of the Franklin Mountains, and is C-shaped with limbs that point northeast and northwest. The north limb closely follows Fusselman Canyon to the south boundary of the mapped area (pl. 1), where it curves southward and passes west of South Franklin Mountain. Farther south it completes a gentle southeastward curve and closely parallels McKelligon Canyon, much as is shown by Richardson (1909).

The fault plane dips about 80° E. at South Franklin Mountain, and therefore it appears to be a normal fault with the inner block depressed relative to the outer block. Stratigraphic displacement in Fusselman Canyon where the Bliss Sandstone is brought against the Lanoria Quartzite is about 1,800 feet.

Other major structural features in the northern Franklin Mountains do not intersect Fusselman Canyon fault and therefore its relative age is uncertain. West of South Franklin Mountain, Avispa fault and Fusselman Canyon fault are less than a mile apart, but they do not intersect at the surface. In the mapped area (pl. 1), three small faults are cut off by Fusselman Canyon fault, which is probably later than the high-angle normal faults that trend northeastward.

### LOW-ANGLE NORMAL FAULTS

Irregular curving normal faults dip at low angles to the east along the east front of the Franklin Mountains. They include a long fault (16, fig. 5) and several fault outliers (17–20, fig. 5) that may be landslide blocks (pls. 1 and 3, sections *A–A′*, *D–D′*, and *E–E′*).

At the Texas-New Mexico boundary, a low-angle fault (16, fig. 5) dips about 10° NE. The trace of the fault plane is sinuous. Paleozoic rocks that dip steeply westward form the upper and lower blocks. Apparent movement on the upper block is downward and northeastward; the stratigraphic displacement ranges from 400 to 1,400 feet. At one place on the east face of a low ridge, a sharp bench or groove in the fault plane trends northeast and indicates that actual relative movement of the upper block was down the dip of the fault plane. Therefore, this fault is interpreted as a low-angle normal fault. The fault plane is very sharp, and no drag folding is apparent.

Locally, the fault steepens and splits into two parallel faults that are too closely spaced to be shown separately on the geologic map (pl. 1). At one southerly exposure of the fault the Fusselman Dolomite in the upper block is overturned and dips 70° E.

The low-angle normal fault (16, fig. 5) is very like a fault mapped by Dunham (1935, fig. 20) on the east front of the southern San Andres Mountains.

In the tin-mine district northeast of Mundys Gap, four hills and ridges in the granite terrane are capped by outliers of Paleozoic and Precambrian rocks that normally crop out high on the mountain front to the west. The outliers rest on the granite along nearly horizontal fault planes above which breccia zones 10 feet thick or more are present in the sedimentary rocks. This and the absence of signs of igneous intrusion indicate that the underlying granite does not intrude the outliers as was interpreted by Richardson (1909, fig. 8, p. 8). The rocks above the fault planes dip generally westward into the granite and are shattered by myriads of joints and are crossed by faults that do not continue into the underlying granite. Although a thickness of 4,500 feet of rocks (Lanoria Quartzite through Fusselman Dolomite) is exposed at one outlier near Mundys Gap, the fault planes beneath the outliers are everywhere within 200–300 feet of the present land surface, which strongly suggests that they are landslide faults.

The two largest fault outliers (pl. 3, section *A–A′*) were obviously once connected, and the other two may be separate landslide blocks or erosional remnants of one large block atop a single undulatory plane that dips eastward and steepens at it approaches the mountain front. The easternmost outlier consists of Bliss Sandstone and El Paso Limestone, which rest on granite and Lanoria Quartzite 1½ miles from the main Bliss outcrop (pl. 3, section *E–E′*); the relationship on the geologic map (pl. 1) suggests that the outlier has been displaced at least 1 mile. The northernmost fault outlier (20, fig. 5) (pl. 1, section *D–D′*) is almost certainly a landslide feature rather than a deeply buried fault, for it is flanked by higher granite ridges on the north and west.

Landslide blocks on shale slopes are common, but apparently they are not common on fresh granite which does not have the obvious lubricating qualities of shale. It seems, however, that loose euhedral feldspar and quartz crystals on a weathered granite slope do provide a good surface for landsliding.

## QUATERNARY FAULTS

The latest structural features in the area of the northern Franklin Mountains are faults that displace Holocene alluvium and the

Pleistocene gravel and caliche rimrock along the east front of the mountains. The faults trend generally northward and are curved. In each place, the east or basinward block has been depressed relative to the mountains.

The Quaternary fault (21, fig. 5) of greatest displacement is very sinuous and roughly parallels the bedrock mountain front although its trace is confined to the Cenozoic deposits to the east (pl. 1, section *C–C′*). The west side of the fault is marked by discontinuous east-facing scarps that are capped by relatively resistent layers, such as the gravel and caliche rimrock and a locally calichified next lower terrace eroded on the basin deposits. Terrace deposits northeast of Fusselman Canyon are nearly 200 feet above the adjacent bolson, and the fault displacement is probably between 200–300 feet. To the north, the fault appears to die out east of Anthonys Nose. To the south, it may be the same fault as a normal fault with an apparent displacement of 410 feet near William Beaumont Hospital in northeast El Paso (Sayre and Livingston, 1945, p. 34–35, 46).

Curving, north-trending lines on Hueco Bolson 2–3 miles east of the Franklin Mountains are visible from the air and are conspicuous on aerial photographs (fig. 5, 22). The lines are caused by dense vegetation on the east faces of scarplets less than 10 feet high. The scarplets are attributed to faulting because they do not follow the present contour of the land as would be expected of wave-cut lake benches. The scarplets are formed in locally calichified Quaternary alluvium, and their height is probably the same as their fault throw. One of the fault scarps can be traced 5 miles and is less than 5 feet high (pl. 1, section *C–C′*).

The fault scarps in the Quaternary deposits, which were first described by Richardson (1909, p. 9), are very like a fault scarp along the east front of the Organ Mountains (Reiche, 1938). The Quaternary faults may represent continued or renewed activity along the major faults along which the mountains were uplifted.

## MINERAL DEPOSITS

### TIN

Tin ore was discovered in 1899 near the foot of the east front of the Franklin Mountains 4 miles north of the south boundary of the mapped area (pl. 1). Eight tons of the pure metal was smelted at a small mill, and a furnace was erected at the mines (Weed, 1901; Richardson, 1909; Chauvenet, 1911). The tin was valued at $6,813, and the ore is the only tin ore that has been mined commercially in the State of Texas. Production ceased about 1912, and the following account is taken from the descriptions of Weed, Richardson, and Chauvenet, although the opencuts, a shaft about 50 feet deep, and the concrete-mill foundations are little changed after half a century.

The tin ore is in and near six quartz veins in the granite. The quartz veins are nearly perpendicular to the mountain front; they trend due west to N. 65 W. and are almost vertical. They are less than 2 feet wide and 1,300 feet long, and they tend to pinch out upward and downward. The northernmost and southernmost veins are about 4,000 feet apart. They are thought to be Precambrian in age.

The ore consists of cassiterite in disseminated crystals and massive chunks in both the quartz veins and the surrounding granite. The granite consists almost entirely of fine- to medium-grained quartz and orthoclase; cassiterite appears to replace both minerals. Scattered crystals of wolframite, fluorite, topaz, tourmaline, and pyrite are associated with the ore.

The ore is of high quality, and the cassiterite is easily concentrated and smelted, but the veins are thin and lenticular, and the reserves may be small.

## IRON

Iron has been prospected near the base of the eastward-projecting spur of the Franklin Mountains 1.8 miles south of the Texas-New Mexico boundary. The mineral is black to brownish-gray siderite that has erratically replaced parts of the Castner Limestone where the limestone is intruded by granite. The siderite apparently is not abundant, and its iron content rarely exceeds 40 percent.

## GYPSUM

Gypsum has been quarried, for use in cement making at El Paso (Dunham, 1935, p. 244), at the north end of the syncline outlined by the Hueco Limestone between Anthony and Anthony Gap in the western foothills of the Franklin Mountains (secs. 32 and 33, T. 26 S., R. 4 E., Dona Ana County, N. Mex.). The gypsum occurs in two beds that are separated by 186 feet of limestone and thin talus-covered intervals. These beds probably are the only economic gypsum deposits in the El Paso area.

The lower gypsum bed is assigned to the upper member of the Magdalena Formation and has been quarried in the NW¼ sec. 33. The gypsum bed dips about 45° SW., and, although less than 50 feet of it is exposed in the quarry, it is 112 feet thick. Intermixed with the gypsum are nodules and thin beds of dense light-gray limestone or dolomite, which seems to be the only impurity.

The upper gypsum bed is in the lower unit of the Hueco Limestone and has been quarried in the NE¼ sec. 32. It is near the axis of the syncline and dips 31° S. Less than 50 feet of gypsum was exposed in the quarry when the present study was made, but the total thickness of the gypsum is about 115 feet. The bed contains 10–30 percent limestone or dolomite in nodules and lenticular beds.

### MAGNESIUM

The Montoya and Fusselman Dolomites of Ordovician and Silurian age are thick formations that contain about 10 percent magnesium by weight. The metal, which is in great demand as an alloying agent, is abundant but is expensive to extract. Most magnesium is produced from sea water or natural brines, but it can be produced commercially from dolomite.

The magnesium potential of dolomite deposits in southern New Mexico was described by Kottlowski (1957), who concluded that the region has large dolomite reserves of high purity, as well as sufficient electricity, iron ore, and sand necessary in the two methods of refining magnesium. The conclusion can be applied as well to the Franklin Mountains, where the Fusselman Dolomite is 600 feet thick and crops out in large areas that are suitable for stripping operations.

## OIL AND GAS

### PREVIOUS EXPLORATION

Five wells had been drilled for oil and gas in the mapped area (pl. 1) by December 31, 1958. The wells were abandoned as dry holes, but they were shallow and drilling was started in the Cenozoic deposits with no indication of favorable structure in the underlying bedrock. Data on these wells are shown in table 11.

Seven significant oil and gas test wells had been drilled without success in the region surrounding the Franklin Mountains by 1958. Two of these wells (Ernest Located Land 1 and Burns and King Fee 4) were drilled in Hueco Bolson east of the Franklin Mountains, where they found thick Cenozoic basin deposits. Only a thin interval in Pennsylvanian and Permian rocks was tested, and no indication of favorable bedrock structure is present at the well sites. The other five wells were drilled in the Hueco Mountains area, where they tested all the Paleozoic formations in areas of favorable surface structure. No deep wells have been drilled in the Mesilla basin west of the Franklin Mountains. Data on the seven wells are shown in table 12.

TABLE 11.—*Wells drilled for oil and gas in the mapped area*

[Compiled from Cooley (1958, p. 70–72)]

| Location | Company and well | Completion date | Elevation (feet) | Total depth (feet) | Geologic formation | |
|---|---|---|---|---|---|---|
| | | | | | Surface rocks | Bottom rocks |
| **Dona Ana County, N. Mex.** | | | | | | |
| Sec. 14, T. 26 S., R. 5 E. | Mid-State Oil and Gas Co. M. J. Boretz Permit 1. | 1932? | 4, 060 | Not available. | Basin deposits | Data not available. |
| **El Paso County, Tex.** | | | | | | |
| M. Rodriquez Survey, sec. 35. | J. S. Merriweather Brown Realty Co. 1. | 1947 | 3, 880? | 335 | Basin deposits | "Lime." |
| Scrap File Survey, sec. 254. | J. S. Merriweather et al. Luis Bobadilla 1. | 1945 | 4, 020 | 1,578 | do | "Granite wash." |
| Do | Tristate Oil Corp. Bobadilla 1 | 1934 | 4, 160 | 3,401 | do | "Gray shale to brown lime." |
| Scrap File Survey, sec. 237. | Southwest Oil Co. Kinkel 1 | 1941 | 3, 977 | 3,571 | do | Data not available. |

TABLE 12.—*Significant oil and gas test wells in the Franklin Mountains region, Texas and New Mexico*

[Compiled from Cooley (1958) except as noted]

| Location | Company and well | Completion date | Elevation (feet) | Total depth (feet) | Geologic formation: Surface rocks | Geologic formation: Reported bottom rocks | Certain units and reported depth (in feet) to their tops | |
|---|---|---|---|---|---|---|---|---|
| **Otero County, N. Mex.** | | | | | | | | |
| T. 25 S., R. 7 E., sec. 20 | Ernest Located Land 1 [1] | 1942 | 4,150? | 3,941 | Basin deposits. | Magdalena | Hueco | 2,182 |
| | | | | | | | Virgil equivalent | 2,312 |
| T. 26 S., R. 11 E., sec. 18 | Seaboard Oil Co. Trigg-Federal 1. | 1955 | 5,309 | 5,600 | do | Magdalena (Des Moines equivalents). | "Abo" | 562 |
| | | | | | | | "Powwow" | 3,040 |
| | | | | | | | Missouri equivalent | 3,785 |
| | | | | | | | Des Moines equivalent | 3,990 |
| **El Paso County, Tex.** | | | | | | | | |
| T&P Survey, T. 1 block 80, sec. 24 | Burns and King Fee 4 | 1926 | 3,990 | 4,910 | Basin deposits. | Basin deposits | | |
| PSL Survey, block 5, sec. 17 | Elbert R. Jones Clem Sorley 1 | 1947 | Unknown | 2,220 | do | Precambrian | Fusselman | 277 |
| | | | | | | | Montoya | 675 |
| | | | | | | | El Paso | 809 |
| | | | | | | | Bliss | 1,871 |
| | | | | | | | Precambrian | 2,172 |
| **Hudspeth County, Tex.** | | | | | | | | |
| PSL Survey, block 14, sec. 6 | Minnie Veal | 1924? | Unknown | 2,276 | Lower Cretaceous. | "Powwow" | Hueco | 127 |
| | | | | | | | Powwow | 2,130 |
| University Lands Survey, block A, sec. 39. | Hueco Basin Oil Co. Lanas 1 | 1922? | 5,120? | 2,507 | Hueco | do | do | 2,030? |
| University Lands Survey, block E, sec. 19. | The California Co. University-Theisen 1. | 1930 | 5,109 | 4,848 | do | Precambrian | Helms | 1,642 |
| | | | | | | | "Woodford" | 2,105 |
| | | | | | | | Devonian chert | 2,160 |
| | | | | | | | "Silurian" | 2.220 |
| | | | | | | | Fusselman | 2.264 |
| | | | | | | | Montoya | 2,818 |
| | | | | | | | El Paso | 3,070 |
| | | | | | | | Bliss | 4,384 |
| | | | | | | | Precambrian | 4,720 |

[1] Data on this well are from Kottlowski, Flower, Thompson, and Foster (1956, p. 79' 82).

## POTENTIAL SOURCE AND RESERVOIR ROCKS

More than 8,000 feet of potential source and reservoir rocks of Paleozoic age crop out in the Franklin Mountains and may be found at depth in the surrounding basins. Thick Cretaceous rocks of petroliferous aspect have been eroded from the mountains but may be present in the basins. Except for the Mississippian formations and the Bliss Sandstone (Cambrian and Ordovician), all the Paleozoic formations have yielded oil in southeastern New Mexico (Dixon and others, 1954). The Cenozoic basin deposits are unlikely sources of petroleum because they are of continental origin. Similarly, the metamorphosed Precambrian rocks are not likely to contain oil. The following paragraphs contain a few specific observations about the possible oil and gas possibilities of the Cretaceous and Paleozoic rocks.

Cretaceous rocks exposed along the international boundary northwest of El Paso include shale and marl of marine origin that are possible source beds, as well as thick beds of sandstone that could act as porous reservoirs. Total thickness of Cretaceous rocks is unknown.

The Hueco Limestone contains abundant fossil debris, but its outcrops are uniformly light gray and nonpetroliferous. The limestone is mostly fine grained and nonporous, and layers of coarse crinoid debris are thoroughly cemented at the outcrop. The thin siltstone units may be porous, but no oil staining was seen in them. Total thickness of the Hueco Limestone is at least 2,200 feet.

The Magdalena Formation presents a thick sequence of dark-gray marine beds that have been favored as targets of drilling for oil in the region. In the neighboring Hueco, Sacramento, and San Andres Mountains, bioherms with porous flanking beds offer excellent potential traps for oil accumulation in the upper part of the Magdalena (King and others, 1945; Plumley and Graves, 1953; Kottlowski and others, 1956). Sandstone and conglomerate beds that could serve as reservoir rocks are also common in the Magdalena in the region. In the Franklin Mountains no likely reservoir rocks are exposed other than the conglomerate bed (pl. 2, measured section 11, unit 108) at the base of the upper member. However, much of the formation is covered, and other porous rocks may be present. Limestone beds in the lower half of the Magdalena are dark gray and appear petroliferous; the few shale beds that are exposed are mostly light yellow, but they are deeply weathered and their fresh color can only be determined in excavations or drill cuttings. Thickness of the Magdalena is 2,700 feet at the outcrop.

The Mississippian formations are promising sources of petroleum, but thick porous beds are lacking. The Helms Formation and the Las Cruces Limestone appear impervious throughout. The Rancheria Formation is mostly dense limestone and shale, but the upper and lower members contain a few uncemented beds of coarse crinoid debris that are very porous and show moundlike swelling of the bed tops. As exposed in the mapped area (pl. 1), all these beds are less than 5 feet thick, but covered intervals in the formation possibly contain thicker beds. At Bishop Cap 10 miles to the north, the lower member of the Rancheria and underlying rocks probably equivalent to the Lake Valley Limestone contain porous beds of coarse crinoid debris 10–20 feet thick. The Mississippian formations are about 640 feet thick.

Devonian rocks are dark gray to black throughout, and near the base a porous zone is present. The Percha Shale is impermeable and, with the underlying shale and marl of the upper part of the Middle Devonian rocks, should act as an upward barrier to the migration of petroleum. The lower part of the Middle Devonian sequence consists of 70 feet of chert and marl that is intricately fractured at the outcrop. Fracturing appears to have been associated with the emplacement of the chert, and fracture porosity may be present at depth. Devonian rocks are about 200 feet thick except at North Anthonys Nose, where 90 feet of them was removed by pre-Las Cruces erosion.

The Fusselman Dolomite is a possible reservoir rock due to open pore spaces between the dolomite grains. The permeability is directly related to grain size, and coarse dolomite in the Fusselman is very permeable. At the base is a zone of medium-grained dolomite in which the crystals interlock, and the rock is impermeable. In most of the formation, the grain size and porosity vary erratically. Near the top of the Fusselman is a zone of variable thickness that contains irregular patches of compact aphanitic limestone surrounded by medium to coarse porous dolomite. Traps formed by porous rock enclosed by impermeable strata probably occur in the formation. The Fusselman is about 600 feet thick at the State line, and it thins northward about 20 feet per mile beneath an unconformity. It presumably thickens southward.

The Montoya Dolomite is dark gray and impermeable, except in the lower member. The Cutter and Aleman Members are compact dolomite, chert, and marl. The Upham Member resembles darker beds in the Fusselman and consists of 100 feet of medium-grained dolomite with irregularly distributed zones of intergranular porosity. The Montoya is uniform in thickness and lithology through the region and is 400 feet thick in the Franklin Mountains.

The El Paso Limestone contains porous beds and is equivalent to part of the Ellenburger Group, which has yielded great quantities of oil in Texas. Porous beds are dolomitized zones in the limestone. Thickness is 1,300 feet near the Texas-New Mexico boundary.

The Bliss Sandstone is tightly cemented by silica in most beds, but permeable layers may be present. Normal thickness is 210 feet, but it may be missing in areas underlain by Precambrian rhyolite.

## GROUND WATER

Sayre and Livingston (1945) and Knowles and Kennedy (1958) described the quality and quantity of ground water in the area and provided specific data needed to locate wells. A few pertinent facts from their publications are repeated here.

The perennially flowing Rio Grande supplies most of the water used on farms in the Rio Grande Valley, but ground water from wells is used in nearly all industries and homes in the El Paso area. In 1953, pumpage from wells at El Paso and Ciudad Juarez was 27,900,000 gallons per day, and the rate was increasing.

The wells tap a vast ground-water reservoir, the unconsolidated basin deposits. After heavy rains, part of the waterflow from the mountain canyons sinks into the ground and reaches the basin deposits, which are everywhere saturated with ground water available to wells drilled a few hundred feet deep.

Some of the ground water is too salty for use. Salt water lies beneath fresh water in the basin deposits at most places, but is found at ordinary drilling depth only near the Hueco Mountains and in the Rio Grande Valley south of El Paso.

Wells drilled east of War Highway 11 and west of Interstate Highway 10 in the mapped area (pl. 1) should find fresh water within 430 feet of the surface. Between the highways and the mountains, the drill may enter impermeable bedrock before the water level is reached. The depth to fresh water is 230-350 feet near the east boundary of the mapped area and less than 100 feet in the Rio Grande Valley at the west boundary.

All wells in the basin deposits require casing. The water is under normal pressure except for artesian wells in a small area near Canutillo.

## MEASURED SECTIONS

The Paleozoic formations were measured and described at the localities shown on the geologic map (pl. 1) and they are illustrated in the graphic sections (pl. 2). Written descriptions of at least one section of each Paleozoic unit follow. These are not, in all instances, the best sections for study but are sections that have not been previously described in the literature. The pre-Pennsylvanian rocks were measured by means of a planetable or tape; the Pennsylvanian and Permian rocks were measured with a Jacob staff.

The Precambrian formations are not described here. They are shown graphically on plate 2, and a bed-by-bed description of the Castner and Mundy Formations has been published (Harbour, 1960, p. 1789).

SECTION 1.—*El Paso Limestone and Bliss Sandstone*

[Measured 0.6 mile south of Anthonys Nose]

| | Feet |
|---|---|
| Montoya Dolomite. | |
| El Paso Limestone: | |
| Upper member: | |
| 25. Limestone, dark-gray, fine-grained; some bioclastic debris; marly; fetid odor. Bedding planes somewhat wavy and indistinct; some beds as thick as 10 ft. Weathers blue-gray with tan reticulations marking porous masses of interstitial chert. Scattered dark-gray chert pods in upper part. At 62 ft above base: *Tritoechia* sp. (USGS colln. D401CO, p. 103) | 134 |
| 24. Dolomite, light gray, fine-grained; in finely laminated beds 1–3 ft thick. Contains crystalline quartz cavity fillings and traces of fine to coarse quartz sand. Weathers very light gray to tan | 67 |
| 23. Dolomite, very light gray, fine-grained, laminated throughout by fine to coarse quartz sand grains. At base is 1 ft of quartzitic sandstone. Unit weathers light tan | 45 |
| Thickness of upper member | 246 |
| Middle member: | |
| 22. Limestone, gray, fine-grained with many layers of bioclastic debris. Yields a fetid odor and contains scattered lenses of light-gray chert. Beds average 3 ft in thickness and are more distinct and parallel than in the underlying unit. Forms a slope | 306 |
| 21. Dolomite and limestone. Upper part is gray, fine-grained limestone with beds of crinoidal clastic debris and lenses of gray chert; lower part is gray dolomite of sugary texture. Basal 80 ft is sandy and upper 100 ft contains numerous cephalopod siphuncles. Unit forms cliffs showing thick discontinuous beds with low stromatolitic mounding | 379 |
| 20. Limestone, gray to dark-gray, fine-grained; some layers contain angular limestone fragments. Chert lenses near base. Beds average 3 ft in thickness and weather light blue gray | 120 |

SECTION 1.—*El Paso Limestone and Bliss Sandstone*—Continued

| | Feet |
|---|---|
| El Paso Limestone—Continued | |
| Middle member—Continued | |
| 19. Limestone, gray, fine-grained. Contains dense gray chert in nodules, reticulations, and discontinuous layers 2 in. thick. Chert weathers brown and unit forms a rust-colored cliff | 28 |
| 18. Limestone, gray, fine-grained, with many angular limestone fragments ¼ in. in diameter. Medium bedded with stromatolitic swelling in upper part. Nodules and lenses of dense light-gray chert are common. Fossil debris abundant. USGS colln. D399CO from 23 feet above base | 102 |
| Thickness of middle member | 935 |
| Lower member: | |
| 17. Limestone, gray, fine-grained; limestone breccia in brown-weathering seams less than ½ in. thick. Laminated by fine quartz sand throughout and upper 5 ft contains 2-in.-thick layers of dense gray chert. Unit forms a cliff | 35 |
| 16. Dolomite, gray, fine-grained; laminated throughout by fine to medium quartz sand. Contains crinoid and other bioclastic debris. Forms a slope and grades into underlying and overlying units | 20 |
| 15. Dolomite, gray, fine-grained; finely laminated by fine to medium quartz sand. Contains a few lenses of light-blue-gray limestone in middle of unit. Forms a tan cliff; contact with underlying unit is arbitrary | 29 |
| 14. Dolomite, light-gray-brown, very sandy; dense and hard with silica cement. Sand is fine angular quartz. Unit is homogeneous and laminated throughout, some small-scale cross-bedding. Weathers to a brown slope | 76 |
| Thickness of lower member | 160 |
| Thickness of El Paso Limestone | 1, 341 |
| Bliss Sandstone: | |
| 13. Sandstone (80 percent) and siltstone. Sandstone is gray and fine grained with courses of feldspathic granule conglomerate and dark quartzitic layers. Siltstone is greenish gray and glauconitic. Worm trails are common along bedding planes | 21 |
| 12. Sandstone, gray, fine- to coarse-grained, hematitic. Glauconitic silty layers with frosted quartz granules divide unit into beds that average 3 ft in thickness. Unit forms a mottled gray, green, and red cliff | 42 |
| 11. Sandstone and siltstone, light-gray to green, thinly interbedded. Unit forms a slope | 3 |
| 10. Sandstone, gray, medium-grained, with coarse grains at top. Beds to 3 ft thick separated by silty layers 2 in. thick | 18 |
| 9. Siltstone, glauconitic | 1 |
| 8. Sandstone, gray, even texture of fine or medium grains. Weathers gray, black, and red | 3 |

SECTION 1.—*El Paso Limestone and Bliss Sandstone*—Continued

| | Feet |
|---|---|
| Bliss Sandstone—Continued | |
| 7. Siltstone, glauconitic | 1 |
| 6. Sandstone, gray, medium-grained; ½-in. angular quartz fragments at top. Unit consists of one bed | 7 |
| 5. Siltstone, grayish-blue, quartzitic | 1 |
| 4. Quartzite, gray, even-textured, fine-grained. Hematite in in minor quantities occurs as cement and along joints and bedding planes. Beds are 1–5 ft thick and are cross laminated at low angles. Crops out in mottled gray, black, and pink cliffs | 63 |
| 3. Siltstone and sandstone, poorly exposed. At base nearby is a 15-ft-thick bed of maroon siltstone with thin beds of of fine-grained sandstone. Upper part consists of thin beds of gray and pink sandstone separated by green siltstone. One 4-ft-thick bed of gray quartzite near top | 46 |
| 2. Sandstone, pink and gray mottled, poorly sorted and conglomeratic. Contains quartz and pink feldspar granules evidently derived from underlying granite. Cemented by silica | 4 |
| Thickness of Bliss Sandstone | 210 |
| Granite. | |

SECTION 2.—*Montoya Dolomite*

[Measured 0.25 mile south of Anthonys Nose]

| | Fee |
|---|---|
| Fusselman Dolomite. | |
| Montoya Dolomite: | |
| Cutter Member: | |
| 4. Dolomite, dark- to medium-gray, very fine grained, calcareous and slightly marly. In unlaminated even beds 2–3 ft thick with abundant dark-gray chert lenses less than 1 in. thick. Unit weathers characteristic light gray; upper contact is definite but parallels the bedding. Fossils of Late Ordovician aspect occur 15–30 ft below the top, 0.3 mile southwest (USGS colln. D404CO) | 101 |
| 3. Covered. Unit forms a persistent notch on east front of mountains. On crest of range 100 yds south, unit consists of 13-ft-thick fossiliferous marl (top); 3-ft-thick cherty, fossiliferous, dark-gray dolomite; 2-ft-thick nodular, marly, gray limestone; and 9-ft-thick fossiliferous blue-gray to yellow shale and marl. Abundant silicified brachiopods were collected from unit on mountain crest and in a west-slope canyon 0.25 mile southwest (USGS collns. D402CO and D403CO, p. 105–106) | 27 |
| Thickness of Cutter Member | 128 |

SECTION 2—*Montoya Dolomite*—Continued

| | Feet |
|---|---|
| Montoya Dolomite—Continued | |
| Aleman Member: | |
| 2. Dolomite (60 percent) and chert. Very fine grained gray to dark-gray dolomite that weathers light gray. Unlaminated black to light-gray chert occurs in nodules and layers a few inches thick with irregular sharp boundaries that truncate faint laminations in the dolomite. Chert makes up from 20 percent of thickness near base to 60 percent near top; thickest interval without chert is about 5 ft. White calcareous gastropods about 1 mm in diameter occur in dolomite near middle of unit. Colln. 2370CO from 42 ft below top. | |
| Thickness of Aleman Member | 156 |
| Upham Member: | |
| 1. Dolomite, gray, even-grained; contains silt-sized crystals throughout. Slightly porous and reaction with acid suggests that intergranular calcite is present. Fine white mottling, much of it dolomitic fossil debris, is common. Lower contact is sharp; medium to coarse quartz sand, masked by dolomite texture, occurs in basal 40 ft. Unit forms a dark cliff in which faint layering at widely separated intervals is visible. | |
| Thickness of Upham Member | 96 |
| Thickness of Montoya Dolomite | 380 |

SECTION 3.—*Fusselman Dolomite*

[Measured 0.6 mile southwest of Anthonys Nose]

| | Feet |
|---|---|
| Devonian rocks. | |
| Fusselman Dolomite: | |
| 7. Dolomite, gray to dark-gray, fine- to coarse-grained, calcareous; some layers show intergranular porosity. Basal 60 ft forms poorly laminated cliffs that are darker than underlying dolomite. Upper part crops out in a slope and is so brecciated that bedding is obscure. Upper contact is an erosional unconformity and the Devonian rocks locally fill channels as deep as 20 ft | 270 |
| 6. Dolomite, light-gray, medium-grained, slightly calcareous. Thick, poorly laminated beds | 21 |
| 5. Dolomite, light-gray, very fine grained, nodular | 3 |
| 4. Dolomite, light-gray, medium- to coarse-grained; slightly calcareous with some intergranular porosity. Very pure, with less than 1 percent clay (light gray) in acid residue. Laminations are poor and widely spaced; unit forms cliffs of lighter color than underlying beds | 98 |
| 3. Dolomite, mottled dark- and light-gray; generally medium grained, but ranges from silt size to coarse sand size. Basal 43 ft contains layers of coarsely recrystallized white brachiopods about 1 in. long, which are convex upward in cross section. Unit is obscurely bedded, but is laminated by the brachiopod layers | 65 |

SECTION 3.—*Fusselman Dolomite*—Continued

| | |
|---|---|
| Fusselman Dolomite—Continued | *Feet* |
| 2. Dolomite, mottled gray and dark-gray, medium-grained; some intergranular porosity. Siliceous, with as much as 12 percent crystalline quartz in lacy, brown-weathering networks between the dolomite grains. Unit is thickly and obscurely bedded and weathers mottled gray, black, and brown, darker than underlying dolomite | 68 |
| 1. Dolomite, very light gray, even grains of medium size sand, nonporous. Dolomite grains on weathered surfaces resemble sand grains. Unit weathers light tan, darker than underlying beds, and the basal contact is sharp but even. Unit forms a cliff, and is very poorly bedded, with indistinct layering at intervals of 5–20 ft | 115 |
| Thickness of Fusselman Dolomite | 640 |
| Montoya Dolomite. | |

SECTION 5.—*Montoya Dolomite, El Paso Limestone, and Bliss Sandstone*

[Measured 1.8 miles north of Anthonys Nose. The Montoya has also been described at this locality by Pray (1958, p. 40) and by Howe (1959, p. 2321)]

| | |
|---|---|
| Fusselman Dolomite. | |
| Disconformity. | |
| Montoya Dolomite: | |
| Cutter Member: | *Feet* |
| 30. Dolomite, gray, very fine grained, slightly calcareous and argillaceous. Poorly laminated even beds where thickness averages 3 ft and nowhere exceeds 6 ft. Within and between the beds are gray chert lenses 2 in. thick that range from frequent (5 percent) near base to sparse at top. Contact with overlying Fusselman Dolomite is distinct and even. The unit forms a distinctive light-gray band along the mountain front. Collns. D426CO from 30 ft above base, D427CO from 8 ft above base, 57RJ69 from 4 ft above base | 107 |
| 29. Covered. A few feet of poorly exposed marl near top of unit. Colln. D428CO from 24 ft above base | 34 |
| Thickness of Cutter Member | 141 |
| Aleman Member: | |
| 28. Dolomite and chert. Dolomite is dark to medium gray, very fine grained, and poorly laminated. Nodules, lenses, and wavy layers of dark- and light-gray chert compose about 40 percent of thickness, ranging from 30 percent near base to nearly 50 percent at top. Member forms cliffs that are strikingly mottled light gray (dolomite) and dark gray (chert). Colln. D411CO from 117 ft above base and colln. D429CO from 112 ft above base. | |
| **Thickness of Aleman Member** | **160** |

SECTION 5.—*Montoya Dolomite, El Paso Limestone, and Bliss Sandstone*—Con.

| | |
|---|---|
| Montoya Dolomite—Continued | |
| Upham Member: | *Feet* |
| 27. Dolomite, gray, with minor white mottling; silt-sized dolomite grains with intergranular calcite and cavities. Contains very little clay, and chert is present only as sparse fossil replacement. Although the fresh rock is homogeneous, weathering reveals a projecting meshwork of light-tan interconnected nodules that are more dolomitic than matrix. These nodules, about 6 in. long, compose nearly 50 percent of the volume near the base but are absent at the top. The base, which is sharp but even, is marked by a 1-in.-thick layer of sandstone. The member crops out in a dark rounded cliff and appears to be one poorly laminated bed. White coarsely crystalline fossil remnants are abundant, and field identifications by R. J. Ross, Jr. (oral commun., 1957) include *Receptaculites oweni*, *Calapoecia* sp., *Favosites* sp., *Streptelasma* sp., and *Maclurites* sp. Colln. 3868CO from 25 ft above the base. | |
| Thickness of Upham Member | 104 |
| Thickness of Montoya Dolomite | 405 |
| El Paso Limestone: | |
| Limestone zone of upper member: | |
| 26. Limestone, dark-gray, fine-grained, dense, slightly marly. Scattered dolomite crystals occur as fine rhombs suspended in limestone. Many beds contain porous dolomoldic chert networks that weather as raised light-tan reticulations (¼ in.) and make up 30–40 percent of the rock. Chert also occurs in dark-gray lenses and nodules and as fossil replacement. The beds vary in thickness, weather light bluish gray, and form a smooth slope. The upper foot contains trilobites, brachiopods, and conodonts (colln. D413CO). Colln. 2239CO from 20 ft below top | 108 |
| Sandy zone of upper member (103 ft): | |
| 25. Dolomite, light-gray, finely coarse, calcareous. Scattered nodules of gray chert | 7 |
| 24. Dolomite, light-gray, medium- to coarse-grained. In unlaminated beds as thick as 2 ft | 15 |
| 23. Dolomite, light-gray, fine-grained, dense. Thinly bedded and finely laminated by fine to coarse sand grains, with some autoclastic breccia. Unit weathers very light gray and forms a cliff | 61 |
| 22. Sandstone and dolomite. Fine and coarse (bimodal?) quartz sand grains in light-gray, fine-grained dolomite. Laminated throughout, with some small-scale cross-lamination. Unit forms a cliff and weathers very light gray with limonite stains near the base | 20 |

SECTION 5.—*Montoya Dolomite, El Paso Limestone, and Bliss Sandstone*—Con.

El Paso Limestone—Continued

B2A zone (253 ft): *Feet*

21. Dolomite, dark-gray, medium-grained, laminated by very fine quartz sand grains. Unit forms a cliff and weathers light gray — 20
20. Dolomite, dark-gray, fine-grained; sparse nodules of white crystalline chert. Unit forms cliffs in which poorly laminated beds about 1 ft thick are visible — 19
19. Limestone, dark-gray, fine-grained. Contains many layers of autoclastic limestone debris as well as porous dolomoldic chert networks which form light-tan reticulations (¼ in.) on weathered surfaces. Chert also occurs as light-gray crystalline nodules. The beds, which range in thickness from about 1 ft near the base to 10 ft at the top, are laminated and weather light bluish gray. Colln. D410CO from base, D411CO from 90 ft above base, D412CO from 120 ft above base — 214

B1 zone (318 ft):

18. Limestone, gray, fine-grained; layers of autoclastic limestone fragments as large as ½ in. In and between the beds are nodules of rusty-weathering light- to dark-gray chert. The unit forms cliffs and is in laminated beds of diverse thickness which weather light bluish gray with tan reticulations of dolomoldic chert. Cephalopod siphuncles in lower part — 126
17. Dolomite, gray, fine-grained, dense. Along the bedding planes are dark-gray chert bodies with sharp, irregular boundaries. The beds, which are poorly laminated, average 1½ ft in thickness near the base, but are thicker toward the top. USGS colln. D432CO from 16 ft above base, 2437CO from 30 ft above base — 129
16. Limestone, dark-gray, fine-grained; much autoclastic limestone debris (¼ in.). Contains light-gray chert in irregular bodies and layers. Unit weathers light bluish gray with raised tan mottling of porous chert bodies — 12
15. Dolomite, dark-gray, fine-grained, poorly laminated and homogeneous. Dark-gray chert pods are abundant to sparse. Unit appears thickly bedded. Colln. D620C0 10 ft above base — 20
14. Limestone, gray, fine-grained, layers of autoclastic limestone fragments (½ in.). Unit is laminated, but is thickly and obscurely bedded — 31

Middle sandy zone and lower limestone zone (447 ft):

13. Dolomite, dark-gray, medium-grained, homogeneous, slightly porous. Fine to medium quartz sand increases toward top; unit contains sparse white specks that may be calcareous fossil debris. Zones of intergranular crystalline chert in upper part are stained by limonite — 53

SECTION 5.—*Montoya Dolomite, El Paso Limestone, and Bliss Sandstone*—Con.

| | |
|---|---|
| El Paso Limestone—Continued | |
| Middle sandy zone and lower limestone zone (447 ft)—Continued | *Feet* |
| 12. Dolomite, gray, fine-grained; sandy with fine to medium quartz grains. Many beds contain autoclastic dolomite debris, and some exhibit lacy interstitial chert networks that weather as tan reticulations in a light-bluish-gray matrix. Unit forms a slope and is poorly exposed. Colln. 2436CO from middle of unit | 75 |
| 11. Limestone, gray, fine-grained; many layers of clastic limestone fragments. Quartz sand in middle part of unit and oolites near the base. The beds, which are laminated at intervals of a few inches, are as thick as 12 ft near the base. Unit forms cliffs, and contact with the underlying limestone is arbitrary | 69 |
| 10. Limestone, gray, fine-grained; contains crinoid debris and angular limestone fragments as large as ½ in. Unit is laminated throughout and forms a slope. Colln. D424CO from 67 ft above base, D425CO from 25 ft above base | 82 |
| 9. Limestone, gray, fine-grained. Chert occurs as solid finely crystalline light-gray nodules and layers and as porous internal laceworks. Iron is concentrated along the chert bodies, and unit crops out in a rust-colored cliff | 8 |
| 8. Limestone, gray, fine-grained; has a few layers containing angular limestone fragments. Weathering reveals porous dolomoldic chert as raised tan reticulations (pelletal at base) in a light-bluish-gray matrix. Unit is in laminated beds about 3 ft thick. Colln. 2435CO from 79 ft above base, D433CO from 31 ft above base, D407CO from 15 ft above base | 108 |
| 7. Limestone and dolomite, light-gray, fine-grained, dense. Laminations are not as fine as in underlying unit, and the sand content is less than 10 percent | 52 |
| Lower sandy zone (84 ft): | |
| 6. Dolomite, light-gray, fine-grained, dense; finely laminated by fine quartz sand, but contains a few lenses of sand-free dolomite. Unit weathers light tan and forms a cliff. Colln. D406CO from 15 ft above base | 27 |
| 5. Dolomite, light-gray, fine-grained, dense, finely laminated; some small-scale cross-lamination by fine grains of quartz, feldspar, and mica. Siliceous cement is indicated by welded sand grains near the base, and iron oxide produces a tan weathered color. Despite its hardness, the unit forms a slope | 57 |
| Thickness of El Paso Limestone | 1,313 |
| Bliss Sandstone: | |
| 4. Sandstone, light-gray, generally medium grained; but ranges from fine to coarse. Quartzitic and hematitic with iron-stained weathered surfaces. Unit is formed of parallel-laminated beds about 2 ft thick that crop out in a series of ledges and benches. Colln. 57RJ40 50 ft below top | 136 |

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SECTION 5.—*Montoya Dolomite, El Paso Limestone, and Bliss Sandstone*—Con.

| | Feet |
|---|---|
| Bliss Sandstone—Continued | |
| 3. Quartzite, very light gray, fine- to coarse-grained; in beds 1–6 ft thick that form a cliff | 20 |
| 2. Sandstone and quartzite, light-gray, fine- to coarse-grained. Beds 1–2 ft thick separated by covered intervals (siltstone?) that compose less than 20 percent of the thickness. Basal contact is covered | 54 |
| Thickness of Bliss Sandstone | 210 |
| Unconformity. | |
| 1. Precambrian granite porphyry sill in the Lanoria Quartzite. | |

SECTION 9.—*Mississippian and Devonian rocks*

[Measured at North Anthonys Nose]

| | Feet |
|---|---|
| Magdalena Formation, La Tuna Member: | |
| 25. Limestone, gray, fossiliferous. Lower 15–20 ft contains shale beds. | |
| Helms Formation as used by Laudon and Bowsher (1949): | |
| 24. Shale, gray; covered on line of section but partly exposed 500 ft to the south. | |
| Thickness of Helms Formation | 150 |
| Rancheria Formation of Laudon and Bowsher (1949): | |
| Upper member: | |
| 23. Limestone, dark-gray, fine-grained, silty and cherty. Beds range in thickness from 5 ft at base to ½ ft at top and are finely laminated by quartz silt and fine sand. Small-scale cross lamination is common. Gray chert is concentrated along sand courses producing rusty-weathering layers with indefinite contacts with the limestone, which weathers light gray. Thin interbeds (shale?) are not exposed | 74 |
| 22. Covered | 3 |
| 21. Limestone, dark-gray, fine-grained. Unit includes one bed laminated by quartz sand grains at base | 3 |
| 20. Limestone, gray, coarsely bioclastic, porous, cross laminated. Contains granule-sized crinoid debris, silicified brachiopods, and sparse mud pellets | 1 |
| 19. Covered. Large productid brachiopods weather from unit | 5 |
| 18. Limestone, dark-gray, fine-grained; has parallel courses of quartz silt and fine sand. Beds are less than 3 ft thick and are probably separated by shale layers | 20 |
| 17. Covered | 5 |
| 16. Limestone, dark-gray, fine-grained. Some layers contain quartz silt and fine sand; gray chert lenses with indefinite margins occur in upper part. Unit weathers light gray (limestone) and rusty (chert) | 22 |
| 15. Covered | 5 |

SECTION 9.—*Mississippian and Devonian rocks*—Continued

| | Feet |
|---|---|
| Rancheria Formation of Laudon and Bowsher (1949)—Continued | |
| Upper member—Continued | |
| 14. Limestone, dark-gray, fine-grained, sandy and cherty. Fine quartz sand and silt grains form parallel bands throughout. Light- and dark-gray chert is concentrated along the bands and appears to replace limestone. Laminae continue unobstructed from limestone into chert. Iron associated with the silica weathers brown. Beds are less than 2 ft thick. Basal contact is sharp; lower part of unit forms a cliff | 92 |
| Thickness of upper member | 230 |
| Middle member: | |
| 13. Limestone, very dark gray, dense, fine-grained. Beds range in thickness from 3 ft at base to 1 ft at top. Unit forms a light-gray band in the hillside. | |
| Thickness of middle member | 35 |
| Lower member: | |
| 12. Limestone, dark-gray, dense, fine-grained, silty. Beds are less than 2 ft thick and show small-scale cross lamination. Gray chert occurs in lenses and in 3-in. silicifications at the bottoms and tops of beds. Unit weathers rusty | 31 |
| 11. Limestone, shale, and chert. Silty fine-grained very dark gray limestone and dark-gray chert interbedded with poorly exposed shale. The limestone beds are less than 1 ft thick and the chert layers average 3 in. in thickness. Unit forms rusty slope | 56 |
| 10. Limestone, dark-gray, very fine grained. Contains rusty-weathering bands of cherty limestone. Unit forms a cliff in which the beds average 1 ft in thickness | 12 |
| 9. Limestone (60 percent) and shale. Dark-gray fine-grained limestone in beds less than 1 ft thick that weather brown becuase of iron associated with quartz silt or secondary silica. The interbedded shale is in poorly exposed beds less than 2 ft thick | 26 |
| Thickness of lower member | 125 |
| Thickness of Rancheria Formation | 386 |
| Las Cruces Limestone of Laudon and Bowsher (1949): | |
| 8. Limestone, black to dark-gray, very fine grained, dense and brittle. Contains silt-sized pyrite cubes, coarse white calcite in numerous fracture fillings, and sparse crinoid fragments. The beds are unlaminated and of uniform (1 ft) thickness. Shale layers a few inches thick probably separate the beds. Unit forms a light-gray cliff | 70 |

SECTION 9.—*Mississippian and Devonian rocks*—Continunued

| | Feet |
|---|---|
| Las Cruces Limestone of Laudon and Bowsher (1949)—Continued | |
| 7. Limestone, very dark gray, fine-grained. In even beds 1 ft thick that resemble overlying limestone and contain dark-gray unlaminated chert in layers a few inches thick between the beds. Unit weathers light gray and is arbitrarily separated from overlying beds by the presence of chert | 20 |
| Thickness of Las Cruces Limestone | 90 |
| Unconformity. The Percha Shale and upper part of the Middle Devonian sequence are missing. | |
| Middle Devonian rocks: | |
| Upper part: | |
| 6. Marl and shale, gray, interbedded. Unit is covered in line of section but crops out 200 ft to the south. | |
| Thickness of upper part | 7 |
| Lower part: | |
| 5. Chert, marl, and shale, thinly interlensed. Dark-gray chert in lenses and irregular layers that distort beds of dark-gray marl and calcareous shale. Unit forms a mottled cliff in which chert weathers dark gray with rusty edges, and marl and shale weather light gray | 66 |
| 4. Chert, dark-gray. One resistant bed | 2 |
| 3. Shale and chert. Calcareous gray shale interbedded with dark-gray chert. Unit forms a slope | 12 |
| 2. Limestone breccia. Angular fragments of Fusselman Dolomite in unbedded sandy matrix of lime and clay. Upper ½ ft is silicified by gray chert; rest of unit forms yellowish-gray slope | 10 |
| Thickness of lower part | 90 |
| Thickness of Middle Devonian rocks | 97 |
| Fusselman Dolomite: | |
| 1. Dolomite and limestone, light-gray, massive. | |

SECTION 13.—*Upper unit of Hueco Limestone*

[Measured 4.5 miles east of Borderland, Tex.]

| | Feet |
|---|---|
| Hueco Limestone: | |
| Upper unit: | |
| 13. Limestone, light-gray, very fine grained. Contains nodules of light-gray chert and silicified brachiopods (*Wellerella*? sp., *Composita*? sp.). Beds are unlaminated and range in thickness from 10 ft or more at base to 1 ft at top. At places, the beds are chaotically jumbled and contain iron-bearing veins and zones of mineralization | 70 |

SECTION 13.—*Upper unit of Hueco Limestone*—Continued

| | Feet |
|---|---|
| Hueco Limestone—Continued | |
| Upper unit—Continued | |
| 12. Siltstone, brown, purplish-red, and yellow, with some mudstone. Beds are contorted as if from solution of gypsum, but unit is wholly exposed in a small southern tributary of the major canyon here. Unit is a likely equivalent of the Deer Mountain Red Shale Member of the Hueco Limestone in the Hueco Mountains (King and others, 1945) | 100 |
| 11. Covered, probably siltstone like 12 | 6 |
| 10. Limestone, gray, fine-grained; contains nodules of light- and dark-gray chert. The beds are unlaminated and range in thickness from 3 ft near base to 1 ft near top. Measurement is complicated by slumping of the beds | 175 |
| 9. Limestone, gray, fine-grained, thin-bedded, nodular-weathering | 18 |
| 8. Siltstone, grayish-yellow, poorly exposed. Weathering from the unit are brachiopods, including *Chonetes* n. sp., snails, and the fusulinids, *Pseudoschwagerina morsei*, *P. uddeni*, *P.*(?) *texana* var. *ultima*, *Schwagerina franklinensis*, *S.* aff. *S. diversiformis* (locs. 16656–PC, f12423, p. 112 | 10 |
| 7. Siltstone and limestone, thinly interbedded | 7 |
| Thickness of upper unit | 386 |
| Middle unit: | |
| 6. Limestone, gray, fine-grained. Contains chert in rusty disseminations; thickest bed is about 5 ft | 58 |
| 5. Covered | 9 |
| 4. Limestone, gray, fine-grained. Contains chert in rusty disseminations, in mottled gray nodules, and as replacement of brachiopods and snails | 102 |
| 3. Covered | 9 |
| 2. Limestone, gray, fine-grained, cherty, thin-bedded | 7 |
| 1. Siltstone and marl, light-grayish-yellow | 10 |

Base of exposures. (Base not exposed.)

SECTION 14b.—*Middle unit, Hueco Limestone*

[Measured south of Avispa Canyon]

| | Feet |
|---|---|
| Hueco Limestone: | |
| Middle unit (combined with sections 14a and 14c): | |
| 109. Limestone, gray, very fine grained, thin-bedded. Contains crinoid fragments, snails, and, at the base, curvilinear markings (leaflike algae?) | (20) |
| 108. Siltstone, light-yellowish-gray, poorly exposed. Unit was traced to section 14c and is unit 108 of that section | 28 |
| 107. Limestone, light- to medium-gray, medium-grained; contains coarse fossil debris: crinoid fragments, echinoid spines. Chert occurs as rusty disseminations and in brown nodules. The beds are thin and irregular | 12 |

SECTION 14b.—*Middle unit, Hueco Limestone*—Continued

| | Feet |
|---|---|
| Hueco Limestone—Continued | |
| Middle unit (combined with sections 14a and 14c)—Continued | |
| 106. Limestone, gray, fine-grained; coarse fossil debris. Beds are thin and may be separated by siltstone; unit is poorly exposed. Forms a slope strewn with nodular limestone blocks | 31 |
| 105. Siltstone, grayish-yellow, calcareous. The upper part, where the only fresh exposures occur, is friable, unlaminated, and is composed of quartz grains about the size of very fine sand | 37 |
| 104. Limestone, dark-gray, very fine grained and dense. Chert sparsely occurs in dark-gray nodules and rusty disseminations. Thinly bedded | 69 |
| 103. Siltstone, grayish-yellow, poorly exposed | 14 |
| 102. Limestone, dark-gray, noncherty, fine-grained; coarse fossil debris; slightly porous. Beds average 1 ft in thickness | 25 |
| 101. Covered | 7 |
| 100. Limestone, dark-gray, noncherty, fine-grained; coarse fossil detritus at base. Unit is in even beds 1 ft thick | 16 |
| 99. Covered. The slope talus contains bioclastic limestone fragments | 19 |
| 98. Limestone, dark-gray, very fine grained, dense; unlaminated. Contains neither chert nor fossils. Weathers light yellow with dark-gray mottling; can be traced more than a mile westward | 2 |
| 97. Siltstone, grayish-yellow, very soft, intermittently exposed | 30 |
| 96. Siltstone (75 percent) and limestone, thinly interbedded. Fine-grained dark-gray limestone beds 1 ft thick separated by poorly exposed and covered intervals which are probably siltstone. The repetition appears rhythmic, and the limestone contains no chert and no fossils except for granular debris | 140 |
| 95. Covered | 7 |
| 94. Limestone, dark-gray, fine-grained to coarsely bioclastic. One bed | 2 |
| 93. Covered | 2 |
| 92. Limestone, dark-gray, fine-grained to coarsely bioclastic. One bed | 2 |
| 91. Covered. A few 6-in.-thick beds of bioclastic limestone are exposed | 23 |
| 90. Limestone, gray to dark-gray, fine-grained; coarse fossil debris. Chert occurs only as sparse fossil replacement; beds are less than 1 ft thick | 17 |
| 89. Covered. The unit overlies cliff-forming limestone and is at the base of a soft zone of unfossiliferous siltstone and limestone which closely resembles (and is correlated with) the middle division of the Hueco Limestone in the Hueco Mountains (King and others, 1945) | 3 |

SECTION 14b.—*Middle unit, Hueco Limestone*—Continued

Hueco Limestone—Continued

Middle unit (combined wite sections 14a and 14c)—Continued *Feet*

88. Limestone, gray, fine-grained; some coarse crinoid fragments. A single layer of limestone breccia 6 in. thick is present, and chert occurs in scattered gray nodules. The beds, which are poorly laminated, average 4 ft in thickness and form cliffs. The limestone appears to grade into the underlying unit ---------- 62

87. Limestone, gray, fine-grained to coarsely crinoidal. Mottled gray chert nodules are scattered throughout; fusulinids occur in the basal 3 ft. Very massive. and the lower 27 ft appears to be one poorly laminated bed. The unit was traced from section 14a where it directly overlies unit 86 ---------- 37

Base of section.

SECTION 14a.—*Lower unit, Hueco Limestone*

[Measured south of Avispa Canyon]

Hueco Limestone:

Middle unit (combined with sections 14b and 14c): *Feet*

86. Limestone, gray, fine-grained; some layers contain coarse fossil detritus. Laminated throughout and contains sparse chert nodules and fusulinids. Middle part forms a rounded cliff; unit was traced northward across a canyon, where it underlies unit 87, section 14b ---------- 25

85. Limestone, gray, fine-grained; much coarse fossil detritus, fetid. Laminated throughout and contains large irregular pods of mottled gray chert. Unit forms a prominent cliff- 25

84. Limestone and siltstone, poorly exposed. Fine-grained gray limestone with curvilinear (algal?) markings and broken fossils, separated into thin beds by silty covered intervals- 22

83. Limestone, gray; composed of granular crinoid debris, fusulinids ---------- 2

82. Covered. Loose fusulinids, apparently weathering from siltstone are numerous (colln. f12437, p. 113) ---------- 10

81. Limestone, gray, fine- to medium-grained, noncherty. Fusulinids are abundant; beds are thin. Middle part of unit is poorly exposed ---------- 10

80. Limestone, gray; coarsely bioclastic with crinoid debris, fusulinids. Unit is thinly bedded and contains gray chert nodules ---------- 29

79. Limestone, dark-gray, fine-grained. Contains abundant fusulinids, chert in fossiliferous gray nodules and rusty disseminations. Beds are thin; lower half is poorly exposed ---------- 32

78. Covered ---------- 7

77. Limestone, dark-gray; composed of fine to coarse debris: limestone breccia, crinoid fragments, echinoid spines, and fusulinids. Contains rusty chert disseminations and is laminated ---------- 3

SECTION 14a.—*Lower unit, Hueco Limestone*—Continued

| | Feet |
|---|---|
| Hueco Limestone—Continued | |
| Middle unit (combined with sections 14b and 14c)—Continued | |
| 76. Covered. Abundant silicified brachiopods, fusulinids, crinoids, and corals which apparently weathered from siltstone | 9 |
| 75. Limestone, gray, very fine grained; in beds a few inches thick separated by covered partings (siltstone?). Contains silicified leaflike fossils | 5 |
| 74. Limestone, gray, fine-grained to coarsely bioclastic. Yields a fetid odor and contains silicified fossils. Unit consists of one unlaminated bed | 2 |
| 73. Covered. Nearby, it consists of calcareous, argillaceous, light-yellow siltstone. Slope debris from the unit is characterized by abundance of obese fusulinids and silicified *Composita* sp. (collns. f12416, FU500, p. 113) | 11 |
| Thickness of middle unit | 992 |
| Lower unit: | |
| 72. Limestone, gray to dark-gray, fine-grained; coarse fossil debris. Contains fossiliferous gray chert nodules, rusty chert disseminations, many fusulinids. The middle part is a single 12-ft-thick bed that forms a prominent cliff | 20 |
| 71. Limestone, dark- or medium-gray, fine-grained. Dark-gray chert flecked with light-gray fusulinids occurs in nodules and in thin layers between the beds; silicified brachiopods and snails are common. The limestone is thinly bedded and, although it is dense and hard, it does not form cliffs | 18 |
| 70. Covered. Loose fusulinids were collected from the ridgetop (colln. f12438, p. 114) | 10 |
| 69. Limestone, dark-gray, fine-grained. Chert occurs in dark-gray pods and as fossil replacement; the upper foot has curvilinear markings (leaflike algae?). The beds are less than 1 ft thick; about 25 percent of unit is not exposed | 12 |
| 68. Limestone, gray, fine-grained; many layers of granular bioclastic debris. Contains gray chert in nodules, many of them fossiliferous, as well as partly silicified fossil debris. Basal bed is 7 ft thick; upper beds are even and average 1–2 ft in thickness. Top of unit is at crest of a prominent east-facing cuesta | 81 |
| 67. Covered. This forms the highest wide bench on the hillside | 10 |
| 66. Limestone, gray, very fine grained. Finely laminated by shale partings and contains nodules of light-brownish-gray chert | 5 |
| 65. Covered | 4 |
| 64. Limestone, gray, fine-grained at base to coarsely bioclastic at top. Upper part contains silicified fossil detritus; basal part contains fossiliferous dark-gray chert nodules | 5 |
| 63. Covered | 8 |
| 62. Limestone, gray, composed of coarse crinoid and brachiopod fragments, a few of them silicified. Unit consists of one unlaminated bed | 3 |

SECTION 14a.—*Lower unit, Hueco Limestone*—Continued

| | |
|---|---|
| Hueco Limestone—Continued | |
| Lower unit—Continued | *Feet* |
| 61. Covered | 3 |
| 60. Limestone, dark-gray, fine-grained; some coarse fossil debris (brachiopods and snails) | 1 |
| 59. Covered | 6 |
| 58. Limestone, dark-gray, fine-grained to coarsely bioclastic. Unit consists of one bed | 2 |
| 57. Covered. Loose fusulinids occur in the slope talus (colln. f12439, p. 114) | 4 |
| 56. Limestone, gray, very fine grained. Chert nodules, mottled dark gray and white (fusulinids), are common at base, sparse above. Beds are even and average 3 ft in thickness; about 20 percent of unit is not exposed and the thickest covered interval is about 4 ft | 59 |
| 55. Covered | 8 |
| 54. Limestone, gray; composed of granular crinoid fragments. Contains scattered small nodules of gray chert, silicified fossil. Unit consists of one or two beds | 3 |
| 53. Covered. Forms a bench on which loose fusulinids weather (colln. f12440, p. 114) | 7 |
| 52. Limestone, dark-gray, fine-grained. Nodules and lenses of fusulinid-bearing dark-gray chert occur in basal part; granular crinoid debris is common in upper part. Beds average 1 ft in thickness | 24 |
| 51. Covered. Fusulinids weather from the unit (colln. f12441, p. 114) | 3 |
| 50. Limestone, dark- or medium-gray, fine-grained. Unit consists of three beds with nodules of fusulinid-bearing dark-gray chert | 2 |
| 49. Covered. Fusulinids occur in the slope debris (colln. f12442, p. 114) | 6 |
| 48. Limestone, light-gray, fine-grained; coarse bioclastic debris. Unit consists of two resistant beds that contain fusulinid-bearing mottled gray chert nodules | 6 |
| 47. Covered. Unit forms a persistent bench and yields compositoid brachiopods and loose fusulinids (colln. f12443, p. 114) | 27 |
| 46. Limestone, dark-gray, fine-grained matrix with coarse fossil detritus. Beds average 2 ft in thickness | 10 |
| 45. Covered; 6 inches of cherty limestone exposed near base; slope debris is unfossiliferous | 11 |
| 44. Limestone, light-gray to gray, fine-grained with granular fossil fragments. Unit consists of one noncherty unlaminated bed | 7 |
| 43. Limestone, dark-gray, very fine grained in most part, with some layers coarsely bioclastic. Thinly bedded with dark-gray chert between the bedding planes. Unit forms a rusty band in the hillside | 8 |
| 42. Covered | 10 |

SECTION 14a.—*Lower unit, Hueco Limestone*—Continued

| | |
|---|---|
| Hueco Limestone—Continued | |
| Lower unit—Continued | *Feet* |
| 41. Limestone, gray, fine-grained. Unit consists of one bed with some fossil debris, silicified echinoid spines | 2 |
| 40. Covered. The slope debris is weathered silty clay with no fusulinids; unit forms a conspicuous bench in the hillside | 18 |
| 39. Limestone, dark-gray, fine-grained. Contains fossil detritus and sparse nodules of dark-gray chert. The beds, which are unlaminated, are 2 ft thick near the base, somewhat thicker toward the top | 36 |
| 38. Covered | 5 |
| 37. Limestone, gray, fine-grained. Basal foot is covered | 5 |
| 36. Limestone, gray, fine-grained. Chert present only as sparse fossil replacement. Unit appears to be one poorly laminated cliff-forming bed that grades into the underlying limestone | 31 |
| 35. Limestone, gray, fine-grained, dense. The weathered surface is laminated by thin layers, lenses, and odd-shaped nodules of dark-gray chert which form a considerable percentage of the rock. This cherty limestone bed can be identified at all outcrops in the Franklin Mountains. Contains silicified crinoid stems and, at the base, fusulinids, some of them within the chert bodies (colln. f12444, p. 114) | 34 |
| 34. Covered | 11 |
| 33. Limestone, gray, fine-grained; contains silicified snails and lacy disseminated chert | 1 |
| 32. Covered | 5 |
| 31. Limestone, gray, fine-grained. Consists of one poorly laminated bed with rusty chert disseminations | 3 |
| 30. Covered. The talus is weathered silty clay containing fusulinids (colln. f12445, p. 114) | 9 |
| 29. Limestone (70 percent) and siltstone or shale. Fine-grained dark-gray limestone in beds less than 2 ft thick, separated by poorly exposed siltstone or shale. Detrital limestone fragments, dark-gray chert nodules occur in some of the limestone beds | 22 |
| 28. Covered. Fusulinids weather from the unit (colln. f12446, p. 114) | 8 |
| 27. Limestone, light-gray, fine- to medium-grained, dense. One unlaminated, noncherty bed | 9 |
| 26. Limestone, light-gray, fine- to medium-grained. Fossiliferous nodules of light-pink chert form 30 percent of the rock | 2 |
| 25. Covered | 4 |
| 24. Limestone, gray, fine-grained. Contains oolites, fusulinids, and disseminated rusty chert | 5 |
| 23. Limestone and siltstone, thinly interbedded, poorly exposed. The limestone is noncherty and contains finely broken fossil fragments | 19 |

SECTION 14a.—*Lower unit, Hueco Limestone*—Continued

| | Feet |
|---|---|
| Hueco Limestone—Continued | |
| Lower unit—Continued | |
| 22. Limestone, gray, fine-grained. Contains sparse disseminations of rusty chert, and the weathered surface is mottled dark and light gray. Unit forms cliffs and appears to be one poorly laminated bed | 19 |
| Fault. The trace nearly parallels strike of beds, west side is downthrown, and an indeterminable but probably small thickness of rocks is missing at surface. | |
| 21. Covered. Snails and fusulinids weather from unit (colln. f12447, p. 115) | 10 |
| 20. Limestone, light-gray, fine-grained with coarse brachiopod fragments, some of them silicified | 2 |
| 19. Covered. Fusulinids occur in the float (colln. f12448, p. 115) | 6 |
| 18. Limestone, gray, very fine grained. Contains coarse crystalline calcite in disseminations, silicified brachiopods. Consists of two unlaminated beds | 2 |
| 17. Covered. Fusulinids in slope debris (colln. f12449, p. 115) | 10 |
| 16. Limestone, mottled dark- and light-gray, very fine grained. Consists of two unlaminated beds | 3 |
| 15. Covered. Loose fusulinids on bench formed by unit (collns. f12450, f12425, p. 115) | 5 |
| 14. Limestone, dark-gray, very fine grained with some bioclastic material. Contains chert as abundant rusty disseminations and as replaced fusulinids. Two beds | 2 |
| 13. Covered | 4 |
| 12. Limestone, mottled dark- and brownish-gray, very fine grained matrix with rounded limestone pebbles. Consists of one laminated bed | 2 |
| 11. Covered | 3 |
| 10. Limestone, brownish-gray, very fine grained. Finely laminated, weathers light gray | 2 |
| 9. Limestone, light-gray, fine-grained with pebbles of fine-grained dark-gray limestone | 2 |
| 8. Covered | 3 |
| 7. Limestone, gray, very fine grained, dense. Consists of one laminated bed | 2 |
| 6. Covered. Slope debris is silty clay containing loose fusulinids (collns. f12451, f12424, p. 115) | 13 |
| 5. Limestone, gray, very fine grained, dense. Light-gray chert occurs in lenses at top; unit appears to be one poorly laminated bed which grades into underlying limestone | 11 |
| 4. Limestone (75 percent) and chert. Dense, fine-grained, light-gray to pink limestone thinly laminated by parallel lenses of light-gray chert | 8 |
| 3. Covered | 8 |

SECTION 14a.—*Lower unit, Hueco Limestone*—Continued

| | Feet |
|---|---|
| Hueco Limestone—Continued | |
| Lower unit—Continued | |
| 2. Limestone, grayish-pink, fine-grained, dolomitic. Unit is in thick fractured and slumped beds. It is arbitrarily chosen as the basal Hueco near the base of what appears to be a zone of transition from siltstone with laminated, generally unfossiliferous limestone (Magdalena) to massive bioclastic limestone with minor siltstone (Hueco) | 13 |
| Thickness of lower unit | 752 |
| Thickness of Hueco Limestone | 2, 120 |
| Magdalena Formation: | |
| Upper member: | |
| 1. Limestone, gray, very fine grained, argillaceous, finely laminated. Contains rusty disseminated chert, crinoid stems, bryozoa | 10 |
| Base of exposures. | |

## FOSSILS AND LOCALITIES

The location and stratigraphic position of fossils collected in the area are shown in the following lists. Collections taken from the measured sections are identified by number on the graphic sections (pl. 2) and in the written descriptions of selected measured sections (p. 83). They can be approximately located on the geologic map (pl. 1) by the lines of measured section. The collections taken from localities other than measured sections are shown by number on the geologic map. E. L. Yochelson, R. J. Ross, Jr., P. T. Hayes, and Hector Ugalde aided the writer in collecting the fossils.

Collections with numbers prefixed "FU" and "57 RJ" were useless for comparison purposes and were discarded. Those prefixed "D" are filed at the U.S. Geological Survey, Federal Center, Denver, Colo., and the remainder at the U.S. National Museum in Washington, D.C.

### CASTNER LIMESTONE (PRECAMBRIAN)

Identified by Richard Rezak.

D958. Graphic section *I*. Lower part, Castner Limestone, 40 ft above granite that intrudes base of formation.

*Collenia frequens* Walcott

### BLISS SANDSTONE (UPPER CAMBRIAN AND LOWER ORDOVICIAN)

Collected by R. J. Ross, Jr., identified by P. E. Cloud, Jr.

57RJ40. Measured section 5, unit 4.

*Lingulepis* cf. *L. accuminata* (Conrad)

## EL PASO LIMESTONE (LOWER ORDOVICIAN)

Fossils identified by R. J. Ross, Jr., unless otherwise noted. The conodonts, which were found in acid residues from some of the fossil material, were not collected systematically.

D401CO. Measured section 1, unit 25.
*Tritoechia* sp.

D399CO. Measured section 1, unit 18.
*Ophileta* sp.

D413CO. Measured section 5, unit 26.
*Diparelasma*? sp.
*Hesperonomia* sp.
*Kirkella* sp.
*Pseudocybele* cf. *P. nasuta* Ross
Conodonts identified by W. H. Hass (October 1958).
*Oistodus* sp. C
*Paltodus*? *variabilis* Furnish
*Scolopodus quadruplecatus* Branson and Mehl
distacodontid conodont fragments

2239CO. Measured section 5, unit 26.
Identified by E. L. Yochelson.
*Trochonema* sp.
nautiloid cephalopod, unidentified

D412CO. Measured section 5, unit 19.
According to R. J. Ross, Jr., the collection consists of:
"A trilobite cranidium and a pygidium, probably belonging to the same species (new). The cranidium resembles one figured by Ross (1951, pl. 29, fig. 20) and the pygidium resembles one figured by Hintz (1952, pl. 15, fig. 18), both from zone G of the Garden City Limestone. They were not known to be precisely contemporaneous."

D411CO. Measured section 5, unit 19.
*Licnocephala* n. sp.
*Paranileus*? sp.

D410CO. Measured section 5, unit 19.
According to R. J. Ross, Jr., the collection consists of:
"two species of trilobites. One may be related to *Rananasus*, and the other to *Cephalocoelia*. The first is found in the Rich Fountain Formation of Cullison (1944) (Lower Ordovician) of the Ozarks, and the second is Cambrian."

2437CO. Measured section 5, unit 17.
Identified by E. L. Yochelson.
piloceratid and orthoconic cephalopod siphuncles, undet.

D432CO. Measured section 5, unit 17.
Cephalopod, unidentified, and sponges

D620CO. Measured section 5, unit 15.
*Archaeoscyphia* sp.

2436CO. Measured section 5, unit 12.
Identified by E. L. Yochelson.
*Ophileta*? sp.

D424CO. Measured section 5, unit 10.
*Nanorthis* sp.
brachiopod, new genus related to *Diaphelasma*
Conodonts identified by W. H. Hass (Oct. 1958).
*Drepanodus lineatus* Furnish
*triangularis* (Furnish)
*Scolopodus quadruplicatus* Branson and Mehl

D425CO. Measured section 5, unit 10.
Conodonts identified by W. H. Hass (October 1958).
*Acontiodus* sp. B
*Drepanodus lineatus* Furnish
*triangularis* (Furnish)
*Paltodus? variabilis* Furnish
*Scolopodus* sp. B
fragments of distacodontid conodonts

2435CO. Measured section 5, unit 8.
Reported by E.L. Yochelson.
piloceratid cephalopod siphuncle, unidentified

D433CO. Measured section 5, unit 8.
*Nanorthis?* sp.
Conodonts identified by W. H. Hass (October 1958).
*Acodus* sp. B
*Drepanodus lineatus* Furnish
*subarcuatus* Furnish
*triangularis* (Furnish)
*Scolopodus* sp. B

D407CO. A loose talus block in measured section 5, unit 8.
According to R. J. Ross, Jr., the specimen consists of:
"Left side of a proparian trilobite cranidium, bearing strong resemblance to *Tesselacauda* sp., but with an ocular ridge distinct from the anterior rim."
Conodonts identified by W. H. Hass (October 1958).
*Acontiodus* sp. B
*Drepanodus lineatus* Furnish
*triangularis* (Furnish)
sp. B
*Paltodus? variabilis* Furnish
*Scolopodus* sp. B
sp. D
distacodontid conodont fragments

D406CO. Measured section 5, unit 6.
*Apheoorthis?* sp.
*Bellefontia* sp.

2291CO, 2292CO. East face of Franklin Mountains, 0.25 mile south of measured section 5; 1.5 miles north and 0.2 mile west of the peak, Anthonys Nose, Tex. Upper part of upper member of El Paso Limestone, 23–26 ft below Montoya Dolomite. Identified by E. L. Yochelson.
*Trochonema* sp.
gastropod, new genus?

D409CO. In fault sliver half a mile south of the Texas-New Mexico boundary, 2.4 miles north and 0.8 mile east of the peak Anthonys Nose, Tex. Uppermost El Paso Limestone, 4 ft below Montoya Dolomite.

brachiopods, indet.
*Kirkella* cf. *K. declivita* Ross
*Kawina* cf. *K. sexapugia* Ross
*Pseudocybele*? sp.
*Paranileus*? sp.
bathyurid trilobite

2438CO. Same locality as D409CO. Upper part of upper member of El Paso Limestone, 14 ft below Montoya Dolomite. Identified by E. L. Yochelson.

*Trochonema* sp.
gastropod, indet.

D408CO. Same locality as D409CO. Upper member of El Paso Limestone, 51 ft below Montoya Dolomite. Conodonts identified by W. H. Hass (October 1958).

*Acodus* sp. A
*Acontiodus* sp. A
*Drepanodus subarcuatus* Furnish
  sp. A
*Oistodus* sp. A
  sp. B
*Scolopodus quadruplicatus* (Branson and Mehl)
  sp. A
  sp. B
distacodontid conodont fragments

2293CO. Crest of Franklin Mountains, 1.3 miles north and 0.4 mile west of North Franklin Mountain. Upper part of Bat Cave Member of Zeller (1965) of El Paso Limestone, exact position unknown. Identified by E. L. Yochelson.

*Ceratopea* sp.

## MONTOYA DOLOMITE (UPPER ORDOVICIAN)

Fossils were identified by R. J. Ross, Jr., unless otherwise specified. The conodonts were found in acid residues.

D404CO. Canyon on west slope near crest of Franklin Mountains, 0.3 mile southwest of measured section 2. Upper part of Cutter Member of Montoya Dolomite, 15–30 ft below top of formation.

*Dinorthis*? sp.
*Diceromyonia* sp.
*Lepidocyclus*? sp.
*Isotelus* sp., identified from an aluminum foil impression

D402CO. Same locality as D404CO. Limestone in basal marl unit of Cutter Member of Montoya Dolomite.

*Plaesyomis* sp.
*Dinorthis* sp.
*Platystrophia* sp.
*Strophomena* sp.

D403CO. Loose specimens from crest of Franklin Mountains 0.05 mile south of measured section 2. Basal marl unit of Cutter Member of Montoya Dolomite, 0–27 ft above base of member.

*Hebertella* cf. *H. sinuata* (Hall)
*Hypsiptycha neenah* (Whitfield)
*Platystrophia* sp.
*Thaerodonta* sp.
*Onniella* sp.

2370CO. Measured section 2, unit 2.

Identified by J. M. Berdan and W. A. Oliver, Jr.

"*Streptelasma*" sp.
*Grewingkia*? sp.

D415CO. East front of Franklin Mountains, 0.3 mile south of measured section 5. Upper part of Cutter Member of Montoya Dolomite, 35 ft below top of formation.

*Lepidocyclus*? sp.
*Hypsiptycha*? sp.
*Paucicrura* or *Diceromyonia* sp.
*Sowerbyella* sp.

D416CO. Same locality as D415CO. Middle part of Cutter Member of Montoya Dolomite, 83 ft above base of member.

*Hypsiptycha* sp.
*Platystrophia* sp.
*Paucicrura* or *Diceromyonia* sp.
*Bighornia* sp.
*Streptelasma trilobatum* Whiteaves

D417CO. Same locality as D415CO. Middle part of Cutter Member of Montoya Dolomite, 65 ft above base of member. Same bed as at colln. D426CO, unit 30, measured section 5.

*Grewingkia*? sp.
"*Streptelasma*" sp.
*Platystrophia* cf. *P. equiconvexa* (Wang)
*Dinorthis* sp.
*Lepidocyclus*? sp., small
*Diceromyonia* cf. *D. tersa* (Sardeson)
*Hypsiptycha* cf. *H. neenah* (Whitfield)
*Thaerodonta* cf. *T. recedens* (Sardeson)
*Thaerodonta* aff. *T. aspera* Wang
*Strophomena* sp.

Conodonts identified by W. H. Hass (October 1958).

*Belodus compressus* Branson and Mehl
*Drepanodus* cf. *D. curvatus* Branson, Mehl, and Branson
*Drepanodus* cf. *D. inclinatus* Branson, Mehl, and Branson
*Drepanodus* cf. *D. subrectus* Branson, Mehl, and Branson
*Lonchodina* sp. A
*Neoprioniodus* sp. A
*Scolopodus* sp. C
*Trichonodella* sp. A

D418CO. Same locality as D415CO. Lower part of Cutter Member of Montoya Dolomite, 42 ft above base of member. Same bed as at colln. D427CO, unit 30, measured section 5.
*Hypsiptycha* aff. *H. neenah* (Whitfield)
*Diceromyonia* sp.
*Thaerodonta* cf. *T. aspera* Wang

D419CO. Same locality as D415CO. Lower part of Cutter Member of Montoya Dolomite, 4 ft above basal marl unit and 38 ft above base of member. Same bed as at D622CO, unit 30, measured section 5.
*Hebertella* cf. *H. sinuata* (Hall)

D414CO. Same locality as D415CO. Upper part of Aleman Member of Montoya Dolomite, 4 ft below bed of colony corals; same bed as at colln. D429CO, unit 28, measured section 5, 48 ft below top of member:
*Hebertella* cf. *H. sinuata* (Hall)
rhynchonellid brachiopod, indet.

D426CO. Measured section 5, unit 30. Same bed as at colln. D417CO.
streptelasmid coral, large
*Sceptropora* cf. *S. facula* Ulrich
*Dinorthis* n. sp., large
*Hypsiptycha* cf. *H. hybrida* Wang
*Rafinesquina*? sp.
*Thaerodonta* sp.
*Diceromyonia* sp.
Conodonts identified by W. H. Hass (October 1958).
*Aphelognathus gracilis* (Branson, Mehl, and Branson)
*Belodus compressus* Branson and Mehl
*Drepanodus* cf. *D. curvatus* Branson, Mehl, and Branson
*inclinatus* Branson, Mehl, and Branson
*subrectus* Branson, Mehl, and Branson
*Lonchodina* sp. A
*Neoprioniodus* sp. A
*Rhipidognathus* sp. A
*Roundya* sp. A
*Scolopodus* sp. C
*Trichonodella* sp. A
*Zygognathus* sp. A

D427CO. Measured section 5, unit 30. Same bed as at colln. D418CO.
*Thaerodonta* sp.
*Diceromyonia* sp.
*Sceptropora* cf. *S. facula* Ulrich
Conodonts identified by W. H. Hass (October 1958).
*Aphelognathus gracilis* Branson, Mehl, and Branson
*Belodus compressus* Branson and Mehl
*Drepanodus* cf. *D. curvatus* Branson, Mehl, and Branson
*Lonchodus* sp. A
*Neoprioniodus* sp. A
*Roundya* sp. A
*Scolopodus* sp. C
*Trichonodella* sp. A
*Zygognathus* sp. A

D622CO. Measured section 5, unit 30. Same bed as at colln. D419CO.
*Hebertella* sp.
*Platystrophia* sp.

D428CO. Measured section 5, unit 29.
*Hebertella* cf. *H. sinuata* (Hall)
*Hypsiptycha* sp.
*Sceptropora* cf. *S. facula* Ulrich
Conodonts identified by W. H. Hass (October 1958).
*Aphelognathus gracilis* Branson, Mehl, and Branson
*Belodus compressus* Branson and Mehl
*Drepanodus* cf. *D. curvatus* Branson, Mehl, and Branson
*inclinatus* Branson, Mehl, and Branson
*subrectus* Branson, Mehl, and Branson
*Neoprioniodus* sp. A
*Plectodina* sp. A
*Rhipidognathus* sp. A
*Roundya* sp. A
*Trichonodella* sp. B
*Zygognathus* sp. A

D411CO. Measured section 5, unit 28.
Identified by W. A. Oliver, Jr..
*Palaeophyllum thomi* (Hall)
*Saffordophyllum*? sp.

D429CO. Measured section 5, unit 28.
*Hebertella* sp.
gastropod steinkerns, immature
Conodonts identified by W. H. Hass (October 1958).
*Aphelognathus gracilis* Branson, Mehl, and Branson
*Belodus compressus* Branson and Mehl
*Drepanodus* cf. *D. curvatus* Branson, Mehl, and Branson
*Neoprioniodus* sp. A
*Scolopodus* sp. C
numerous fragments of distacodontid and bladelike conodonts

3868CO. Measured section 5, unit 27.
Identified by W. A. Oliver, Jr.
*Tollina* [*Manipora*] sp.

D430CO. In fault sliver 0.5 mile south of the Texas-New Mexico boundary, 2.4 miles north and 0.7 mile east of the peak, Anthonys Nose, Tex. Basal marl unit of Cutter Member of Montoya Dolomite, 18 ft above base of member.
*Hebertella* sp.
*Platystrophia* sp.
*Hypsiptycha* sp.
Conodonts identified by W. H. Hass (October 1958).
*Aphelognathus grandis* Branson, Mehl, and Branson
*Drepanodus* cf. *D. curvatus* Branson, Mehl, and Branson
*subrectus* Branson, Mehl, and Branson
*Lonchodina* sp. A
*Lonchodina*? sp. B
*Neoprioniodus* sp. A
*Plectodina* sp. A

*Roundya* sp. A
*Trichonodella* sp. A
sp. B
*Zygognathus* sp. A

D431CO. Same locality as D430CO. About 25 ft below top of Aleman Member of Montoya Dolomite.
*Sceptropora* sp.
*Onniella*? sp.
gastropods, immature
Conodonts identified by W. H. Hass (October 1958).
*Rhipidognathus*? sp. A
conodont fragments, indet.

## MIDDLE DEVONIAN ROCKS

Fossils identified by J. T. Dutro, Jr., except as noted.

4697SD. Measured section 7, unit 22. Base of Middle Devonian rocks 1 ft above Fusselman Dolomite.
*Chonetes*? sp.
*Devonoproductus*? sp.
*Tentaculites* sp.
*Styliolina* aff. *S. fissurella* (Hall)

4696SD. Measured section 7, unit 22. Base of Middle Devonian rocks in contact with the underlying Fusselman Dolomite.
*Barroisella*? sp.
productellid brachiopod similar to that in colln. 4697–SD
brachiopod, indet.
*Tentaculites* sp.

5821SD. Measured section 8, unit 5. From 105 ft above base of Middle Devonian rocks.
*Schizobolus* sp.
*Barroisella*? sp.
*Schuchertella* sp.
*Mucrospirifer*? sp.
brachiopod, indet.
*Styliolina* sp.

5822SD. Measured section 8, unit 3. From 73 ft above base of Middle Devonian rocks.
*Leiorhynchus* sp.
*Chonetes*? sp.
spiriferoid brachiopod, indet.

5823SD. Measured section 8, unit 3. From 69 ft above base of Middle Devonian rocks.
*Schizobolus* sp.

FU251. Canyon bottom 0.3 mile southwest of measured section 8, Vinton Canyon. From 68 to 83 ft above base of Middle Devonian rocks. Identified by W. H. Hass (October 1958).
*Icriodus* sp.
*Polygnathus linguiformis* Hinde
*pennata* Hinde
*Schizobolus* sp.
*Styliolina* sp.

## RANCHERIA FORMATION OF LAUDON AND BOWSHER, 1949 (MISSISSIPPIAN)

Fossils identified by J. T. Dutro, Jr., except as noted.

16674–PC. Measured section 8, unit 15. From 65 ft below top of Rancheria Formation.

Crinoid debris
Fenestrate bryozoan, indet.
Orthotetid brachiopod, indet.
"*Productus*" sp. inflatus type
Spiriferoid brachiopod, indet.
*Cleiothyridina* cf. *C. hirsuta* (Hall)
*Eumetria?* sp.

16675–PC. Measured section 8, unit 14. From 45 ft above base of upper member of the Rancheria Formation.

"*Ambocoelia*" sp.
*Torynifer?* sp.
pleurotomarian gastropod, undet.
goniatite, undet.

16673–PC. Measured section 8, unit 12. From 163 ft above base of Rancheria Formation.

*Torynifer?* sp.

16672–PC. Measured section 8, unit 10. From 51 ft above base of Rancheria Formation.

Crinoid debris
*Spirifer* aff. *S. leidyi* Norwood and Pratten
*increbescens* Hall
*Spirifer* sp.
Compositoid brachiopod, indet.

FU209. Measured section 8, unit 9. Base of Rancheria Formation.
Identified by D. H. Dunkle.

Conchliodont tooth fragment

## HELMS FORMATION AS USED BY LAUDON AND BOWSHER, 1949 (UPPER MISSISSIPPIAN)

Fossils identified by J. T. Dutro, Jr., except as noted.

16668–PC. Measured section 7, unit 5. From 117 to 142 ft below top of Helms

Endothyrid and millerellid foraminifera, undet.
*Linoproductus* aff. *L. pileiformis* (McChesney)
*Cleiothyridina* aff. *C. sublamellosa* (Hall)
*Crurithyris* sp.
*Straparollus* aff. *S. triliris* (Easton) (Gastropod identified by E. L. Yochelson)
Fish fragment, indet.

16676–PC. Measured section 8, unit 19. From 20 to 40 ft below top of Helms.

Crinoid columns
Rhomboporoid bryozoan, indet.
*Schizophoria*? sp.
"*Productus*" sp.
*Spirifer* aff. *S. pellannsis* Weller

Athyrid brachiopod, indet.
(ostracodes identified by I. G. Sohn.)
*Nudirostra*? sp.
*Posidonia*? sp.
*Naticopsis* sp. goniatite impression
*Bairdia* sp.
*Sansabella* sp.

## MAGDALENA FORMATION (PENNSYLVANIAN)

The search for fossils in the Magdalena Formation was concentrated in the upper member; the fauna of the lower members is described in detail by Nelson (1940). L. G. Henbest identified the foraminifera, and E. L. Yochelson identified the other fossils.

16354–PC. Measured section 12, unit 27. From 160 ft below top of upper member of Magdalena Formation.
*Wellerella osagensis* (Swallow)
*Chonetes granulifer* Owen
?*Ditomopyge* sp.

16356–PC. Measured section 11, unit 114. From 95 ft above conglomerate that marks base of upper member of Magdalena Formation.
Lophophyllid corals
Crinoid stems
*Crurithyris planoconvexa* (Shumard)
*Pulchratia* cf. *P. ovalis* Dunbar and Condra
*Hystriculina wabashensis*? (Norwood and Pratten)
*Retaria lasallensis* (Worthen)
?*Dielasma* sp.
*Euphemites* n. sp.
cf. *E. vittatus* (McChesney)
*Bellerophon* (*Pharkidonotus*) *percarinatus* (Conrad)
*crassus* Meek and Worthen
*Knightites* cf. *K. tenuilineata* (Gurley)
*Phymatopleura brazoensis* (Shumard)
*Ananias* n. sp.
*Glabrocingulum* aff. *G. grayvillense* (Norwood and Pratten)
*Worthenia tabulata* (Conrad)
*Trepospira depressa* (Cox)
*Amphiscapha* aff. *A. sulcata* (Knight)
*Naticopsis* (?*Jedria*) sp.
*Sphaerodoma* sp. 1
sp. 2
*Meekospira* sp.
*Astartella concentrica* McChesney
*Nuculopsis ventricosa* (Hall)
?*Yoldia* sp.
Straight and coiled nautiloids, undet.
Goniatites, undet.

f12430. Measured section 11, unit 101. From 153 ft below top of Bishop Cap Member of Magdalena Formation. Included are the highest fusulinids found in section 8.

*Endothyra* sp.
*Bradyina* sp.
*Globivalvulina* sp.
Genus cfr. *Paramillerella* Thompson
*Fusulina* cf. *F. distenta* Roth and Skinner
*Fusulina* spp.

f12795. West side of Franklin Mountains in NW¼NE¼ sec. 28, T. 26 S., R. 4 E., Dona Ana County, N. Mex. The highest fusulinids found in the Magdalena of the New Mexico part of the Franklin Mountains; lower part of the Bishop Cap Member, 1,000 ft above base of formation.

*Wedekindellina euthysepta* (Henbest)
*Fusulina distenta* Roth and Skinner

f12429. Crest of Franklin Mountains, 5.2 miles due east of Anthony, Tex., 0.1 mile south of Texas-New Mexico boundary. Basal part of Berino Member.

*Fusulinella iowensis*? Thompson

## HUECO LIMESTONE (PERMIAN)

Only fusulinids were systematically collected in the Hueco Limestone, many of which were collected as loose specimens weathered from siltstone or shale. L. G. Henbest identified the fusulinids as well as other foraminifera which he found associated with the fusulinids in all the rock samples. E. L. Yochelson identified the other fossils and collected many of them.

f12423. Measured section 13, unit 8. Fossil bed probably at base of upper unit of Hueco Limestone, about 2,000 ft above base of the formation; same bed and locality as locality 85 of Dunbar and and Skinner (1937).

*Pseudoschwagerina morsei* Needham
  *uddeni* (Beede and Kniker)
  *uddeni*?
  ?*texana* var. *ultima* Dunbar and Skinner
*Schwagerina* or *Paraschwagerina* sp.
*Schwagerina* aff. *S. diversiformis* Dunbar and Skinner
  *franklinensis* Dunbar and Skinner

16656-PC. Same locality and bed as f12423.

Echinoid spines
*Chonetes* n. sp.?
*Hystriculina wabashensis* (Norwood and Pratten)
*Composita* sp.
*Wellerella* cf. *W. osagensis* (Swallow)
*Euphemites* sp.
*Omphalotrochus* sp.

f12417. Measured section 14c, units 128–131. Basal part of upper unit of Hueco Limestone, 1,960–2,000 ft above base of formation.
*Schwagerina franklinensis* Dunbar and Skinner
*diversiformis* Dunbar and Skinner
*diversiformis* var.
*eolata* Thompson
*Schwagerina* 2 spp.

16654–PC. Same locality and bed as f12417.
bryozoans, undet.
*Composita* cf. *C. subtilita* (Hall)
*Chonetes* n. sp.?
*Hystriculina* sp.
*Wellerella* cf. *W. osagensis* (Swallow)
*Spiriferina* sp.
*Parallelodon*? sp.
*Glabrocingulum*? sp.

f12418, f12435. Measured section 14c, unit 122. Upper part of middle unit of Hueco Limestone, 1,790 ft above base of formation.
*Schwagerina eolata* Thompson
*hawkinsi* Dunbar and Skinner
sp.
*Pseudoschwagerina*? *laxissima* (Dunbar and Skinner)
*Parafusulina linearis* (Dunbar and Skinner)

f12436. Measured section 14c, unit 112. Upper part of middle unit of Hueco Limestone, 1,600 ft above base of formation.
*Earlandia* sp.
*Geinitzina* sp. (*G. postcarbonaria* Spandel group)
*Spandelina* sp.
*Spandelinoides*? sp.
*Globivalvulina* sp.
*Schubertella* n. sp.
*Pseudoschwagerina convexa* Thompson

f12437. Measured section 14a, unit 82. Lower part of middle unit of Hueco Limestone, 850 ft above base of formation.
*Schwagerina bellula*? Dunbar and Skinner
*Paraschwagerina* sp.
*Pseudoschwagerina*? *texana* Dunbar and Skinner
*morsei*? Needham

f12416. Measured section 14a, unit 73. From siltstone that marks base of middle unit of Hueco Limestone, 750 ft above base of formation.
*Pseudoschwagerina uddeni* (Beede and Kniker)
*gerontica*? Dunbar and Skinner
*Pseudoschwagerina*? *texana* Dunbar and Skinner
?*texana* var. *ultima* Dunbar and Skinner

FU500. Same locality and bed as f12416.
*Composita* cf. *C. subtilita* (Shepard)

f12438. Measured section 14a, unit 70. Upper part of lower unit of Hueco Limestone, 700 ft above base of formation.
*Schwagerina bellula* Dunbar and Skinner
sp.
*Pseudoschwagerina? texana* Dunbar and Skinner
*?texana* var.
*uddeni?* (Beede and Kniker)

f12439. Measured section 14a, unit 57. Upper part of lower unit of Hueco Limestone, 550 ft above base of formation.
*Pseudoschwagerina? texana* Dunbar and Skinner
*Schwagerina andresensis* Thompson

f12440. Measured section 14a, unit 53. Middle part of lower unit of Hueco Limestone, 480 ft above base of formation.
*Schwagerina* sp.
*Schwagerina* or *Paraschwagerina* sp.
*Pseudoschwagerina? laxissima* (Dunbar and Skinner)
*?laxissima* var.

f12441. Measured section 14a, unit 51. Middle part of lower unit of Hueco Limestone, 450 ft above base of formation.
*Pseudofusulina* or *Pseudoschwagerina* sp.
*Schwagerina* or *Paraschwagerina* sp.
*Pseudoschwagerina? laxissima* (Dunbar and Skinner)
*?laxissima* var.

f12442. Measured section 14a, unit 49. Middle part of lower unit of Hueco Limestone, 440 ft above base of formation.
*Pseudofusulina emaciata* (Beede)
*Schwagerina* sp.
*Pseudoschwagerina* or *Pseudofusulina* sp.

f12443. Measured section 14a, unit 47. Middle part of lower unit of Hueco Limestone, 405–432 ft above base of formation.
*Pseudofusulina emaciata?* (Beede)
*Schwagerina* sp.
*Pseudoschwagerina? laxissima* (Dunbar and Skinner)

f12444. Measured section 14a, unit 35. From the persistent cherty limestone in lower part of lower unit of Hueco Limestone, 230 ft above base of formation.
*Climacammina* sp.
*Tetrataxis* sp.
*Schwagerina* 2 spp.
*Pseudoschwagerina* sp.
*morsei* Needham var. *needhami* (Thompson)

f12445. Measured section 14a, unit 30. Lower part of lower unit of Hueco Limestone, 200 ft above base of formation.
*Triticites? eoextenta?* (Thompson)
*Pseudoschwagerina morsei* Needham var.
*Schwagerininae*, indet.

f12446. Measured section 14a, unit 28. Lower part of lower unit of Hueco Limestone, 170 ft above base of formation.
*Pseudoschwagerina* or *Paraschwagerina* sp.
*Pseudoschwagerina morsei* Needham var.
*Schwagerininae*, indet.

f12447. Measured section 14a, unit 21. Lower part of lower unit of Hueco Limestone, 106 ft above base of formation.
*Triticites*? aff. *T.*? *eoextenta* (Thompson)
*Pseudoschwagerina morsei*? Needham
sp.

f12448. Measured section 14a, unit 19. Lower part of lower unit of Hueco Limestone, 96 ft above base of formation.
*Pseudoschwagerina morsei* Needham
*morsei* var.

f12449. Measured section 14a, unit 17. Lower part of lower unit of Hueco Limestone, 86 ft above base of formation.
*Pseudoschwagerina morsei* Needham
*morsei* var.

f12425, f12450. Measured section 14a, unit 15. Lower part of Hueco Limestone, 75 ft above base of formation.
*Pseudoschwagerina morsei* var. *needhami* (Thompson)
*Pseudoschwagerina* or *Triticites* sp.

f12424, f12451. Measured section 14a, unit 6. Lowermost Hueco Limestone, 46 ft above base of formation.
*Pseudoschwagerina morsei* var. *needhami* (Thompson)
*uddeni*? (Beede and Kniker)

f12431. Measured section 12, unit 78. Upper part of lower unit of Hueco Limestone, 450 ft above base of formation.
*Pseudoschwagerina*? *texana* Dunbar and Skinner var.
aff. *beedei* Dunbar and Skinner
?*laxissima* (Dunbar and Skinner)

16659–PC. Same locality and bed as f12431.
ramose bryozoan, undetermined
*Rhipidomella carbonaria* (Swallow)
*Composita subtilita* (Shepard)
*Chonetes granulifer* Owen
*Dictyoclostus wolfcampensis* (R. E. King)
*Kozlowskia capaci* (Orbigny)
*Wellerella* sp.

12514. Measured section 12, unit 64. Middle part of lower unit of Hueco Limestone, 307 ft above base of formation.
*Earlandia* sp.
*Climacammina* sp.
*Endothyra* sp.
*Geinitzina postcarbonaria* Spandel
*Spandelina*? sp.
*Monotaxis* sp.
*Tetrataxis* sp.
*Globivalvulina* sp.
*Schubertella kingi* Dunbar and Skinner var.
*Pseudofusulina* sp.
*Pseudofusulina* aff. *P. emaciata* (Beede)
sponge spicules, monaxous

f12434. Outlier west of Franklin Mountains, 2.5 miles south and 4 miles east of Rio Grande bridge at Canutillo, Tex. Weathering from siltstone probably at base of upper unit of Hueco Limestone, about 2,000 ft above base of formation.

*Pseudoschwagerina uddeni* (Beede and Kniker) var.
*gerontica*? Dunbar and Skinner
?*texana* Dunbar and Skinner var.
*Schwagerina franklinensis* Dunbar and Skinner
*diversiformis* Dunbar and Skinner var.
?*Paraschwagerina nelsoni* (Dunbar and Skinner)

16658. Same locality and bed as f12434.

*Lophophyllidium* sp.
bryozoans, undetermined
crinoid stems
echinoid spines
*Derbyia* cf. *D. crassa* (Meek and H yden)
*Crurithyris* cf. *C. planoconvexa* (Shumard)
*Chonetes* sp.
*Marginifera capaci* (Orbigny)
*Dictyoclostus wolfcampensis* (R. E. King)
*Huestedia huecoensis* R. E. King
*Spirifer* n. sp.
*Composita subtilita* (Shepard)
*Wellerella osagensis* (Swallow)
*Stenoscisma huecoeana* (Girty)
*Spiriferinella* n. sp.?
*Euphemites* sp.
*Omphalotrocus* sp.
*Ditomopyge* sp.

f12433. Outlier west of Franklin Mountains, 1.2 miles south and 4.1 miles east of Rio Grande bridge at Canutillo, Tex. Weathering from siltstone probably at base of upper unit of Hueco Limestone about 2,000 ft above base of formation.

*Pseudoschwagerina gerontica* Dunbar and Skinner var.
*convexa*? Thompson
*Paraschwagerina*? *nelsoni* (Dunbar and Skinner)

16657. Same locality and bed as f12433.

lophophyllid coral fragment
*Lophophyllidium* sp.
*Derbyia* n. sp.
*Chonetes granulifer* Owen
*Dictyoclostus wolfcampensis* (R. E. King)
*Kozlowskia* sp.
*Composita subtilita* (Shepard)
*Euphemites* sp.
*Omphalotrochus* sp.
*Conocardium* n. sp.
*Colpities* sp.
nautiloid cephalopod, undet.

f12422. Fault block immediately north of Avispa Canyon, 2 miles north and 4.1 miles east of Canutillo, Tex. Upper part of middle unit of Hueco Limestone, exact position unknown.
*Pseudoschwagerina? texana* Dunbar and Skinner
?*Paraschwagerina nelsoni* (Dunbar and Skinner)
*Schwagerina franklinensis* Dunbar and Skinner
*Parafusulina* aff. *P. schucherti* Dunbar and Skinner

FU509. Same locality and bed as f12422.
echinoid spines
lamellar and ramose bryozoans
*Dictyoclostus* sp.
*Composita subtilita* (Shepard)
cf. *C. mexicana* (Hall)
*Omphalotrochus* sp.
*Pleurophorus* sp.

16655. Outlier west of Franklin Mountains, 1.1 miles north and 3.1 miles east of bridge across Rio Grande at Vinton, Tex. Stratigraphic position unknown, probably in middle unit of Hueco Limestone.
*Wewokella* sp.
bryozoan, undet.
echinoid spines
*Crurithyris* sp.
*Cancrinella*? sp.
"*Dictyoclostus*" *wolfcampensis* (R. E. King)
*Linoproductus* cf. *L. cora* (Orbigny)
*Composita subtilita* (Shepard)
*Wellerella* cf. *W. osagensis* (Swallow)
sp.
*Plagioglypta* sp.
*Euphemites* sp.
*Knightites* sp.
*Omphalotrochus* sp.
*Straparollus* cf. *S. cornudanus* (Shumard)
*Glabrocingulum* sp.
neritacean gastropod, indet.

f12419. First outcrop of Hueco Limestone north of Vinton Canyon, 0.1 of a mile west of limestone quarry, 0.6 of a mile north and 4.4 miles east of Vinton Bridge. From siltstone that marks base of middle unit of Hueco Limestone, 700 ft above base of formation; same bed and locality as locality 87 of Dunbar and Skinner (1937).
*Pseudoschwagerina uddeni* (Beede and Knifer)
*uddeni* var.
*gerontica*? Dunbar and Skinner
*Pseudoschwagerina*? *texana* Dunbar and Skinner
?*texana* var.
?*texana* var. *ultima* Dunbar and Skinner

FU503. Same locality and bed as f12419.
horn coral, undet.
bryozoan, indet.
crinoid stems
*Composita subtilita* (Shepard)
*Schizodus* sp.
gastropod, indet.

f12420. West side of Franklin Mountains on west limb of syncline in Permian rocks, 2.7 miles north and 3.4 miles east of Vinton Bridge. The siltstone that marks base of middle unit of Hueco Limestone, 700 ft above base of formation.
Fusulinids similar to those in f12419

FU504. Same locality and bed as f12420.
horn coral, undet.
echinoid plates
*Dictyoclostus wolfcampensis* (R. E. King)
*Composita subtilita* (Shepard)
sp.
*Hustedia mormoni* (Mancow)
*Dielasma* cf. *D. bovidens* (Morton)
*Bellerophon* sp.
*Omphalotrochus obtusispira* (Shumard)

f12421. West side of Franklin Mountains, west of syncline in Permian rocks, 2.4 miles north and 2.8 miles east of Vinton Bridge. From siltstone at base of middle unit of Hueco Limestone, 700 ft above base of formation.
*Pseudoschwagerina uddeni* (Beede and Kniker)
*gerontica*? Dunbar and Skinner
?*texana* Dunbar and Skinner
?*texana* var.
*Paraschwagerina*? sp.

FU505. Same locality and bed as f12421.
*Composita subtilita* (Shepard)
*Dictyoclostus wolfcampensis* (R. E. King)
nautiloid cephalopod, indet.

16355. North of Boundary Commission quarry at Vinton Canyon, 0.6 of a mile north and 4.5 miles east of Vinton Bridge. Middle part of lower unit of Hueco Limestone, above the persistent cherty limestone bed, about 350 ft above base of formation. The fossil bed is repeated in the hillside by a bedding-plane fault. J. H. Johnson (1950, pl. 17) described algal-foraminiferal balls from this locality.
algal-foraminiferal balls
ramose and fenestrate bryozoans
*Derbyia crassa* (Meek and Hayden)
*Composita subtilita* (Shepard)
*Reticulatia huecoensis* (R. E. King)
*Knightites* sp.
*Aviculopecten* sp.

f12361. West side of Franklin Mountains on north flank of syncline, in W½NW¼ sec. 33, T. 26 S., R. 4 E., Dona Ana County, N. Mex. Middle part of lower unit of Hueco Limestone, about 300 ft above base of formation, and 80 ft above a gypsum quarry which is capped by the persistent cherty limestone bed of lower map unit.

*Spandelinoides* sp.
*Endothyra* sp.
*Globivalvulina* sp.
*Ozawainella huecoensis* Dunbar and Skinner
*Schubertella kingi* Dunbar and Skinner
*Pseudofusulina powwowensis* (Dunbar and Skinner)
*huecoensis* Dunbar and Skinner var.

f12362. Same locality as f12361, about 30 ft above the gypsum quarry.

*Climacammina* sp.
*Spandelinoides* sp.
*Geinitzina* sp. (*G. postcarbonaria* Spandel group)
*Globivalvulina* sp.
*Tetrataxis* sp.
*Schubertella kingi* Dunbar and Skinner
*Pseudoschwagerina*? *texana* Dunbar and Skinner (very early variety)
*Schwagerina*? sp. (fragment)

f12362a. Same locality as f12361, about 10 ft above the gypsum quarry.

*Schwagerina*? sp. (fragment)
*Pseudoschwagerina uddeni* (Beede and Kniker)

16353. Same locality and bed as f12362a.

lophophyllid coral
crinoid stems
echinoid spines
ramose and fenestrate bryozoans
*Composita subtilita* (Shepard)
*Omphalotrochus* sp.

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