DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

PROFESSIONAL PAPER 108—C

A COMPARISON OF PALEOZOIC SECTIONS IN SOUTHERN NEW MEXICO

BY

N. H. DARTON

Published May 29, 1917

Shorter contributions to general geology, 1917
(Pages 31-55)

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ILLUSTRATIONS.

A COMPARISON OF PALEOZOIC SECTIONS IN SOUTHERN NEW MEXICO.

By N. H. DARTON.

INTRODUCTION.

In studying the geology of different parts of southern New Mexico the writer has obtained many new data on the distribution and relations of the sedimentary rocks. The stratigraphy of the Pennsylvanian series was investigated in detail, and in Luna County all the formations were studied.[1] A recently published folio [2] gives many new facts for the stratigraphy of the Silver City region, some of which are utilized in the present paper. Richardson's work in the El Paso region [3] established the succession in the southeastern part of New Mexico. There are also many details in publications by Gordon and Graton, Lee, Herrick, and others.

It has been known for some time that in southern New Mexico there are representatives of portions of later Cambrian, Ordovician, Silurian, Devonian, earlier Mississippian, and Pennsylvanian time, and that the lower formations thin out to the north, so that in central New Mexico the strata of the Pennsylvanian series lie directly on the pre-Cambrian crystalline rocks, as shown in Plate XIV, *B*. There are also numerous irregularities in the overlap relations of the formations. The broader features of the stratigraphy of this region are here presented. The principal Paleozoic formations in southern New Mexico are shown in the columnar sections (fig. 2), and some conditions of the distribution of the formations are indicated on the map (Pl. XIII).

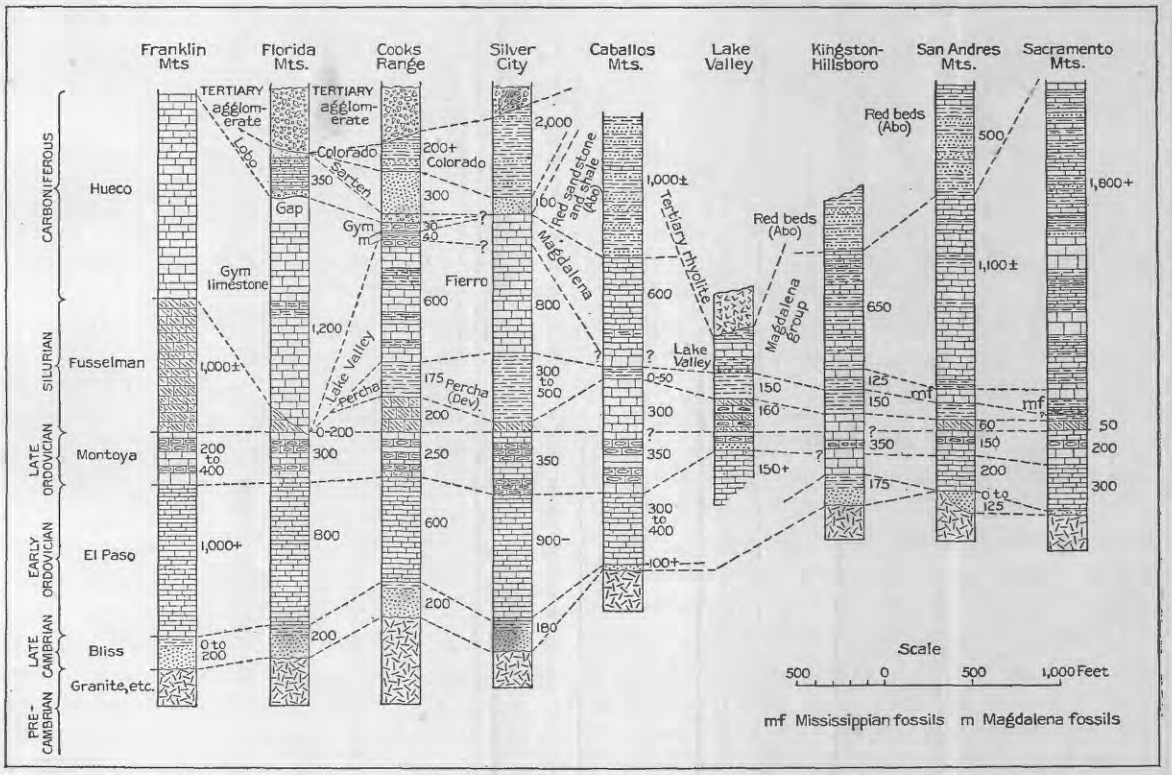


FIGURE 2.—Columnar sections showing stratigraphic relations of Paleozoic rocks in southern New Mexico.

[1] Darton, N. H., Geology and underground waters of Luna County, N. Mex.: U. S. Geol. Survey Bull. 618, 188 pp., 13 pl., 1916.

[2] Paige, Sidney, U. S. Geol. Survey Geol. Atlas, Silver City folio (No. 199), 1916.

[3] Richardson, G. B., U. S. Geol. Survey Geol. Atlas, El Paso folio (No. 166), 1909.

CAMBRIAN SYSTEM.

GENERAL FEATURES.

The presence of Cambrian strata in New Mexico was announced by Gordon and Graton[1] in 1906, on the evidence afforded by the discovery of *Obolus stoneanus* in sandstones on the west side of the Caballos Mountains near Shandon. In 1910 the name "Shandon quartzite"[2] was given to the beds at this place, and they were tentatively correlated with the Bliss sandstone of the Franklin Mountains, near El Paso, Tex., defined by Richardson[3] in 1904. Sandstones and other rocks of Cambrian age occur at many places in Arizona, where apparently they underlie wide areas. The name Bliss sandstone has been adopted for southern New Mexico because of its priority in the El Paso region. It replaces the name "Shandon quartzite."

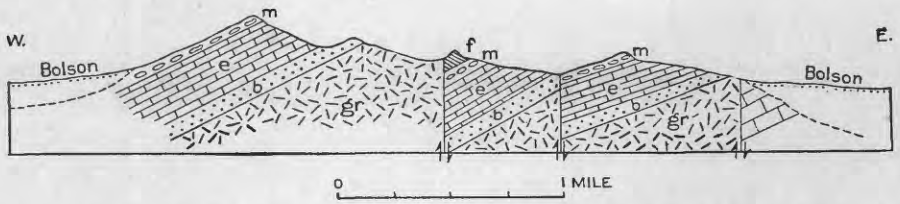


FIGURE 3.—Section across the Franklin Mountains 3 miles north of El Paso, Tex. (After Richardson.) gr, Granite; b, Bliss sandstone; e, El Paso limestone; m, Montoya limestone; f, Fusselman limestone.

BLISS SANDSTONE.

Franklin Mountains.—In its type locality, at the east base of the Franklin Mountains, the Bliss sandstone consists of small grains of quartz embedded in a matrix of sericite and kaolin. The basal beds are mostly quartzitic and locally conglomeratic, and the higher beds are softer and finer grained. The prevailing color is brown, but some portions have lighter tints. A thickness of 300 feet is attained in places, but locally the formation thins out and overlying limestones rest on the pre-Cambrian rocks. It appears to grade upward into the El Paso limestone. Annelid borings are abundant, and a few brachiopods in the lower beds comprise *Lingulepis acuminata, Obolus matinalis?*, and fragments of *Lingulella.* Some relations of the Bliss sandstone in the Franklin Mountains are shown in figure 3.

Florida Mountains and Cooks Range.—In Luna County the Bliss sandstone is similar in character, thickness, and relations to the formation in its type locality. It crops out in the Florida Mountains and Cooks Range, as well as in several outliers, everywhere lying with strong unconformity on granite, as shown in Plate XVI, *B* (p. 34), and grading upward into the El Paso limestone. Gray to brown sandstone prevails; part of it is quartzitic, but the upper beds are slabby and have intercalations of sandy and limy shale. The formation contains much glauconite. Its average thickness is 150 feet, but locally it is much thinner. No fossils were found in these areas.

Silver City region.—In the Silver City region the Bliss sandstone consists of quartzite and limy sandstone containing some glauconite throughout. The thickness averages 180 feet, but varies somewhat. At most places the basal member is quartzite, which grades upward as a rule into fine-grained greenish sandstone but locally into soft ferruginous sandstone, and here and there the greater part of the formation is quartzite. At the top there is generally a thin quartzite or glauconitic sandstone, grading upward into limy sandstone that appears to merge with the overlying El Paso limestone. A typical section given by Paige[4] is as follows:

Section of Bliss sandstone 7 miles northwest of Silver City, N. Mex.

	Feet.
Sandstone, coarse, glauconitic	12
Limestone, sandy; thin, wavy bedding; fucoid markings	47
Quartzite, coarse, slightly cross-bedded	17
Sandstone, limy; thin, wavy bedding; fucoids?	57

[1] Gordon, C. H., and Graton, L. C., Lower Paleozoic formations in New Mexico: Am. Jour. Sci., 4th ser., vol. 21, p. 392, 1906. See also Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, p. 225, 1910.

[2] Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., op cit., p. 225.

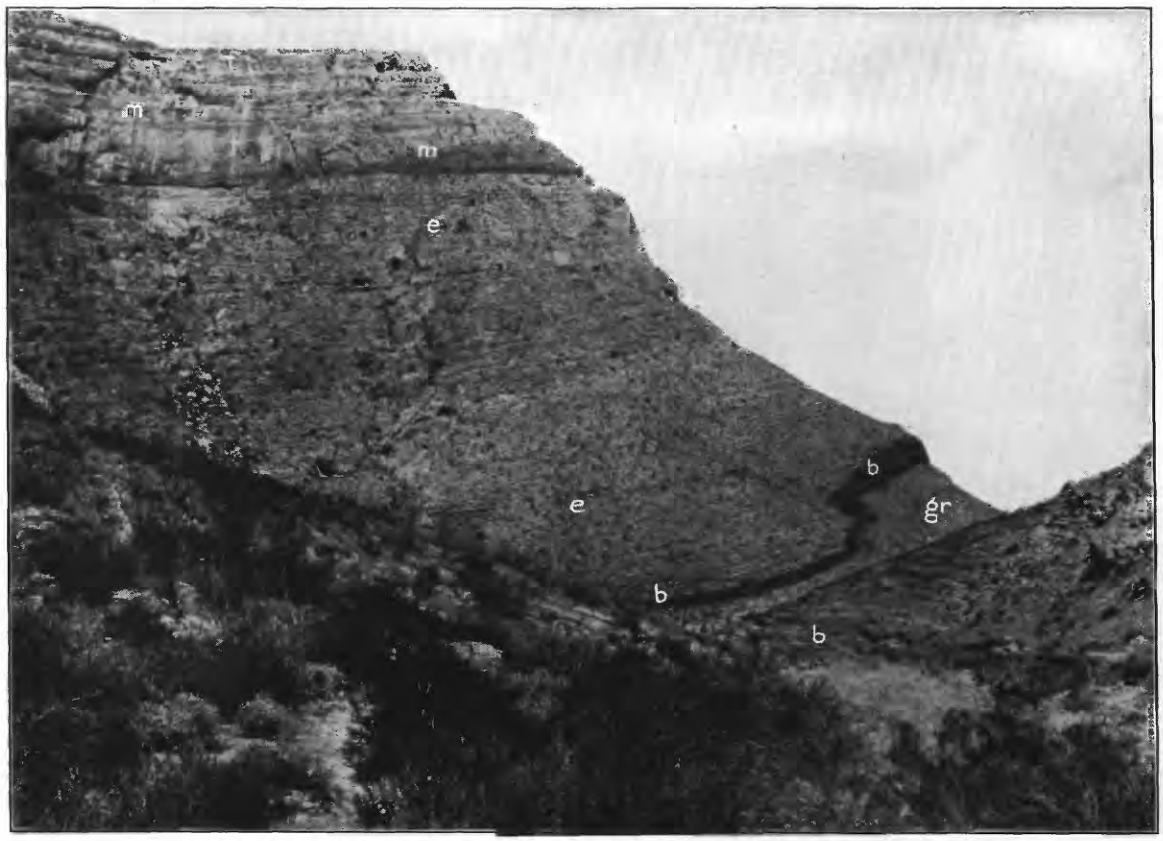
[3] Richardson, G. B., Report of a reconnaissance in trans-Pecos Texas north of the Texas & Pacific Railway: Texas Univ. Mineral Survey Bull. 9, p. 27, 1904.

[4] Paige, Sidney, Geol. Survey Geol. Atlas, Silver City folio (No. 199), 1916.

MAP OF PART OF NEW MEXICO AND ADJOINING REGIONS, SHOWING RELATIONS OF LOWER PALEZOIC ROCKS.

A. BLISS SANDSTONE IN BENNETT CANYON, 18 MILES NORTHEAST OF LAS CRUCES, N. MEX.
B, Contact of Bliss sandstone and El Paso limestone.

B. WEST FACE OF SANDIA MOUNTAINS AT BERNALILLO, N. MEX.
a, Sandia formation on granite, etc.



A. VIEW LOOKING EAST OUT OF MOUTH OF HEMBRILLO CANYON.

f, Fusselman limestone; m, Montoya limestone; e, El Paso limestone; b, Bliss sandstone; gr, granite.

B. VIEW LOOKING NORTHEAST IN GOODFORTUNE CANYON.

mgr, Microgranite; mg, limestone of Magdalena group; lv, Lake Valley limestone; p, Percha shale; m, Montoya limestone; e, El Paso limestone; b, Bliss limestone; gr, granite.

VIEWS ON EAST SIDE OF SAN ANDRES MOUNTAINS, WEST OF ALAMOGORDO, N. MEX.

	Feet.
Quartzite, massive, cross-bedded, ferruginous, glauconitic; pebbly streaks	17
Sandstone, soft, glauconitic	13
Quartzite, massive, coarse (on granite)	15
	178

The area of outcrop of the formation is small. It appears along the west slope of the ridge northwest of Silver City and on some outlying ridges and in a small exposure at the west end of Lone Mountain, 6 miles southeast of Silver City. The beds near the base yielded abundant specimens of *Billingsella coloradoensis*, an Upper Cambrian fossil.

Caballos Mountains.—The Bliss sandstone in the Caballos Mountains has been described by Gordon and Graton[1] and by Lee.[2] As explained above, the beds at this place were called "Shandon quartzite." They lie on a smooth plane on granite, which is exposed to a height of about 1,000 feet above the Rio Grande on the west slope of the range, as shown in figure 8 (p. 39) and Plate XVI, *A* (p. 34). Gordon and Graton described a thin basal member of dark quartzite, absent in places; white quartzite 4 to 5 feet thick; and an upper member, 40 feet thick, of dark-brown and green sandy shales and thin-bedded quartzite carrying *Obolus*. The beds recorded by Lee in a section 3 miles north of Shandon consist of a basal quartzite 10 feet thick, in places conglomeratic, grading upward into 90 feet of dark-green shale. The shale yielded *Obolus (Westonia) stoneanus*, *Obolus sinoe?*, *Eoorthis desmopleura*, and *Lingulella acutangulata?*, determined by C. D. Walcott and regarded as Upper Cambrian. A similar section was observed by Lee in Cerro Cuchillo, near Palomas Spring. (See Pl. XVII, *A*, p. 35.) In both places the overlying limestone is the El Paso. Lee states that the basal quartzite thickens to 300 feet 8 miles south of Shandon.

San Andres Mountains.—The Bliss sandstone crops out continuously along the east slope of the San Andres Mountains, but it becomes very thin in the north end of the range. (See figs. 9, p. 42, and 11, p. 45.) The formation is a conspicuous feature in Bennett Canyon, 18 miles northeast of Las Cruces, where it is 125 feet thick and lies between granite and the El Paso limestone. This exposure is shown in Plate XIV, *A*. The Bliss is 60 feet thick 2 miles northeast of Organ, where it is cut off by igneous rocks. At this locality the rocks are sandstone, mostly hard, and many layers contain considerable glauconite. In San Andres Canyon the formation comprises 110 feet of beds, consisting of a lower member of gray quartzite, mostly massive; a medial member of brown sandstone, partly slabby; and an upper slabby member that apparently merges with the base of the El Paso limestone. In the central part of the range, at Deadman and Hembrillo canyons, the thickness is from 30 to 40 feet. (See Pl. XV.) In Sulphur Canyon it consists of 25 feet of brown sandstone, conglomeratic at the base, grading upward into 30 feet of thin, slabby softer sandstone, in part glauconitic, which appears to grade into slabby, finer sandstone, and this in turn into an impure buff slabby limestone that is certainly the El Paso. In Rhodes Canyon the sandstone that separates the El Paso beds from the granite is 6 feet thick, and this thin deposit extends northward, as shown in Plates XV, *B*, and XVIII, *A* (p. 36).

Sacramento Mountains.—In the small exposure of the base of the sedimentary rocks just south of the mouth of Agua Chiquita Canyon, in the Sacramento Mountains, the El Paso limestone is separated from a dark granite by a few feet of hard sandstone, which is presumably Bliss. It is not especially characteristic, however, and yielded no fossils, so that the correlation can be only tentative.

Mimbres Mountains.—According to Gordon,[3] the limestone in the east slope of Mimbres Mountains is separated from the granite by quartzite, which undoubtedly represents the Bliss sandstone. (See fig. 10, p. 44.) Exposures on Carbonate Creek show 75 feet of dark-red quartzite, which includes a 3-foot bed of shale near the middle and rests on an irregular surface of red granite. In most of the slopes of these mountains the basal formations of the sedimentary series are hidden by younger igneous rocks, which cap the range.

[1] Am. Jour. Sci., 4th ser., vol. 21, pp. 391–392, 1906; U. S. Geol. Survey Prof. Paper 68, pp. 225–226, 1910.

[2] Lee, W. T., Notes on the lower Paleozoic rocks of central New Mexico: Am. Jour. Sci., 4th ser., vol. 26, pp. 180–181, 1908.

[3] U. S. Geol. Survey Prof. Paper 68, pp. 268, 269, 1910.

ORDOVICIAN SYSTEM.

GENERAL FEATURES.

Ordovician rocks were first discovered in the Southwest by G. G. Shumard in 1856,[1] who found fossils now known to be characteristic of the Ordovician in the Franklin Range at El Paso. Some years later the geologists of the Wheeler Survey [2] found similar fossils at several localities, including the vicinity of Silver City, N. Mex.

Gordon and Graton [3] found other fossiliferous localities in southern New Mexico in 1905. The beds of Ordovician age which they describe are about 750 feet thick, and in 1910 these beds, together with a Silurian limestone that overlies them in places, were designated the "Mimbres limestone."[4] All these limestones are well represented in the Franklin Mountains north of El Paso, where Richardson [5] subdivided them into the El Paso and Montoya limestones, of Ordovician age, and the Fusselman limestone, of Silurian age. As these formations are separable throughout southern New Mexico, the name "Mimbres limestone" is no longer useful. Throughout the region the middle part of the Ordovician and the lower part of the Silurian appear to be absent.

The Ordovician succession in southern New Mexico shows everywhere uniform and very marked characteristic features. They are wonderfully distinct at the many widely scattered exposures examined by the writer, from the Franklin Mountains west to Silver City, and to the north in Cooks Range, Lake Valley, and the San Andres, Caballos, and Sacramento mountains. The El Paso limestone, at the base of the section, is in most places of unmistakable character, its conspicuous features being thin bedding, a light color on weathering, and brownish-buff reticulations on the bedding planes, caused by irregular layers of an iron-silica deposit probably due to a seaweed. This formation is overlain by dark massive limestone at the base of the Montoya; locally a thin sandstone separates the two limestones, and everywhere there is a sharp break. The upper member of the Montoya invariably consists of alternating layers of limestone and chert carrying abundant Richmond fossils.

[1] Shumard, G. G., A partial report on the geology of western Texas, p. 103, Austin, 1886.

[2] U. S. Geog. and Geol. Expl. W. 100th Mer. Rept., vol. 3, pp. 515–517, 1875.

[3] Am. Jour. Sci., 4th ser., vol. 21, pp. 392–393, 1906.

[4] U. S. Geol. Survey Prof. Paper 68, p. 226, 1910.

[5] Richardson, G. B., U. S. Geol. Survey Geol. Atlas, El Paso folio (No. 166), 1909.

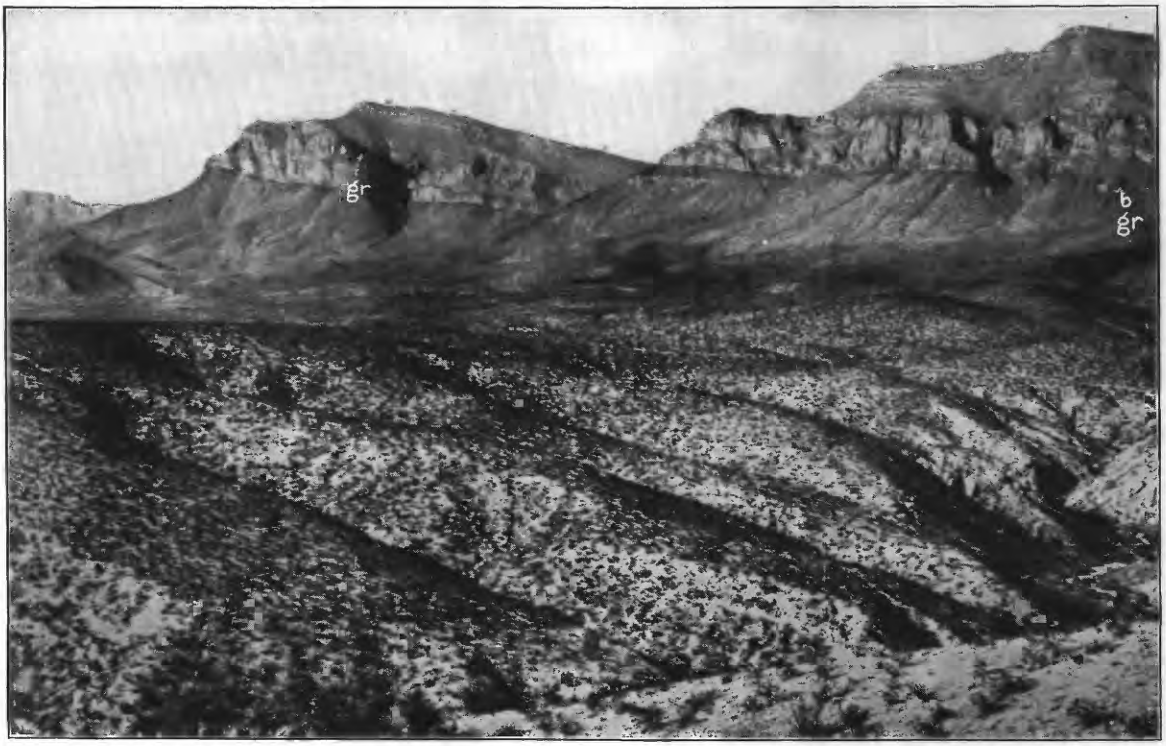
EL PASO LIMESTONE.

Franklin Mountains.—The El Paso limestone was separated from other Ordovician strata in the Franklin Mountains north of El Paso by Richardson.[6] In the type locality the formation consists of about 1,000 feet of gray limestone mostly massive but in part slabby. The lower 100 feet contains some sand and weathers brown. Where it is in contact with pre-Cambrian rocks the basal member 20 feet thick consists of round pebbles of porphyry in a limy matrix. In the middle of the formation occur thin connected nodules of brown chert in streaks parallel to the bedding, but this feature, characteristic here, was not observed in other regions. Magnesia is a general constituent in variable amount. The principal outcrop is along the eastern flank of the Franklin Mountains, where the relations are those shown in figure 3 (p. 32). Distinctive Lower Ordovician fossils were found in the formation at many places.

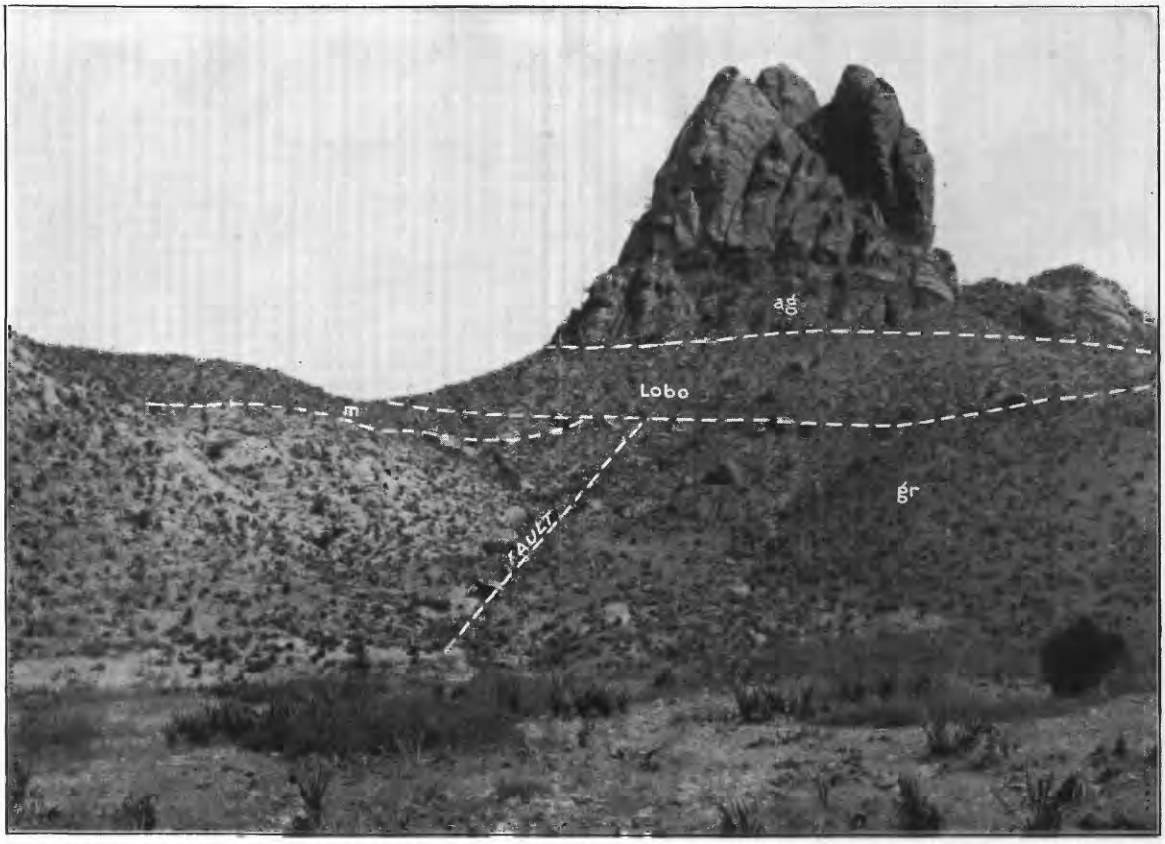
Florida Mountains.—The El Paso limestone is extensively exposed in the south-central part of the Florida Mountains and also on the northwestern slope of that range a short distance southwest of Deming. (See Pl. XVI, *B*.) At the latter place the thickness is about 800 feet and the lower 140 feet is darker and more massive than in other outcrops. The greater part of the formation consists of light-gray slabby dolomitic limestone with pale reddish-brown blotches over the bedding planes. There is very little chert. The upward gradation from the Bliss sandstone is well marked, and the change to the overlying Montoya limestone is abrupt. The structural relations in the southern part of the range are shown in figure 15 (p. 54).

Cooks Range.—At the north end of Cooks Range and in Fluorite Ridge, at its south end, the El Paso is well exhibited. The northern exposures show 600 feet of beds between the Bliss sandstone and the sandstone member at the base of the Montoya. The relations near

[6] U. S. Geol. Survey Geol. Atlas, El Paso folio (No. 166), 1909.

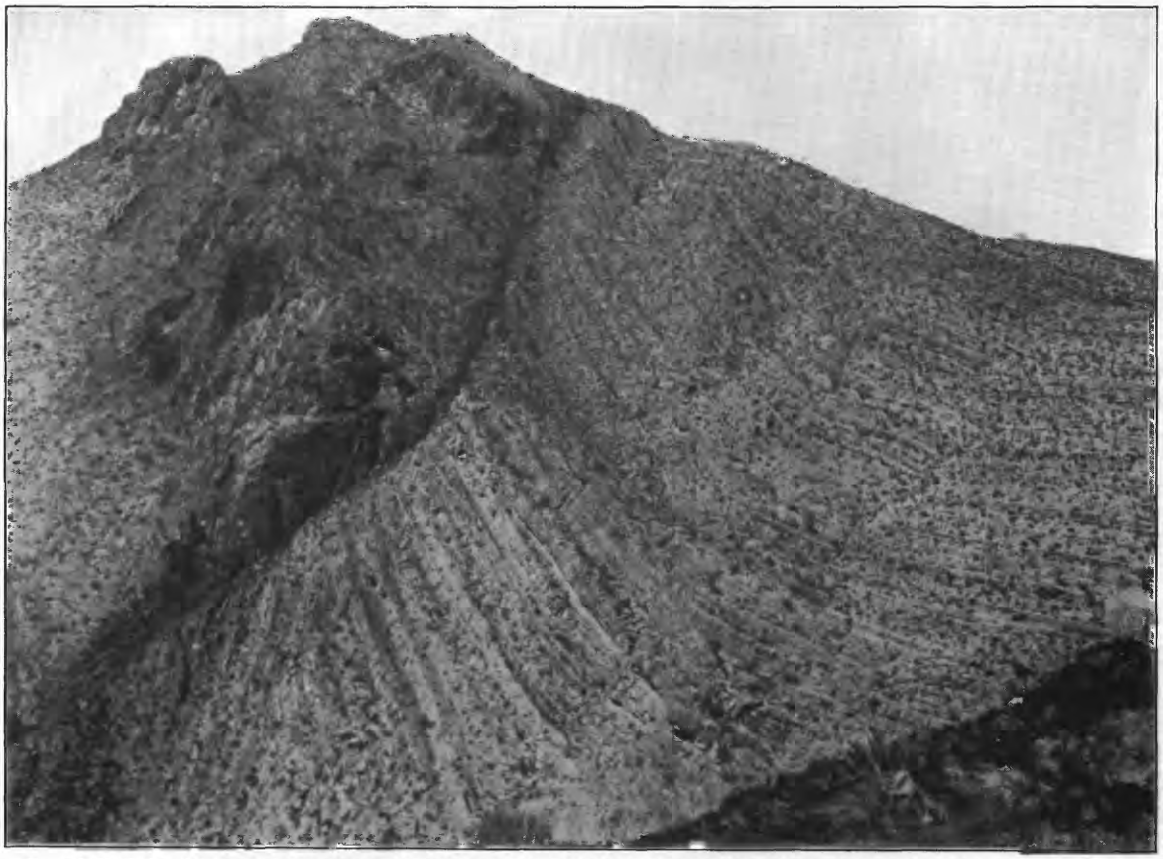


A. WEST FACE OF CABALLOS MOUNTAINS NEAR APACHE CANYON, SIERRA COUNTY, N. MEX.
Looking northeast. gr, Granite; b, Bliss sandstone.



B. PALEOZOIC ROCKS ON GRANITE AT CAPITOL DOME, FLORIDA MOUNTAINS, LUNA COUNTY, N. MEX.
Looking northeast. ag, Agglomerate; m, Montoya limestone; e, El Paso limestone; gr, granite.

A. SIERRA CUCHILLO WEST OF PALOMAS SPRINGS, N. MEX.
Looking northwest. Granite, Bliss sandstone, Ordovician and Pennsylvanian limestones.



B. FAULT IN LIMESTONE AT PALOMAS GAP, CABALLOS MOUNTAINS, SIERRA COUNTY, N. MEX.
Looking north.

Cooks are shown in figure 4. In Fluorite Ridge, 12 miles north of Deming, the beds are so crushed and faulted that only about 400 feet of the El Paso limestone appears.

Snake Hills.—The east end of the Snake Hills, a small range rising out of the desert a few miles southwest of Deming, consists of El Paso limestone showing distinctive features and fossils. The base of the formation is not exposed, but to the west, as shown in figure 6 (p. 37), its top passes under the Montoya limestone with marked unconformity.

Victorio Mountains.—The knob constituting the northeastern member of the Victorio Mountains presents extensive exposures of El Paso limestone, 600 to 700 feet thick at least, dipping south toward a mass of Montoya limestone which constitutes much of Mine Hill. The El Paso beds present the usual slabby character, weather to a light color, and show

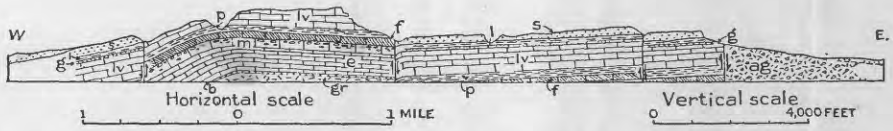


FIGURE 4.—Section across Cooks Range at Cooks, N. Mex. gr, Granite; b, Bliss sandstone; e, El Paso limestone; m, Montoya limestone; f, Fusselman limestone; p, Percha shale; lv, Lake Valley limestone; g, Gym limestone; l, Lobo formation; s, Sarten sandstone (Cretaceous); ag, agglomerate.

abundant pale-brown reticulations on the bedding planes.

Klondike Hills.—The Klondike Hills, 12 miles south of the Victorio Mountains, consist mainly of the El Paso and Montoya limestones, the former mostly in the western part of the ridge as shown in figure 5. At one place the underlying Bliss sandstone is exposed. The thickness is about 650 feet and all the usual features are presented. At the top there is an unconformable overlap of sandy beds at the base of the Montoya limestone, but the attitude of both formations is practically the same.

Silver City region.—In the vicinity of Silver City the El Paso limestone is mostly gray or grayish blue and in part magnesian. It appears to grade upward from the Bliss sandstone, the lowermost 100 feet becoming progressively less sandy. The lower and middle parts are slabby, and the slabs have the characteristic mottled surface seen in other areas. In the upper part the formation is more massive and contains considerable chert. The total thickness is about 900 feet. The formation has nearly the same distribution as the Bliss sandstone in Lone Mountain in the Silver City Range, northwest of Silver City, and in an area north of Bear Mountain.

Caballos Mountains.—The El Paso limestone is a prominent feature in the great section along the west front of Caballos Mountains, where it has the relations shown in figure 8 (p. 39) and Plate XVI, *A*. The Bliss sandstone grades upward into the El Paso, and above it are typical cherty beds of the Montoya limestone. It constitutes 300 or 400 feet of the lower part of the limestone cliffs, and the rocks present the same characteristics that are seen in the Franklin Mountains and Luna County. However, Lee [1] notes a section 8 miles south of Shandon in which it consists of 200 feet of cherty limestone, overlain unconformably by 500 feet of cherty limestone (Montoya and later). Characteristic fossils were found by Lee in both formations.

Lake Valley district.—The lower 150 feet of the limestone in Quartzite Ridge, on the west side of the Lake Valley mining district, is made up of El Paso beds. On the east these beds are overlain by 20 feet of hard sandstone at the base of the Montoya limestone, and on the west they are cut off by igneous rocks. The relations are shown in figure 10 (p. 44). The rocks are the highly characteristic slabby limestone, weathering to a light color and having most of the bedding planes stained with brownish reticulations.

Mimbres Mountains.—Gordon and Graton [2] report an extensive section of Ordovician rocks in the Mimbres Mountains near Kingston. At this place the lower division doubtless represents the El Paso limestone, but it is mostly a blue and white marble, and the distinctive fossils were not found. On Carbonate Creek the basal limestone is exposed in contact with sandstone of Cambrian age (Bliss).

[1] Am. Jour. Sci., 4th ser., vol. 26, p. 180, 1908.
[2] Idem, vol. 21, p. 392, 1906.

San Andres Mountains.—The El Paso limestone extends continuously along the east face of the San Andres Mountains, from the igneous contact near Organ to the north end of the range. Its relations are shown in figures 9 (p. 42) and 11 (p. 45). (See also Pls. XV and XVIII, *B*.) Its thickness is about 300 feet at the south but gradually diminishes northward from San Andres Canyon to 160 feet on Lostman Canyon, 125 feet at Rhodes Canyon, and 80 feet in Lava Gap. In Sulphur Canyon, which is nearly due west of Tularosa, it is 160 feet. The limestone lies on or grades upward from the Bliss sandstone and has characteristic slabby structure with the slabs weathering light gray and having surfaces mottled with reticulations of brownish-buff markings, probably due to a seaweed. Locally the medial beds are massive and less distinctive in appearance. Fossils were found at many places. The relations 18 miles northeast of Las Cruces and in Lava Gap are shown in figure 9 (p. 42).

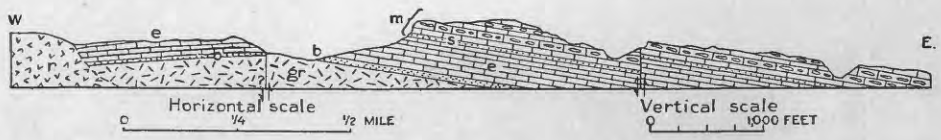


FIGURE 5.—Section through the Klondike Hills, Luna County, N. Mex. gr, Granite; b, Bliss sandstone; e, El Paso limestone; m, Montoya limestone with sandstone (s) at base; r, rhyolite.

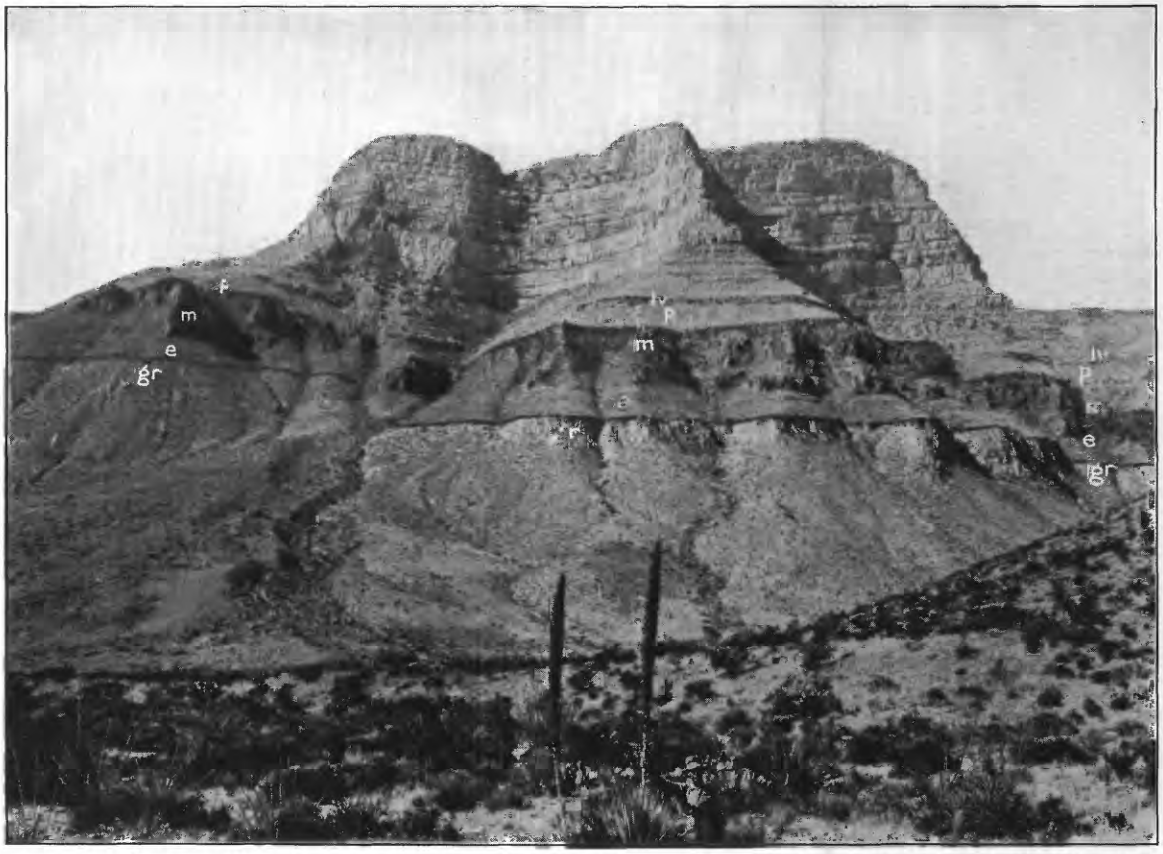
The formation is conspicuous in Rhodes Canyon, a few miles south of Salinas Peak (see Pl. XVIII, *B*), in about latitude 33° 10′, where it is separated from the granite by only 6 feet of sandstone, and this relation continues to the north end of the range.

Sacramento Mountains.—The basal limestone in the west front of the Sacramento Mountains from Alamo Canyon to a point near Grapevine Canyon is typical El Paso, showing all the features distinctive in other areas, including fossils. The relations are shown in figures 13 (p. 50) and 14 (p. 51). The thickness is 250 feet, but except in a small area near the mouth of Agua Chiquita Canyon the basal beds are covered by talus. In Alamo Canyon 125 feet of the El Paso is well exposed in the cliff on the north side of the creek, capped by thin sandstone and dark massive limestone at the base of Montoya, as shown in Plate XIX, *A* (p. 37). At Dog Canyon 200 feet is exposed. The rocks are slabby limestones, weathering to a light tint, and in part the bedding planes show brownish-buff reticulations. The medial beds are more massive than at most other localities.

Fossils.—Fossils occur in the medial and upper beds of the El Paso limestone at all localities, but they are not numerous either individually or in species. A small coiled shell, *Ophileta*, is by far the most common form. Richardson [1] found the fauna very meager in the Franklin Mountains but collected *Ophileta* and other gastropods, and also cephalopods related to *Piloceras* and *Cameroceras*. Higher beds near Deming have yielded a form resembling *Dalmanella pogonipensis*, *Strophomena* near *S. nemea*, *Hormotoma* sp., and *Trochonema*. In the Silver City region the fossils collected by Paige [2] were *Calathium anstedi*, *Dalmanella* cf. *D. wempeli*, *Protowarthia* cf. *P. rossi*, *Bucanella nana?*, *Lophospira* sp., *Raphistoma trohiscum?*, *Eccyliopterus* sp., *Maclurea* cf. *M. oceana*, *Holopea* sp., *Piloceras* cf. *P. wortheni*, *Cameroceras*, and the usual *Ophileta*. In the Caballos Mountain section Lee [3] collected *Ophileta* cf. *O. complanata* and *Hormotoma* cf. *H. artemesia*. In the exposure in Bennett Canyon in the San Andres Mountains, 15 miles northeast of Las Cruces, were obtained *Polygyrata rotuliformis?* and an indeterminable cystid. In the canyon 3 miles south of San Andres Peak were collected *Calathium* cf. *C. anstedi*, *Polygyrata trohiscus*, and *Piloceras* sp. In San Andres Canyon *Calathium* cf. *C. anstedi* was found and this distinctive fossil was observed throughout the exposures in the San Andres Range. From the cliff in Alamo Canyon, in the Sacramento Mountains, were collected *Calathium* cf. *C. anstedi* and *Dalmanella pogonipensis*.

Age and correlation.—The fossils in the El Paso limestone are regarded by Ulrich and Kirk as Lower Ordovician, representing late Beekmantown time. It is possible that in some areas strata of early Chazy age have been included with the El Paso. On this basis the

[1] U. S. Geol. Survey Geol. Atlas, El Paso folio (No. 166), p. 4, 1909.
[2] Idem, Silver City folio (No. 199), p. 4, 1916.
[3] Am. Jour. Sci., 4th ser., vol. 26, p. 180, 1908.

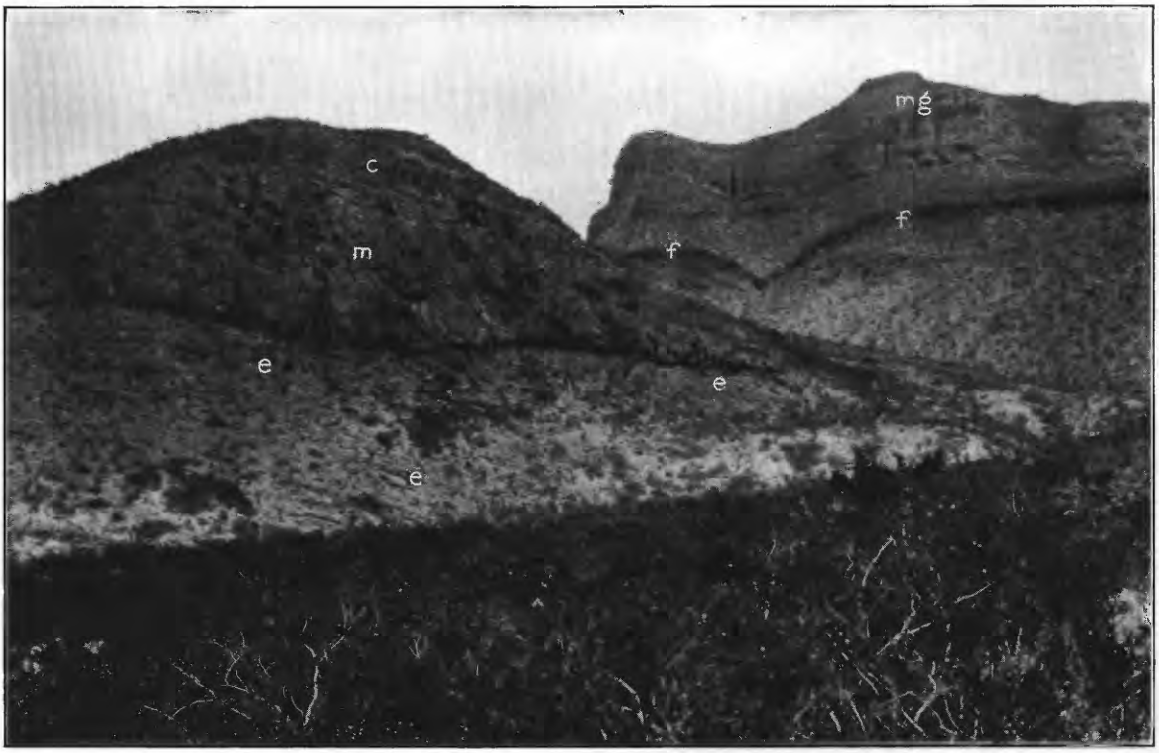


A. LIMESTONES FROM ORDOVICIAN TO PENNSYLVANIAN ON GRANITE, SHEEP MOUNTAIN, SAN ANDRES MOUNTAINS, SOCORRO COUNTY, N. MEX.

Looking south. lv, Lake Valley limestone; p, Percha shale; m, Montoya limestone; e, El Paso limestone; gr, granite.

B. EAST FACE OF SAN ANDRES MOUNTAINS AT RHODES CANYON, SOCORRO COUNTY, N. MEX.

p, Percha shale; m, Montoya limestone; e, El Paso limestone on Bliss sandstone; gr, granite.



A. NORTH SIDE OF ENTRANCE TO ALAMO CANYON, 3 MILES SOUTHEAST OF ALAMOGORDO, N. MEX.

mg, Limestone of Magdalena group; c, cherty member of Montoya; f, Fusselman limestone; m, dark massive member of Montoya; e, El Paso limestone.

B. KELLY LIMESTONE AT GRAPHIC MINE, NEAR MAGDALENA, N. MEX.

limestone has been correlated by Richardson [1] with part of the Longfellow limestone in the Clifton district, Ariz., and the upper 1,000 feet or more of the Arbuckle limestone in the Wichita Mountains, Okla.

Although the El Paso sediments appear to grade downward into the Bliss sandstone, there is no evidence that the lowest part of the El Paso limestone is latest Cambrian or transitional from Cambrian to Ordovician. No fossils were found in these lower beds.

MONTOYA LIMESTONE.

General relations.—The Montoya limestone, of Richmond age, underlies the greater part of southern New Mexico as far north as latitude 33°; possibly it extends some distance farther north under overlapping beds. It lies everywhere on the El Paso limestone without noticeable discordance of dips or strongly marked unconformity, although there is a hiatus at the contact representing much of later Ordovician time. In nearly all parts of the area the limestone is overlain by the Fusselman limestone, the beds of which have the same attitude as those of the Montoya.

Franklin Mountains.—The fossils found near El Paso by G. G. Shumard [2] in 1856 were in the Montoya limestone. In 1903 Richardson [3] studied the Franklin Mountains, and although in his first publication he included in the El Paso limestone all the strata containing Ordovician fossils, in a later publication [4] he separated as Montoya the beds carrying a Richmond fauna. At one time it was thought that beds of Galena age were also included in the Montoya, but on further study the fossils were found to be Richmond.

In these mountains the Montoya formation consists of 250 feet of beds carrying Richmond fossils throughout. The lower 100 feet is dark colored; the upper beds range from very light to dark gray and include layers of chert. The rocks contain considerable magnesium carbonate. They crop out along the east slope of the Franklin Mountains and also in a narrow band in the Hueco Mountains, 9 miles southeast of Hueco Tanks.

Luna County.—The Montoya limestone is well defined in the Florida Mountains, Cooks Range, and some outlying ridges as far west as the Victorio Mountains and Klondike Hills. In all these areas the formation consists of light-gray slabby limestone with highly fossiliferous layers, a large amount of chert, and at the bottom a dark massive limestone or sandstone. Chert is a characteristic feature and gives prominence to the outcrops. It occurs mostly in thin beds alternating with thin layers of limestone, and such beds in greater part constitute two thick members, each of which is bordered on both sides by beds of purer limestone. The average thickness of the formation is 300 feet.

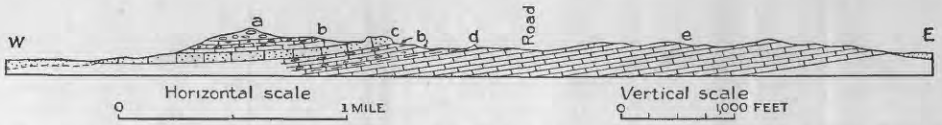


FIGURE 6.—Section through the Snake Hills, southwest of Deming, N. Mex. e, El Paso limestone; d, dark sandy limestone at base of Montoya; b, cherty members in Montoya limestone; c, massive dark-gray limestone; a, limestone with chert in large bodies high in Montoya limestone.

In places it is difficult to separate the Montoya from the overlying Fusselman, but in the region north of Cooks Peak there is an abrupt change. Here the top member consists of 60 feet of light-colored slabby limestone with a very fossiliferous 6-foot member at its base. This is underlain by 150 feet of limestone containing numerous cherty layers. The basal member, 40 feet thick, is a dark-colored massive limy sandstone. The total thickness is 250 feet. In the Snake Hills, a few miles southwest of Deming, the greater part of the formation, 300 feet in all, is exposed. It lies on the El Paso limestone, and the relations are shown in figure 6. At the base is dark massive limestone; next very cherty limestone with alternating layers of purer limestone; 30 feet of dark-gray sandy limestone grading upward into purer, partly massive limestone that weathers to an olive tint; then a 60-foot member of alternating layers of chert and limestone, with fossils; and at the top a thick mass of

[1] U. S. Geol. Survey Geol. Atlas, El Paso folio (No. 166), p. 4, 1909.

[2] Shumard, G. G., A partial report on the geology of western Texas, pp. 46, 103, Austin, 1886.

[3] Richardson, G. B., Report of a reconnaissance in trans-Pecos Texas, north of the Texas & Pacific Railway: Texas Univ. Mineral Survey Bull. 9, p. 29, 1904.

[4] Richardson, G. B., Paleozoic formations in trans-Pecos Texas: Am. Jour. Sci., 4th ser., vol. 25, pp. 478–479, 1908.

highly cherty rock at the crest of the ridge. In the Klondike Hills (see fig. 5, p. 36) the basal member is a dark-gray sandstone, 6 to 8 feet thick, lying on the slightly irregular surface of the El Paso limestone. It is overlain by 30 to 40 feet of dark massive sandy limestone, capped as in other areas by a succession including two or three thick cherty members with limestone layers that contain many fossils, listed on page 40.

Silver City region.—The first observers of the Montoya limestone in southwestern New Mexico were Howell and Gilbert,[1] who in 1873 collected "Cincinnati" fossils from limestones near Silver City and in the Santa Rita Range.

In the Silver City area the Montoya limestone shows its characteristic features and has a thickness of about 300 feet. Its relations in the ridge west of Silver City are shown in figure 7. Although most of the formation is limestone, it contains a large amount of chert, mainly in thin beds interlaminated with the limestone. One member of this character, 80 feet thick, begins about 40 feet above the top of the El Paso limestone, from which it is separated by magnesian limestone. The base is not distinct. Above the thick chert members are alternating thin beds of smooth whitish limestone and massive beds of blue limestone with cherty layers at intervals. Fossils of the Richmond fauna are abundant, especially in two layers, one near the base and the other near the top of the formation.

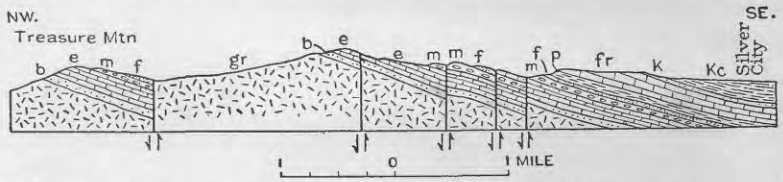


FIGURE 7.—Cross section showing relations of Paleozoic rocks in the Silver City region, N. Mex. (After Paige.) gr, Granite, etc.; b, Bliss sandstone; e, El Paso limestone; m, Montoya limestone; f, Fusselman limestone; p, Percha shale; fr, Fierro limestone; K and Kc, sandstone and shales of Cretaceous age.

Caballos Mountains and adjoining regions.—In the Caballos Mountains, southwest of Engle, the Montoya limestone is extensively exposed. Lee[2] has given many details of its features, with a list of fossils determined by Ulrich. In a section 3 miles north of Shandon, shown in figure 8 and Plate XVI, *A*, the cherty limestone near the top of the first great limestone cliff yielded distinctive fossils. Between this cherty member and the limestone containing Pennsylvanian fossils is 500 feet of limestone whose age was not determined. Lee[2] also reports outcrops of the cherty limestone in the Sierra Cuchillo, near Palomas Springs, west of the Rio Grande (see Pl. XVII, *A*), and in the north slopes of Robledo Mountain, 15 miles south of Rincon, but the fossils collected at the latter locality appear more probably to be Fusselman.

Lee[2] reports that the cherty limestone carrying distinctive Montoya fossils is exposed in the south end of the Caballos Mountains, 8 miles south of Shandon, but the rocks are so faulted and crushed that it is difficult to make a section. Below these cherty beds is limestone containing El Paso fossils. In exposures along the same line of outcrop, about 6 miles west of Rincon, 300 feet of cherty limestone exposed at the foot of the cliffs yielded a number of Montoya fossils. Apparently here, as elsewhere, the Montoya lies directly on the El Paso limestone, no intermediate Ordovician rocks being present.

Lake Valley.—Lying on the El Paso limestone in the west front of Quartzite Ridge, west of Lake Valley, is 20 feet of gray hard sandstone, above which is 25 feet or more of cherty and brecciated limestone that doubtless represents the Montoya. No fossils were found here. The relations are shown in figure 10 (p. 44). Next above is 80 feet of compact limestone that weathers to a very light color and is similar to beds which are tentatively included in the Fusselman in other uplifts. Apparently it does not contain fossils.

Mimbres Mountains.—According to Gordon and Graton,[3] the Ordovician limestones outcrop at intervals along the east slopes of the Mimbres Mountains from the vicinity of Kingston to and beyond Hermosa. From Hillsboro southward the upper siliceous beds,

[1] U. S. Geog. and Geol. Expl. 100th Mer. Rept., vol. 3, pp. 515–517, 1875.
[2] Am. Jour. Sci., 4th ser., vol. 26, pp. 181–182, 1908.
[3] Am. Jour. Sci., 4th ser., vol. 21, p. 392, 1906.

including the silicified portions of the overlying shale, appear at many places in irregular reefs projecting above the surface of the ground or as ledges capping escarpments. In the canyon of the Rio Percha, about a mile east of Hillsboro, the "upper limestone" is overlaid unconformably by a bed of red and white conglomeratic quartzite 6 to 10 feet thick, containing nodules that are possibly phosphatic. This stratum is overlain by a reddish-brown compact siliceous rock which may be a secondary deposit. Some of the strata carry Richmond fossils, but the limit of beds that should be classed as Montoya is not indicated.

San Andres Mountains.—The Montoya limestone is a prominent feature in the great eastward-facing escarpment of the San Andres Mountains. It appears on the north side of the igneous mass of the Organ Mountains and extends continuously northward to the north end of the range, where it thins out. It lies on the El Paso limestone throughout this area, and it is overlain by the Fusselman limestone to the south, as in the Franklin Mountains, and by the Percha shale north of the latitude of Tularosa. The principal features of thickness, stratigraphy, and relations to other formations are shown in figure 11 (p. 45). Some features are also shown in figure 9 (p. 42).

Two members are everywhere present—an upper member of alternating thin beds of chert and limestone, averaging about 75 feet in thickness but thinning to 30 feet at Hays Gap; and a lower member of very massive dark-colored limestone, about 100 feet thick, except north of Rhodes Canyon, where it thins gradually. The lower member includes locally at its base a sandstone that lies on the slightly uneven surface of the El Paso beds. This bed is 9 feet thick in the slopes 3 miles south of San Andres Peak and 15 feet thick in San Andres Canyon. At all places there is a sharp break at the base of the Montoya. The Montoya limestone ledge forms a high cliff of dark color and in places makes a shelf or bench along the mountain front, as shown in Plates XV and XVIII, *B*.

Sacramento Mountains.—The dark ledges of Montoya limestone are a prominent feature in the great series of limestones exposed in the higher part of the Sacramento uplift from the vicinity of Alamo Canyon to a point near Grapevine Canyon. The relations are shown in figures 14 (p. 51) and 15 (p. 54).

The two members that occur in the San Andres and Franklin mountains and other uplifts present characteristic features. The upper one, 60 feet thick, consists largely of alternating thin beds of chert and limestone with abundant Richmond fossils. The lower member is a dark-colored very massive limestone which crops out as a high cliff; its thickness is 75 feet at Dog Canyon and 120 feet at Alamo Canyon. At the latter place (see Pl. XIX, *A*) its base is gray sandstone and it is separated from the underlying El Paso beds by an abrupt change in character of material and apparently there is a slight channeling of the surface of the older formation.

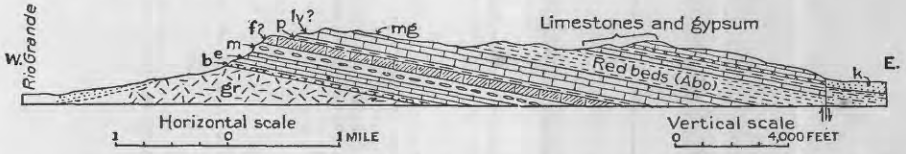


FIGURE 8.—Section across the Caballos Mountains, southwest of Engle, N. Mex. gr, Granite; b, Bliss sandstone; e, El Paso limestone; m, Montoya limestone; f, Fusselman limestone (?); p, Percha shale (?); lv, Lake Valley limestone (?); mg, limestone of Magdalena group; c, Cretaceous sandstone.

Fossils.—The fossils found in the Montoya limestone in the Franklin Mountains, north of El Paso, were identified by E. O. Ulrich. The fossils in the lower part comprised *Receptaculites* near *R. oweni*, *Maclurina manitobensis*, and *Hormotoma major* (?). The fossils in the upper part are as follows:

Streptelasma rusticum.
Hemiphragma imperfectum.
Monotryprella quadrata.
Strophomena flexuosa.
Leptaena unicostata.
Dinorthis subquadrata.
Platystrophia acutilirata.
Rhynchotrema capax.
Orthis near O. davidsoni.
Plectorthis whitfieldi.
Parastrophia divergens.

These fossils are all of Richmond age. The fossils from outcrops in Luna County, as identified by Mr. Ulrich, comprise the following:

Eurydictya cf. E. montifera.
Dinorthis subquadrata.
Plectorthis whitfieldi.
Herbertella occidentalis.
Dalmanella cf. D. meeki.
Dalmanella near D. jugosa.
Platystrophia acutilirata var.
Strophomena cf. S. subtenta.
Rafinesquina loxorhytes.
Leptaena unicostata.
Plectambonites saxea.
Rhynchonella anticostiensis.
Rhynchotrema capax
Rhynchotrema perlamellosa.
Zygospira recurvirostris.
Streptelasma rusticum.
Cyrtodonta sp.
Vanuxemia sp.
Bumastus sp.

These forms are characteristic of the Richmond fauna that occurs in many parts of the Rocky Mountain region. No fossils were found in the basal dark massive member.

In the Caballos Mountains Lee [1] collected *Rafinesquina* cf. *R. kingi*, *Plectambonites saxea*, *Plectambonites* n. sp., *Favosites asper*, *Zygospira recurvirostris*, *Rhynchotrema capax*, *Calapoecia canadense*, and *Platystrophia dentata* var.

Many fossils were collected by Paige [2] in the Silver City area near the base and near the top of the formation. The following were determined by E. O. Ulrich:

Streptelasma.
Columnaria alveolata var.
Columnaria vicina.
Tetradium sp. nov.
Favosites asper.
Favosites cf. F. asper.
Stromatocerium huronense.
Dicranopora cf. D. fragilis.
Plectorthis kankakeensis.
Dalmanella tersa (?).
Dinorthis sp.
Dinorthis subquadrata.
Hebertella sinuata.
Platystrophia n. sp., near P. acutilirata
Strophomena sp.
Rhynchotrema capax.
Rhynchotrema anticostiensis.
Rhynchonella neenah.
Ctenodonta cf. C. coata.
Conradella sp.
Lophospira cf. L. perangulata.
L. medialis.

From the basal beds were collected *Eridotrypa mutabilis* (?), *Batostoma* cf. *B. varium*, *Dalmanella testudinaria* var., and *Zygospira recurvirostra* var.

In the vicinity of Hillsboro Gordon [3] obtained some corals identified by Ulrich as *Columnaria alveolata*, *Favosites asper* (late Ordovician variety), and *Stromatocerium* cf. *S. pustulosum*, regarded as Richmond.

In the San Andres Range fossils were collected at several localities. One ledge of cherty limestone in Sulphur Canyon yielded the following, determined by Edwin Kirk:

Bythopora gracilis.
Bythopora cf. B. meeki.
Bythopora striata.
Monotrypella quadrata.
Eridotrypa sp.
Dalmanella sp.
Zygospira recurvirostris (Richmond variety).
Calymene.

In the canyon 3 miles south of San Andres Peak *Dinorthis subquadrata* was found, and in Cottonwood and Rhodes canyons were collected numerous specimens of *Dalmanella testudinaria* var.

Along the west front of the Sacramento Mountains fossils are abundant in the cherty layers of the upper member and many corals are scattered through the lower massive dark limestone. From the lower member near Dog Canyon were obtained *Halysites gracilis*, *Streptelasma* sp., *Receptaculites* sp., and *Rhynchotrema capax*. The cherty member at this locality yielded abundant *Dalmanella* cf. *D. corpulenta*.

Age and correlation.—Most of the fossils collected in the Montoya limestones are species common in the Richmond of the Mississippi Valley and indicate that the formation comprises two, or possibly three, representatives of the Richmond epoch. The lowest may be correlated with the Fernvale of the Mississippi Valley, the lower part of the Bighorn dolomite of Wyoming, the Whitewood limestone of the Black Hills, and the middle of the Fremont limestone of eastern Colorado. The upper part of the Montoya may be correlated with some portion of the upper Bighorn and probably with the upper part of the Fremont and with the Stony Mountain limestone of Manitoba. It is not represented in the Black Hills and apparently not in the Mississippi Valley. The

[1] Am. Jour. Sci., 4th ser., vol. 26, p. 181, 1908.
[2] U. S. Geol. Survey Geol. Atlas, Silver City folio (No. 199), p. 4, 1916.
[3] U. S. Geol. Survey Prof. Paper 68, p. 227, 1910.

Montoya is equivalent to part of the Lone Mountain limestone of Nevada. Apparently the formation is absent in Arizona.

SILURIAN SYSTEM.

FUSSELMAN LIMESTONE.

Franklin Mountains and eastward.—The existence of rocks of Silurian age in New Mexico was discovered by Gordon and Graton,[1] who found fossils at Silver City in 1905.[1] Their presence in the Franklin Mountains north of El Paso was announced by Richardson[2] in 1904, in a formation which he later designated the Fusselman limestone.[3] It is found that this limestone is separable in many parts of southern New Mexico.

In its type locality the Fusselman limestone is estimated to be about 1,000 feet thick and is of considerable topographic prominence, capping the range for several miles and appearing in a number of detached knobs. It also crops out in the Hueco Mountains, 3 miles east of El Paso. The rock is mostly a massive light-colored magnesian limestone. Fossils are scarce on the whole, but they abound at a few horizons, especially a characteristic *Pentamerus* that indicates upper Niagara age.

The upper limit of the Fusselman is indistinct, and a thin representative of the Devonian or Mississippian may possibly be present at the top. In an exposure 5½ miles west of south from Hueco Tanks, 30 miles northeast of El Paso, white limestone containing Silurian fossils is overlain by 100 feet of thin-bedded gray limestone in which no fossils were found. This formation dips much more steeply than the one below it. Overlying it with the same steep dip are beds that carry Pennsylvanian fossils. In the Hueco Mountains a similar thin-bedded gray to purplish limestone that contains some chert and weathers buff separates the beds containing Silurian and Pennsylvanian fossils and dips at a less angle than the Silurian. On the northwest flank of the Franklin Mountains, however, thin-bedded cherty limestone containing Pennsylvanian fossils overlies the Fusselman without discordance of dip. In the Van Horn area, farther east in Texas, Silurian, Devonian, and Mississippian representatives are absent.

[1] Am. Jour. Sci., 4th ser., vol. 21, p. 394, 1906.
[2] Texas Univ. Mineral Survey Bull. 9, p. 31, 1904.
[3] Am. Jour. Sci., 4th ser., vol. 25, pp. 479–480, 1908.

The Fusselman limestone lies on the Montoya limestone without conspicuous unconformity; at one locality 2 miles north of El Paso its lower layers carry small pebbles of black limestone similar to some that occurs in certain beds of the Montoya.

Cooks Range.—The Fusselman limestone is well developed in the Cooks Peak mining district, where it is the principal rock containing the ores of lead, silver, and zinc. It crops out extensively along the road from Cooks to the mountain top and along the slopes 2 miles to the north. It is a massive gray limestone of exceptionally hard, compact texture, but its upper part is cavernous in places, and in the cavities, a short distance below the Percha shale, most of the rich ore pockets have been found. In this region the thickness of the formation is about 200 feet. The distinctive *Pentamerus* occurs in places. The limestone appears in the south end of the range, near the fluorspar mines, but its relations are obscure owing to igneous intrusions and faults.

Florida Mountains.—In places in the southern half of the Florida Mountains the Fusselman limestone is absent in the varied overlaps. The Percha shale apparently is also absent, and the Fusselman limestone where present is overlain by the Gym limestone.

Victorio Mountains.—The Montoya limestone in Mine Hill is overlain by the Fusselman limestone, which constitutes the summit and west side of the hill. The silver ore deposits occur in this limestone, as in the Cooks Peak district. Its thickness appears to be somewhat more than 100 feet, but the top may be eroded. In other ridges to the west it is cut off by faults and also hidden by overlapping Gym limestone.

Silver City region.—In the Silver City region the Fusselman limestone consists of 30 to 40 feet of gray limestone and dolomitic beds, not plainly separated from the underlying Montoya. In its upper part there are abundant casts of the characteristic *Pentamerus*.

Caballos Mountains.—Above the massive cherty limestone with Montoya fossils in the Caballos Mountains Lee[4] found 500 feet of white to brown limestone, cherty in places, from which no fossils were obtained. These beds extend to the base of the limestone that carries Pennsylvanian fossils, and doubtless they include the Fusselman and possibly also

[1] Idem, vol. 26, p. 181.

strata of Devonian and Mississippian age. In the slopes 8 miles south of Shandon 300 feet of black shale, probably the Percha, is present in the section, and very likely it is, as usual, underlain by the Fusselman.

Robledo Mountain.—In a small exposure of cherty limestone not far below Pennsylvanian limestone on the northern slope of Robledo Mountain, 5 miles south of Rincon, Lee[1] obtained *Lophospira, Trochus?, Bucania?, Trochonema, Eotomaria,* and a pentameroid shell, all suggestive of Silurian age and if so indicating the Fusselman limestone.

tinctive fossils were collected. The upper member is probably the 12 feet of pink limestone referred to by Gordon,[2] who obtained from it some fragments of corals regarded as Silurian by Ulrich. According to Keyes[3] this limestone is dark colored and compact but contains crevices filled with red clay which give it a pink appearance.

Mimbres Mountains.—It appears probable from the statements of Gordon[4] that the Fusselman limestone is present, at least in places, in the Kingston-Hillsville region, but he reports no fossils. The statement that the

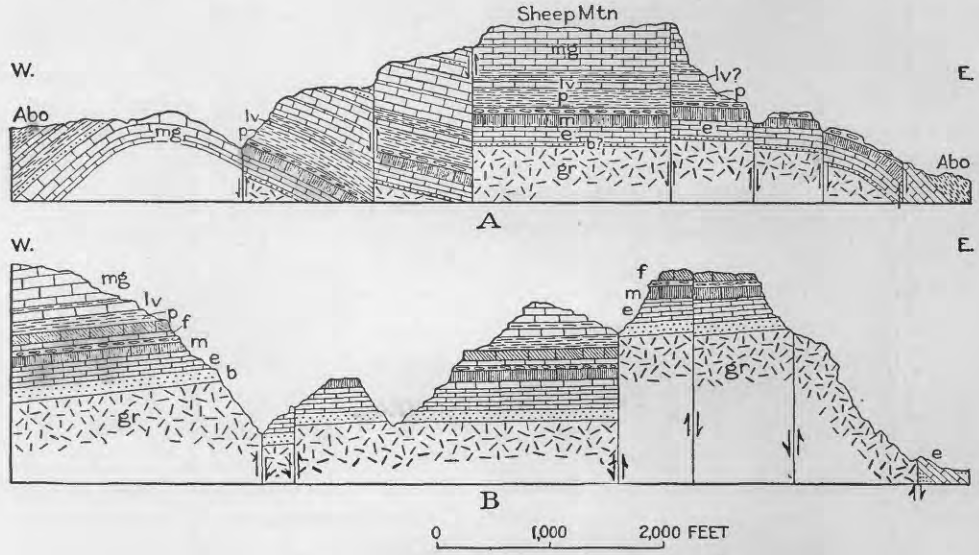


FIGURE 9.—Sections across the San Andres Mountains, Socorro and Dona Ana counties, N. Mex. A, Section across Sheep Mountain at Lava Gap; B, section southwest of San Nicolas Spring, in latitude 32° 35′ N.; gr, granite; b, Bliss sandstone; e, El Paso limestone; m, Montoya lime stone; f, Fusselman limestone; p, Percha shale; lv, Lake Valley limestone; mg, limestone of the Magdalena group.

Lake Valley.—It was found that the limestones underlying the Percha shale in the Lake Valley area (see fig. 10, p. 44) include 200 feet or more of the Fusselman limestone, which contains many distinctive fossils. At the base, overlying beds that are probably Montoya, there is an 80-foot bed of massive limestone which weathers to light tint, and which yielded no fossils but is tentatively regarded as the Fusselman, as in other regions. Next above are 40 feet of cherty beds, somewhat like the Montoya in character but carrying distinctive fossils. These beds grade upward into 80 feet or more of massive limestone of light color, constituting the summit of Quartzite Ridge for some distance and extending down its east slope to the Percha shale in the valley. In cherty layers on this slope dis-

"footwall lime" at Kingston and Tierra Blanca is similar to the ore-bearing sandstone in the Cooks mining district is highly suggestive in this connection.

San Andres Mountains.—The Fusselman limestone is a conspicuous feature in the limestone succession along the east front of the San Andres Mountains from a point near Organ, where it is cut off by igneous rocks, to a point 2 or 3 miles north of Sulphur Gap, where it thins out. Some of its relations are shown in figures 9 and 11. The thickness ranges from 220 feet in the southern part of the range to 120 feet in the middle part and at Sulphur Gap, and there is rapid thinning toward its north-

[1] Am. Jour. Sci., 4th ser., vol. 26, p. 185, 1908.

[2] U. S. Geol. Survey Prof. Paper 68, pp. 227, 277, 1910.

[3] Keyes, C. R., Genesis of the Lake Valley, New Mexico, silver deposits: Am. Inst. Min. Eng. Trans., vol. 39, p. 146, 1909.

[4] U. S. Geol. Survey Prof. Paper 68, p. 227, 1910.

ern termination. The formation comprises two members—an upper bed of hard dark-colored massive limestone, marked by a cliff at most places, and a lower member of fine-grained limestone, most of which weathers nearly white. The upper member contains distinctive fossils, but the lower one has yielded no fossils and is arbitrarily placed in the formation because of its distinctness from the underlying cherty beds, which are characteristic of the upper part of the Montoya. The massive bed gives rise to a shelf at the base of the slope of the overlying Percha shale. Its thickness is 80 feet in the southern part of the range, but it gradually thins northward to 40 feet in Lostman Canyon, 30 feet in Hembrillo Canyon (see Pl. XV, *A*), and 25 feet in Sulphur Gap. The lower limestone is 140 feet thick in the south end of the range, but it thins somewhat north of San Andres Peak. It is nearly 100 feet thick in Sulphur Gap but thins out and disappears in slopes north of the gap. In places some of its beds are soft and earthy, as in Lostman Canyon, but most of it is a fine-grained, compact dark-gray rock that weathers to very light gray or nearly white so that it is conspicuous in all outcrops.

Sacramento Mountains. — The Fusselman limestone makes a prominent ledge along the east front of the Sacramento Mountains from Alamo Canyon to a point near Agua Chiquita Canyon. Its disappearance to the north and south is due to the downward pitch of the anticline that brings it to the surface. (See fig. 14, p. 51.) The thickness ranges from 105 to 130 feet; the maximum is reached in Alamo Canyon. (See Pl. XIX, *A*, p. 37.) As in the San Andres Mountains and other uplifts, the formation comprises two members—an upper one, about 50 feet thick, of hard dark limestone carrying distinctive fossils, and a lower one of compact, fine-grained gray limestone that weathers nearly white, and is 60 feet thick in Dog Canyon and 85 feet thick in Alamo Canyon. The lower member yielded no fossils, but is arbitrarily included in the formation because of its unlikeness to underlying distinctively cherty beds at the top of the Montoya limestone. It constitutes a steep light-colored slope below the dark cliff of limestone of the upper member of the formation. This cliff is well shown in Plate XIX, *A*.

Fossils and correlation.—In general fossils are rare in the Fusselman limestone, but at some localities a few of the beds yield abundant remains. The most common and characteristic form is a *Pentamerus*, but many corals occur at some places.

The fossils found by Richardson[1] in the Franklin Mountains included *Amplexus*, *Favosites*, and numerous casts of *Pentamerus*, all indicative of Niagara age. The same *Pentamerus* is abundant in the upper beds near Cooks and Silver City. On the south side of Mine Hill, in the Victorio Mountains, numerous corals were collected, including *Heliolites megastoma*, *Favosites* cf. *F. venustus*, *Cyathophyllum* cf. *C. radicula*, *Halysites catenulatus* (large and small varieties), and *Syringopora* sp., also an orthoid suggesting *Rhipidomella hybrida*. These were determined by E. O. Ulrich, who regards them as probably late Niagara and similar to a coral fauna found by Kindle in the Laketown dolomite of northeastern Utah.

From the upper ledge of the limestone in the San Andres Mountains 1½ miles southwest of San Nicolas Spring, or about 22 miles northeast of Las Cruces, the writer collected the following forms, determined by Edwin Kirk: *Pentamerus* sp., *Cyathophyllum* sp., *Heliolites* sp., and *Hormotoma* sp.—a distinctive Fusselman fauna.

The *Pentamerus* was observed at many other localities in the San Andres Mountains as far north as Sulphur Gap and also in the east front of the Sacramento Mountains.

Fossils were collected at three horizons in the Fusselman limestone at Lake Valley, all from beds above the 80-foot member that weathers to a light color. Cherty layers not far above this member yielded *Monomerella* n. sp. and *Zaphrentis* sp. In cherty layers about 100 feet higher *Monomerella* was very abundant, and near the top, about 30 feet below the base of the Percha shale, were collected *Zaphrentis* sp., *Amplexus* sp., and a variety of *Pentamerus oblongus* that is characteristic of the upper beds in other regions.

[1] U. S. Geol. Survey Geol. Atlas, El Paso folio (No. 166), 1909.

DEVONIAN SYSTEM.

PERCHA SHALE.

General relations.—Only a small part of Devonian time is now represented in New Mexico. The deposits consist of the Percha shale, in which Gordon and Graton [1] found Devonian fossils in the Lake Valley and Kingston regions. The formation is named from Percha Creek, near Kingston. It overlies the Fusselman limestone, but in places it is absent and the Fusselman is overlain by beds of Carboniferous age. Notwithstanding the long interval between the Fusselman and Percha epochs, the beds show no noticeable difference in attitude, but there is an abrupt change from massive limestone to black shale.

Lake Valley and Hillsdale region.—In the Lake Valley mining region the Percha shale appears in a narrow outcrop that extends for about 3 miles along a valley just west of the ridge of Lake Valley limestone, as shown in figure 10. It is mentioned in several published reports regarding the relations of the ores of the district. Two members were recognized by Gordon [1]—an upper grayish-yellow to blue shale 60 feet thick (c in fig. 10) and a black fissile shale 100 feet thick (d in fig. 10). Neither of these is fossiliferous at Lake Valley, but beds near the top of the upper member yielded an extensive fauna at Hillsboro and Kingston. Keyes [2] stated that the overlying nodular limestone, 50 feet thick, at Lake Valley is also Devonian and proposed for it the name Barenda. He described it as consisting of three distinct members. The lowest one is a massive, compact gray limestone, like lithographic stone, 10 feet thick, weathering rusty brown and carrying a "typical late Devonian fauna." The medial member, 30 feet thick, is gray thin-bedded limestone, in part fine grained, with no fossils. The upper member consists of 10 feet of bluish thin-bedded limestone made up largely of chert in elongated nodules and containing no fossils. According to Keyes, "it contrasts strikingly with the massive compact blue limestone lying immediately above."

In the Kingston-Hillsboro region portions of the basal beds are altered to a fine-grained red to black siliceous rock of a jaspery character, somewhat brecciated and seamed with quartz. The quartz seams are believed to have been formed by heated siliceous water.

Cooks Range.—In Luna County the Percha shale appears in Cooks Range and Fluorite Ridge, where it has a thickness of 175 feet. The rock is a uniform black shale of moderate hardness separating into thin brittle layers. It crops out extensively along the limestone slopes on both sides of the range northwest of Cooks, where it immediately overlies the ore-bearing Fusselman limestone. It is absent in the Victorio Mountains.

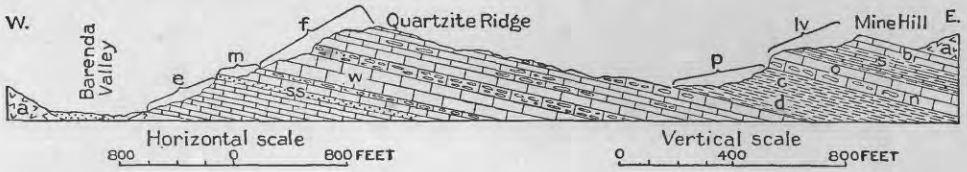


FIGURE 10.—Section through the Lake Valley mining district, Sierra County, N. Mex. e, El Paso limestone; m, Montoya limestone, with sandstone (ss) at base; f, Fusselman limestone, with white limestone (w) at base; p, Percha shale, including lower member (d) and upper member (c); n, nodular limestone; lv, Lake Valley limestone, including ore horizon, or "footwall lime" (o), shale and thin limestone (s); limestones, upper beds cherty (b), and andesite and rhyolite (a).

Florida Mountains.—In the southern part of the Florida Mountains there is a dark shale which closely resembles the Percha but which appears to be in the Gym limestone succession. though this apparent relation may be due to overlap or faulting.

Silver City.—The Percha shale crops out in several small areas about Silver City, and it also occurs in the vicinity of Georgetown and Hanover, a few miles to the east. The maximum thickness in this area is 500 feet, but in places the amount is much less.

Caballos Mountains.—Gordon [3] suggested that the black shale in the Caballos Mountains is the Percha, but he reported no fossils. In places, especially to the north, the shale is absent and the Pennsylvanian limestone lies on the Montoya or higher limestones. According

[1] Am. Jour. Sci., 4th ser., vol. 21, p. 394, 1904.
[2] Am. Inst. Min. Eng. Trans., vol. 39, p. 147, 1909.
[3] U. S. Geol. Survey Prof. Paper 68, p. 226, 1910.

to Lee,[1] in the section 8 miles south of Shandon 300 feet of black shale intervenes between "late Ordovician" cherty limestone and limestones of Carboniferous age.

Franklin Mountains.—As Richardson [2] found Carboniferous and Silurian fossils very near together in the Franklin Mountains, it appears that the Devonian is not represented in the succession of limestones in that range.

Sacramento Mountains.—The Devonian is probably represented in the section exposed along the west front of the Sacramento Mountains southeast of Alamogordo, in the lower part of the shale that lies on the Fusselman limestones, but the fossils found were not sufficiently well preserved to be determined specifically.

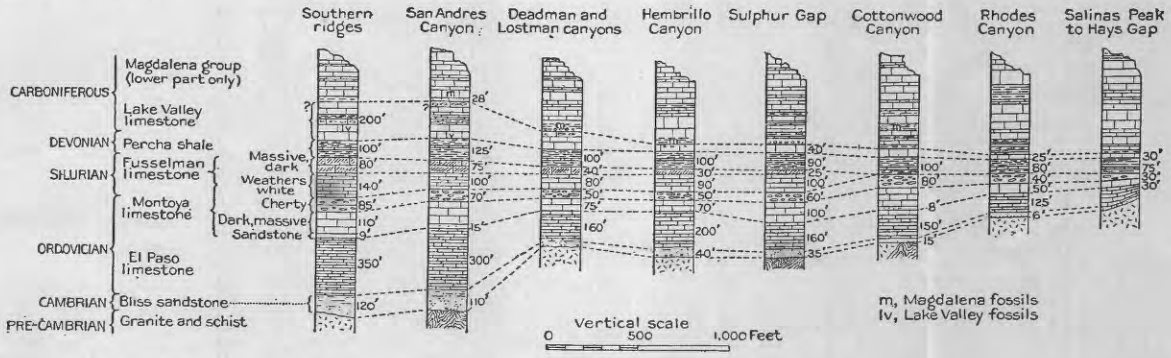


FIGURE 11.—Columnar sections showing stratigraphic variations in lower Paleozoic rocks in the San Andres Mountains, Dona Ana and Socorro counties, N. Mex.

San Andres Mountains.—Shale with Upper Devonian fossils extends along the San Andres Mountains from a point 2 miles northeast of Organ, where igneous intrusions cut off the succession, nearly to Mockingbird Gap. Its thickness is 50 feet or more, and it crops out in a slope between the prominent ledge of massive limestone above and a shelf or cliff of Fusselman or Montoya limestone below. The basal beds are black shale, above which are layers of slabby and nodular limestone separated by gray shale. Possibly in places the uppermost layers of shale are Carboniferous. The fossils found were mostly in the medial beds. Some of the relations are shown in figures 9 and 11 and Plates XV (p. 33) and XVIII (p. 36).

Fossils.—The Devonian fossils reported by Gordon and Graton [3] were found in abundance in blue shales near the upper part of the upper member at Kingston and at a locality 2 miles east of Hillsboro. The following were identified by Girty and Kindle:[4]

Zaphrentis sp.
Spirorbis sp.
Leptaena rhomboidalis.
Productella coloradensis var. plicatus.
Productella spinigera.
Productella hillsboroensis.
Schizophoria striatula var. australis.
Camarotoechia (Plethorhyncha) endlichi.
Camarotoechia contracta.
Eunella sp.
Athyris coloradensis.
Pugnax pugnus.
Spirifer whitneyi.
Spirifer whitneyi var. animasensis.
Spirifer notabilis.
Syringospira prima.
Reticularia spinosa.
Meristella barrisi.

Fossils found by Paige in the Percha shale at Silver City are as follows:

Schizophoria striatula var. australis.
Productella coloradensis.
Productella spinigera.
Productella laminatus.
Camarotoechia contracta?
Camarotoechia (Plethorhyncha) endlichi.
Pugnax pugnus.
Spirifer notabilis.
Spirifer whitneyi.
Reticularia spinosa.
Athyris coloradensis.
Aviculipecten n. sp.
Bellerophon sp.
Euomphalus eurekensis?
Corals and bryozoans.

The following fossils were found in the Percha shale in 1915 a mile south of Capitol

[1] Am. Jour. Sci., 4th ser., vol. 26, p. 182, 1908.
[2] U. S. Geol. Survey Geol. Atlas, El Paso folio (No. 166), p. 4, 1909.
[3] Am. Jour. Sci., 4th ser., vol. 21, p. 394, 1904.
[4] See Kindle, E. M., The Devonian fauna of the Ouray limestone: U. S. Geol. Survey Bull. 391, 1909.

Peak, in the northern part of the San Andres Mountains. They were identified by Edwin Kirk:

Tropidoleptus carinatus var.
Alveolites sp.
Spirifer n. sp.
Stropheodonta near S. arcuata Hall.
Productella hallanus.
Atrypa reticularis.
Atrypa hystrix.
Schizophoria striatula var. australis?
Diaphosostoma sp.

On the north slope of Sheep Mountain, in Lava Gap, a mile farther south, were obtained *Zaphrentis*, *Atrypa reticularis*, *Cyrtia* n. sp., *Productella hallanus*, and *Stropheodonta* near *S. arcuata*. In Sulphur Gap, which is not far north of the latitude of Alamagordo, the following forms were collected from medial beds:

Atrypa hystrix.
Atrypa reticularis.
Schizophoria striatula var. australis.
Pugnax pugnus.
Camarotoechia contracta?
Chonetes sp.
Stropheodonta n. sp.
Spirifer whitneyi var. animasensis.
Spirifer sp.

In a canyon 3 miles south of San Andres Peak were found *Rhipidomella* sp., *Spirifer* sp., and *Chonetes* sp. In Cottonwood Canyon the shale yielded *Spirifer whitneyi*.

In nodular beds in the middle of the formation in San Andres Canyon were found the following:

Zaphrentis sp.
Fenestella sp.
Productella cf. Productella coloradoensis var. plicata.
Ambocoelia sp.
Schizophoria striatula var. australis.
Leiorhynchus? sp.
Spirifer cf. Spirifer utahensis.
Reticularia undifera var.
Phacops sp.

At the same horizon in Hembrillo Canyon were obtained *Fenestella*, *Atrypa reticularis*, *Pugnax pugnus*, *Cyrtia* sp., *Stropheodonta* near *S. arcuata*, *Gypidula* sp., and *Productella* sp.

A few fragmentary fossils were collected from black shale a few feet above the Fusselman ledge near Dog Canyon, in the west front of the Sacramento Mountains, but they could not be determined. Mr. Kirk recognized one of the brachiopods as *Meristella* or some closely allied genus, almost certainly Devonian.

Age and correlation.—The fossils from the Percha shale are regarded by Mr. Kirk as indicating that the formation is late Devonian, equivalent to the lower part of the Ouray limestone and the upper part of the Martin limestone (Upper Devonian) of the Bisbee region, Ariz., and the upper 2,000 feet of Nevada limestone of the Eureka district, Nev. As the lower beds of the Percha shale in the type locality have not yielded fossils, the formation may represent a somewhat greater range than is indicated by the collections recorded. The beds in the San Andres Mountains appear to carry a smaller number of the typical lower Ouray forms than are present in Lake Valley, and more of the forms characteristic of the Martin limestone and Nevada limestone. However, all the New Mexico collections are too fragmentary to permit precise correlation.

CARBONIFEROUS SYSTEM.

GENERAL FEATURES.

In southern New Mexico rocks of Carboniferous age comprise representatives of the earlier part of Mississippian and of a large part of Pennsylvanian and Permian time, the later Mississippian being unrepresented there, as in most other portions of the West. In the Lake Valley region and to the south the formation of lower Mississippian age is the Lake Valley limestone, which appears in most of the uplifts between latitudes 32° 20′ and 34°. The rocks of supposed Mississippian age in the Magdalena region are known as the Kelly limestone. The beds of the Pennsylvanian and Permian series occur throughout the area and in the adjoining States. They comprise a great thickness of limestone, which to the northeast is accompanied by the red sandstone and shale of the Abo sandstone and many thick deposits of gypsum.

In Luna County the formations of the Pennsylvanian and Mississippian series are separated by a hiatus of considerable amount, and there is an overlap of the higher limestone toward the south. Thus, in the Florida, Victorio, and Franklin mountains the later Carboniferous rocks lie directly on the Silurian limestone, and the Mississippian and earlier Pennsylvanian (Magdalena group) appear to be absent. The Manzano group, or later Carboniferous, is represented by a thick limestone formation,

the Gym limestone. A still younger formation, separated as the Lobo and tentatively assigned to the Triassic, may possibly represent the upper part of the Manzano.

A comparison of the Carboniferous rocks of southern New Mexico with those of Arizona shows close similarity. The Lake Valley limestone has the same fauna as the Modoc limestone at Clifton,[1] 180 feet thick, and the Escabrosa limestone of the Bisbee region,[2] 700 feet thick. The Magdalena group is represented in whole or part by the Tule Spring limestone of Clifton, 500 feet thick, and by part of the Naco limestone of the Bisbee region. The Naco, which is 3,000 feet or more thick, appears to include in its upper part a thick representative of the Hueco limestone of western Texas. Farther west and north in Arizona, especially in the Grand Canyon region, the Redwall limestone, 1,000 feet or more thick, comprises representatives of both the Pennsylvanian and the earlier Mississippian, the Pennsylvanian beds being equivalent to the Magdalena group. The overlying red beds of the Supai formation, 1,200 feet thick, probably correspond to the Abo sandstone (red sandstone), 700 to 1,000 feet thick, at the base of the Manzano group. The overlying Coconino sandstone and Kaibab limestone, the latter in places containing gypsum deposits, are probably equivalent to the great succession of sandstone, gypsum, and limestone that constitute the upper part of the Manzano group in New Mexico. G. H. Girty regards the fauna of the upper limestone of the Manzano group as closely similar to that of the Kaibab limestone. Representatives of the Supai and Abo red beds are lacking to the south, notably in southern New Mexico, in southwestern Texas, and in the Naco limestone succession of the Bisbee region.

LOWER MISSISSIPPIAN LIMESTONES.

Lake Valley region.—The Lake Valley limestone received its name from the Lake Valley mining district, where it crops out in an area about 3 miles long and half a mile wide. In that district it consists of about 200 feet of limestone underlain by the Percha shale and at the top eroded and in part overlain by Tertiary igneous rocks. (See fig. 10, p. 44.) Distinctive lower Carboniferous (Mississippian) fossils were found in these limestones by Cope[3] in 1881 and by others at intervals later, notably by Springer,[4] who published a detailed list of many forms, including an extensive crinoid fauna closely similar to the lower Burlington of Iowa. The section given by Springer is as follows:

Section of Lake Valley limestone at Lake Valley mining camp, N. Mex.

	Feet.
9. Cherty limestone, with irregular flinty masses, in places light colored and full of crinoids	30
8. Limestone, heavy bedded, pink to drab; marly partings; many crinoids, corals, and other fossils	40
7. Limestone, thin bedded, bluish, mostly shaly; many crinoids, corals, bryozoans, and other fossils	20
6. Limestone, hard, granular, sandy, pinkish to bluish	6
5. Shale, light yellow, with flinty nodules	15
4. Limestone, irony, coarse, irregularly bedded, with marly partings; corals and crinoid fragments	30
3. Sandstones, dark brown, heavy bedded and hard below, shaly above	12
2. Shale, light yellowish, with irregular flinty masses; no fossils	8
1. Slope covered by débris.	

Beds 7 and 8 yielded most of the fossils. The beds below No. 7 Springer referred to the Kinderhook group. No fossils were reported from bed 3. A section given by Gordon,[5] who visited the locality in 1905 is as follows:

Section of Lake Valley limestone at Lake Valley, N. Mex.

	Feet.
9. Capping of andesite.	
8. Limestone, coarse, subcrystalline, yellowish white; moderately thick beds, some cherty; many crinoids and other fossils; top eroded	60
7. Shale, blue; includes thin bluish limestone beds; many fossils but fewer crinoids than No. 8	75
6. Limestone, grayish blue, hard, more or less siliceous, called "blue limestone" in the mines. Local breccia of flint at top. At base 5-foot bed of coarse crystalline yellowish-white limestone	25
5. Limestone, compact, grayish, filled with nodular chert; partings mostly thick	50
Percha shale.	

[1] Lindgren, Waldemar, U. S. Geol. Survey Geol. Atlas, Clifton folio (No. 129), 1905.

[2] Ransome, F. L., U. S. Geol. Survey Geol. Atlas, Bisbee folio (No. 112), 1904.

[3] Cope, E. D., Geology of the Lake Valley mining district: Am. Naturalist, vol. 15, pp. 831–832, 1881.

[4] Springer, Frank, on the occurrence of the Lower Burlington limestone in New Mexico: Am. Jour. Sci., 3d ser., vol. 27, pp. 97–103, 1884.

[5] Gordon, C. H., Mississippian formations in the Rio Grande valley, N. Mex.: Am. Jour. Sci., 4th ser., vol. 24, pp. 58–64, 1907.

No. 5 (n, fig. 10) is the nodular limestone of Clark,[1] who described the region in considerable detail. Keyes,[2] however, placed this member in the Devonian and called it the Barenda limestone.

Cooks Range.—In Luna County the Lake Valley limestone occurs only in Cooks Range, where its thickness is between 600 and 700 feet. It consists mainly of light-gray, massive to slabby limestone, with several intercalated members of shale, partly limy. The limestone members crop out mostly as cliffs 80 to 100 feet high, separated by shaly slopes. The basal member consists of 150 feet of bluish-gray limestone, with some chert in its lower part. The upper member contains some thick bodies of white chert and cherty limestone. A small body of Lake Valley limestone lies on the Percha shale in Fluorite Ridge, at the south end of Cooks Range, near Cooks Peak. It is cut by some beds, and the lower ones yield many Mississippian forms.

Mimbres Mountains.—Gordon[4] states that the Lake Valley limestone crops out at many points along the east side of the Mimbres Mountains, and he gives the section reproduced here as figure 12, showing its relations in that region. At Kingston the formation consists of thick-bedded blue limestones with nodular cherty beds and shaly thin-bedded limestone, 100 to 125 feet in all. Many distinctive fossils occur in it.

Caballos Mountains.—It is not unlikely that some Lake Valley limestone is included in the great section on the west front of the Caballos Mountains, but no data are available on this point.

Magdalena Mountains.—The Kelly limestone, or so-called "Graphic Kelly" limestone, the ore-bearing formation in the silver-lead

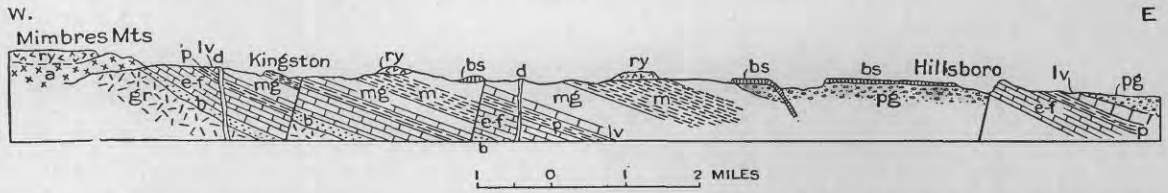


FIGURE 12.—Section from the Mimbres Mountains eastward through Kingston and Hillsboro, N. Mex. (After Gordon.) gr, Granite; b, Bliss sandstone; e-f, Mimbres limestone [El Paso, Montoya, and Fusselman]; p, Percha shale; lv, Lake Valley limestone; mg, Magdalena group; m, Manzano group; pg, Palomas gravel; bs, basalt sheet; a, andesite; ry, rhyolite; d, dike.

the great porphyry intrusion and interrupted by several faults. Fossils are abundant in the limestone in this locality.

Silver City region.—In the Silver City region the two divisions of the Carboniferous are grouped together by Paige[3] as the Fierro limestone. The rocks are limestones, ranging in color from light gray to dark blue or purplish. West of Silver City the upper half is chiefly light gray or light blue and the lower part darker blue. All but the upper 100 feet is cherty, and near the base there is some red chert. Some thin, more or less shaly beds are included. The Fierro limestone varies in thickness because of the unconformity at its top, and doubtless also between its two divisions, but the maximum thickness is about 800 feet. It is widely distributed, constituting much of the range northwest of Silver City, part of Lone Mountain, and areas near Fort Bayard and north of Santa Rita. Fossils are abundant in mines at Kelly, is supposed to be of Mississippian age, Herrick[5] and Keyes[6] having reported that crinoids were found in it. This limestone is white and crystalline, and occurs in thick beds, about 125 feet in all, lying on pre-Cambrian schist and granite. (See Pl. XIX, *B*.) Near the middle is a 5-foot layer of dark-blue noncrystalline rock, weathering yellowish drab, which the miners call "Silver Pipe limestone."

Keyes[6] gives the following section of the limestones in the Magdalena Mountains, including the Kelly limestone, in which Mississippian crinoids were obtained:

Section of limestone in Magdalena Mountains.

	Feet.
Limestone, blue, heavy bedded, with thick shale partings	300
Shale, sandy, greenish	200
Sandstone, greenish, micaceous, soft	50
Sandstone, quartzite, pebbly (base of Magdalena group)	60

[1] Clark, Ellis, The silver mines of Lake Valley, N. Mex.: Am. Inst. Min. Eng. Trans., vol. 24, pp. 138-169, pl., 1884.

[2] Am. Inst. Min. Eng. Trans., vol. 39, p. 147, 1909.

[3] U. S. Geol. Survey Geol. Atlas, Silver City folio (No. 199), p. 5, 1916.

[4] U. S. Geol. Survey Prof. Paper 68, p. 229, 1910.

[5] Herrick, C. L., Laws of formation of New Mexico mountain ranges: Am. Geologist, vol. 33, p. 310, 1904.

[6] Keyes, C. R., Northward extension of the Lake Valley limestone: Iowa Acad. Sci. Proc., vol. 12, pp. 169-171, 1904.

	Feet.
Shale, dark, siliceous (Mississippian)	50
Limestone, gray, crinoidal (Mississippian)	45
Limestone, heavy bedded, crinoidal ("upper vein")	30
Limestone, blue, impure, fine grained, siliceous ("Silver Pipe lime")	8
Limestone, gray, subcrystalline (contact vein)	60
On schists, granite, greenstone, etc.	

San Andres Mountains.—The Lake Valley limestone occurs in an area of considerable extent in the San Andres Mountains, but it is not thick and may be discontinuous. In the central part of the range a heavy bed of limestone overlying the Percha shale yielded lower Mississippian (Lake Valley) fossils at several localities, notably in San Andres Canyon and on the slopes 3 miles south of San Andres Peak, and also at a locality, shown in figure 9 (p. 42), west of San Nicolas Spring, or about 16 miles northeast of Las Cruces. The greatest thickness observed was in San Andres Canyon and northward for 10 or 12 miles, where the amount may be 100 feet or more. The principal bed that yielded Lake Valley fossils is a massive limestone, cherty in its upper part; but some overlying softer beds and a higher massive bed may possibly be included in the formation. In San Andres Canyon the higher massive bed is capped by 28 feet of hard gray sandstone, immediately above which is shaly limestone containing Magdalena fossils. In Hembrillo Canyon the only member present is the first massive bed that caps the Percha shale, for the strata next above carry Pennsylvanian fossils. This bed extends northward past Salinas Peak to and beyond Hays Gap, where, however, no fossils were found in it. In Sulphur Canyon it is 60 feet thick and is capped by 30 feet of a peculiar sandstone, including considerable conglomerate of large pebbles and fragments of white chert. This material is presumably basal Magdalena. Some of it appears also in Lostman Canyon. In Deadman Canyon the massive limestone bed above the Percha shale is 80 feet thick and grades upward into 50 feet of limestone with cherty layers. In Rhodes Canyon the ledge is only 25 feet thick, and in Lava Gap it is 30 feet thick. The outcrop at the latter place is shown in Plate XVIII, *B*.

Sacramento Mountains.—In 1900 C. L. Herrick [1] announced the discovery of fossils of the Mississippian series in the west front of the Sacramento Mountains but gave but little information as to the conditions of occurrence. The bed was stated to be 560 feet above the base of the section in Dog Canyon (see Pl. XIX, *A*), and the thickness of the "Burlington limestone," as Herrick termed it, is 250 feet. In 1908, G. H. Girty examined a section east of Alamogordo, in which 1,500 feet of limestone and shale containing Pennsylvanian fossils, were found to be underlain by 150 feet of limestone containing Mississippian forms. Some of the same species were collected in Alamo Canyon, a few miles farther south, by G. B. Richardson, and also in 1915 by the writer. An unpublished section, kindly furnished by Mr. Girty, is as follows:

Section of Carboniferous racks in ridge N. 63° E. of Alamogordo, N. Mex.

	Feet.
43. Massive limestone	50±
42. Thinner beds and concealed	100±
41. Dark limestone	50±
40. Concealed	30
39. Dark limestone	3
38. Concealed	50
37. Soft greenish gritty sandstone	10
36. Concealed; débris, limestone and thin greenish sandstone	100
35. Dark massive limestone, weathering brown	25
34. Concealed	20
33. Dark limestone	5
32. Sandy shale, partly concealed	10
31. Earthy limestone (fossils)	4
30. Dark shale above (20 feet), concealed below	50
29. Argillaceous and calcareous shale (fossils)	10
28. Dark siliceous limestone	10
27. Greenish sandy shale	15
26. Greenish-brown gritty sandstone	10
25. Shaly material	5
24. Thin dark siliceous limestone	10
23. Concealed; probably thin impure limestone	15
22. Massive dark limestone	10
21. Concealed	15
20. Siliceous limestone below, concealed in middle, purer and fossiliferous limestone above	20
19. Greenish gritty sandstone, thin bedded below, massive in middle, thinner above	60
18. Partly concealed; upper part with thin black limestone, weathering bluish and yellowish	50
17. Lower 30 feet probably thin gritty sandstone; upper 20 feet massive; some layers calcareous, with quartz pebbles and fossils	50
16. Gritty sandstone, calcareous below and fossiliferous	10
15. Dark-brown limestone, somewhat shaly, many fossils	10
14. Poorly exposed; probably thin dark siliceous limestone, weathering brown, poor fossils	100±

[1] Herrick, C. L., Univ. New Mexico Bull., vol. 2, No. 3, p. 8. The geology of the white sands of New Mexico: Jour. Geology, vol. 8, pp. 112–128, 1900.

	Feet.
13. Black limestone, siliceous, weathering brown...	3
12. Poorly exposed; probably thin impure limestone and a few ledges of dark cherty limestone; poor fossils.....	50
11. Light-colored sandstone and fine conglomerate; poorly exposed.....	100±
10. Shale with calcareous layers; fossils.....	30
9. Dark impure limestone.....	15
8. Unexposed; probably thin sandstone and then impure limestone; *Productus cora* and *P. semireticulatus* in débris.....	100
7. Whitish and rusty gritty sandstone, and fine conglomerate, not well exposed; perhaps as much as.....	300
6. Light-colored crinoidal limestone; some very soft and weathering to gravel.....	75
5. Dark siliceous limestone with chert in bands...	30
4. Massive, rather soft calcareous shale; big crinoid stems and *Schizophoria*.....	5

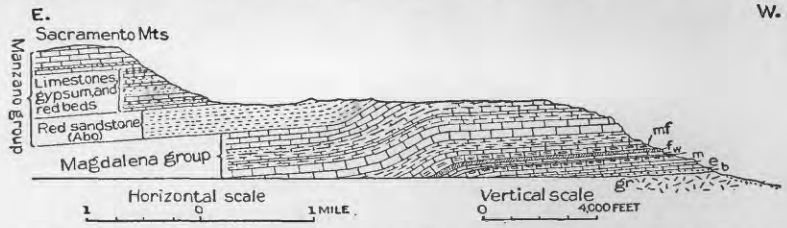


FIGURE 13.—Section of the west front of the Sacramento Mountains, 12 miles southeast of Alamogordo, N. Mex. gr, Granite; b, sandstone (Bliss?); e, El Paso limestone; m, Montoya limestone (dark massive limestone, overlain by cherty limestone); w, limestone, white when weathered (Fusselman?); f, Fusselman limestone; mf, shaly limestone, with Mississippian fossils.

3. Dark limestone and thin shale interbedded; limestone with "*Caudagalli*".....	20
2. Same as No. 1 but more massive.....	15
1. Dark bluish-gray calcareous shale, thin bedded and rather massive; base not seen.	

Fossils of Mississippian age were obtained from bed 6 (see list on p. 52), as well as in the lower beds, and this member is tentatively regarded as the top of the Mississippian, although possibly bed 7 should also be included. Beds 1 and 2 extend down to the edge of the valley fill. The strata containing Mississippian fossils extend all along the west front of the range, from a point opposite Alamogordo nearly to Grapevine Canyon. The most abundantly fossiliferous beds are in the 100-foot member of shales and slabby limestone lying between a massive ledge of coarse-grained limestone and the top of the cliff of Fusselman limestone.

The relations of these Mississippian beds are shown in figures 13 and 14, the latter showing the long arch extending along the mountain front east-southeast of Alamogordo. (See also Pls. XX and XXI.)

Sierra Ladrones.—The northernmost known rocks of Mississippian age in New Mexico occur on the south side of the Sierra Ladrones, Socorro County, where in 1905 W. T. Lee[1] obtained distinctive Mississippian fossils. (See list on p. 52.) The locality was in the canyon of Rio Salado, about one-eighth of a mile from the granite ledges and therefore very near the base of the sedimentary succession. Not far above are limestones with fossils of Pennsylvanian age, and in 1913 the writer found Pennsylvanian fossils within 3 or 4 feet of the granite on the northwest side of the mountain. Evidently the Salado Canyon exposure is either an outlying lens of the Mississippian limestone or an extension northward from Magdalena Mountain. The Mississippian is not present east of Socorro and in the Manzano, Sandia, Zuni, Nacimiento, and Rocky mountains, where rocks of the Pennsylvanian series lie directly on pre-Cambrian granite.

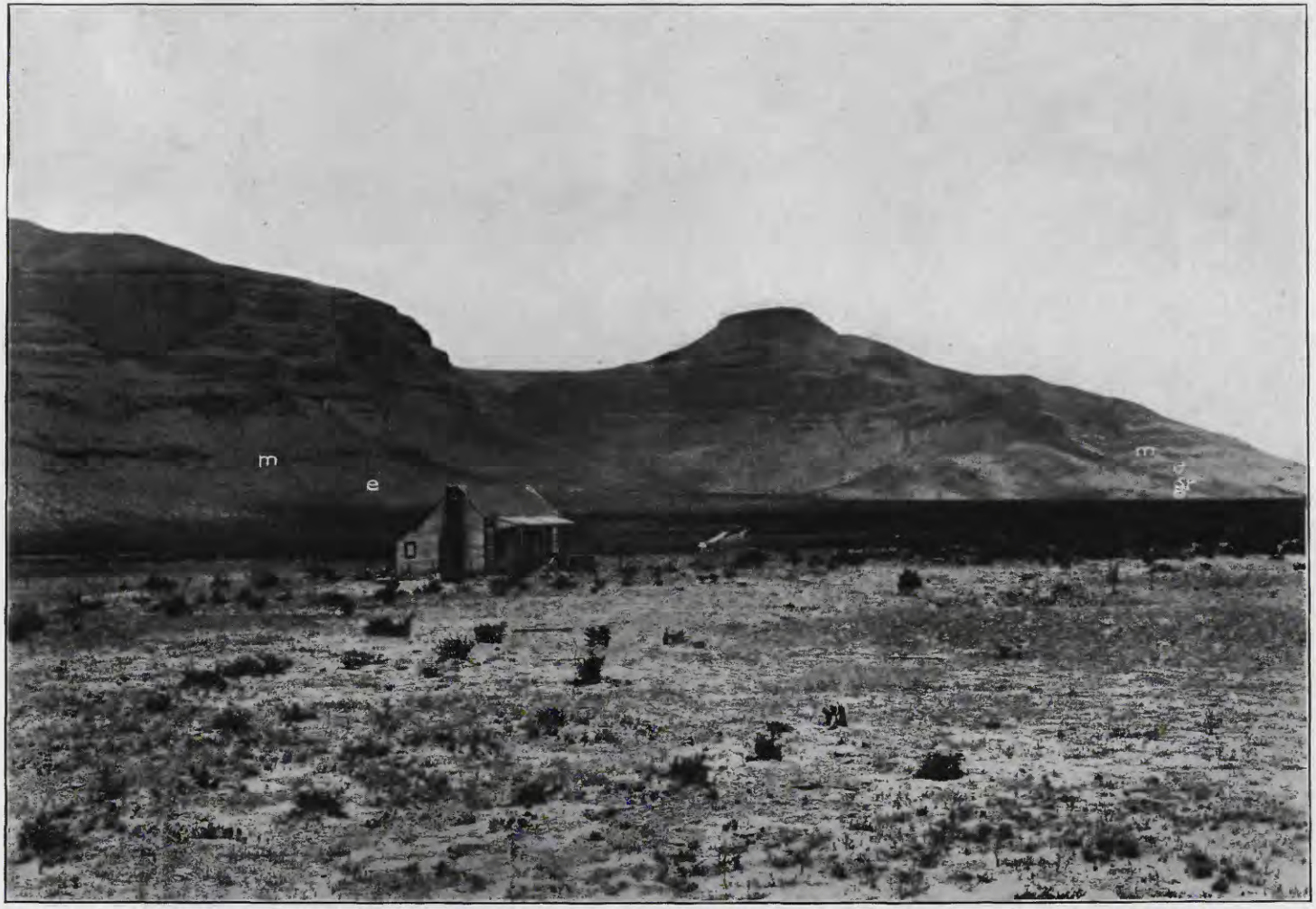
Fossils.—In the type locality at Lake Valley, from beds 7 and 8 in the section given on page 47, were obtained the following fossils. The identifications were made by G. H. Girty, except those of the crinoids, which were made by Frank Springer:

Cladochonus sp.
Favosites aff. F. valmeyerensis.
Zaphrentis sp.
Amplexus aff. A. fragilis.
Platycrinus peculiaris.
Platycrinus parvinodus.
Platycrinus pileiformis.
Periechocrinus whitei.
Megistocrinus evansi?
Dorycrinus unicornis.
Physetocrinus lobatus.
Physetocrinus planus.
Steganocrinus sculptus.
Fistulipora americana.
Cheilotrypa? sp.
Fenestella sp.
Pinnatopora sp.
Rhombopora sp.

[1] Gordon, C. H., Mississippian formations in the Rio Grande valley, N. Mex.: Am. Jour. Sci., 4th ser., vol. 24, p. 58, 1907.

VIEW LOOKING SOUTHEAST ALONG WEST FRONT OF SACRAMENTO MOUNTAINS FROM ALAMOGORDO, OTERO COUNTY, N. MEX.

A, Mouth of Alamo Canyon; O, canyon with small orchard at its mouth; F, northwest-southeast fault; S, San Andres Canyon; e, El Paso limestone; m, Montoya limestone; f, Fusselman limestone; mf, limestone with Mississippian fossils above which are Pennsylvanian limestones.



VIEW ALONG WEST FRONT OF SACRAMENTO MOUNTAINS AT AGUA CHIQUITA CANYON, OTERO COUNTY, N. MEX.

Looking southeast. m, Montoya limestone; e, El Paso limestone; gr, granite.

Crania aff. C. missouriensis.
Schizophoria aff. S. swallowi.
Productus aff. P. burlingtonensis.
Productus aff. P. arcuatus.
Productus aff. P. sampsoni.
Pustula n. sp.
Pustula sp.
Rhynchopora occiden talis.
Camarotoechia aff. C. metallica.
Spirifer aff. S. grimesi.
Spirifer aff. S. vernonensis.
Brachythyris aff. B. suborbicularis.
Delthyris novamexicana.
Reticularia aff. R. cooperensis.
Pseudosyrinx aff. P. gigas.
Athyris lamellosa.
Cliothyridina temeraria.
Cliothyridina aff. C. obmaxima.
Cliothyridina aff. C. incrassata?
Eumetria? tuta.
Platyceras aff. P. equilatera.
Goniatites sp.
Orthoceras? sp.
Phillipsia aff. P. peroccidens.
Proetus sp.
Griffithides? sp.

The crinoids were not as abundant in bed 8 as in bed 7. Beds 5 and 6 contain corals and crinoids, but nothing was determined. According to Keyes bed 5 is Devonian,[1] consisting of three members, the lowest of which carries a typical late Devonian fauna.

In the exposure of Lake Valley limestone, 2 miles east of Hillsboro, Gordon[2] found beds 5 and 6 absent and beds 7 and 8 lying on fossiliferous Devonian shales. The following fossils were obtained:

Cyathaxonia? sp.
Zaphrentis sp.
Amplexus aff. A. fragilis.
Periechocrinus whitei.
Rhodocrinus wortheni var. urceolatus.
Cactocrinus multibrachiatus.
Leptaena analoga.
Cactocrinus proboscidialis.
Steganocrinus pentagonus.
Platycrinus subspinosa.
Platycrinus sp.
Physetocrinus lobatus.
Physetocrinus copei.
Fistulipora americana.
Schizophoria aff. S. swallowi.
Rhipidomella dalyana.
Leptaena analoga.
Productus aff. P. burlingtonensis.
Pustula n. sp.
Spirifer aff. S. vernonensis.
Spirifer aff. S. grimesi.
Delthyris novamexicana.
Brachythyris aff. B. suborbicularis.
Spiriferina sp.
Athyris lamellosa.
Cliothyridina aff. C. glenparkensis.
Platyceras aff. P. equilatera.
Platyceras sp.
Orthonychia sp.
Phillipsia aff. P. peroccidens.
Proetus aff. P. loganensis.

At Kingston, 9 miles west of Hillsboro, the following fossils were found by Gordon:[3]

Zaphrentis sp.
Amplexus aff. A. fragilis.
Platycrinus sp.
Fenestella sp.
Rhombopora sp.
Leptaena analoga.
Schizophoria aff. S. swallowi.
Pustula n. sp.
Spirifer aff. S. vernonensis.
Brachythyris aff. B. suborbicularis.
Pseudosyrinx aff. P. gigas.
Athyris lamellosa.
Cleiothyridina aff. C. incrassata.

From limestone overlying the Percha shale a short distance east of Kingston the writer collected the following forms, identified by G. H. Girty:

Fenestella, several sp.
Polypora sp.
Rhombopora sp.
Cheilotrypa? sp.
Cystodictya aff. C. pustulosa.

In another bed were found the following:

Cladochonus sp.
Cyathaxonia arcuata?
Fenestella sp.
Polypora sp.
Rhombopora sp.
Rhipidomella? sp.
Productus aff. P. mesialis.
Delthyris? sp.
Spiriferina sp.
Cliothyridina aff. C. glenparkensis.

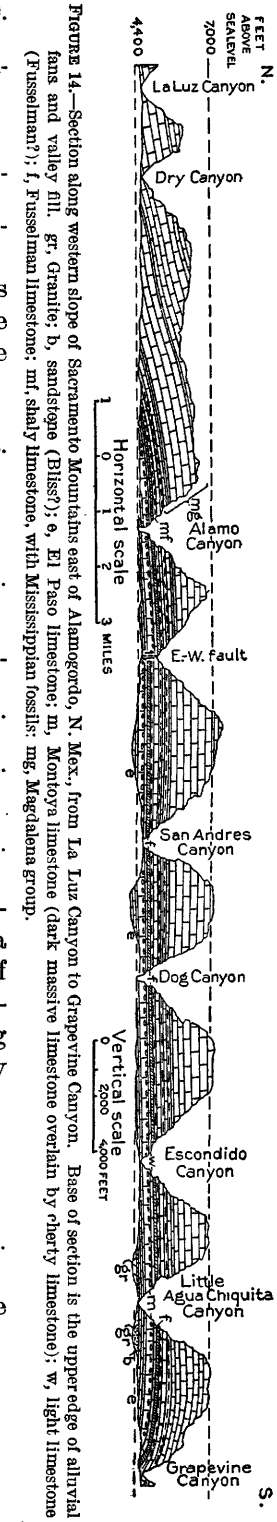


FIGURE 14.—Section along western slope of Sacramento Mountains east of Alamogordo, N. Mex., from La Luz Canyon to Grapevine Canyon. Base of section is the upper edge of alluvial fans and valley fill. gr, Granite; b, sandstone (Bliss?); e, El Paso limestone; m, Montoya limestone (dark massive limestone overlain by cherty limestone); w, light limestone (Fusselman?); f, Fusselman limestone; mf, shaly limestone, with Mississippian fossils; mg, Magdalena group.

[1] Am. Inst. Min. Eng. Trans., vol. 39, p. 147, 1909.
[2] Am. Jour. Sci., 4th ser., vol. 24, p. 61, 1907.
[3] Idem, p. 62.

The fossils collected by Lee in the canyon of Rio Salado, on the south side of the Sierra Ladrones, were determined by G. H. Girty,[1] as follows. All of them are lower Mississippian forms:

Zaphrentis 2 sp.
Granatocrinus? sp.
Platycranus? sp.
Rhipidomella aff. R. dubia.
Spirifer aff. S. logani.
Spirifer aff. S. tenuicostatus.
Spiriferella aff. S. neglecta.
Athyris lamellosa.
Cliothyridina aff. C. obmaxima.
Phillipsia sp.

There are abundant fossils in the Lake Valley limestone in the Cooks Peak region. The following were determined by G. H. Girty:

Rhombopora sp.
Cystodictya aff. C. pustulosa.
Paraparchites sp.
Leptaena analoga.
Rhipidomella pulchella?
Productus semireticulatus.
Productus ovatus.
Productus aff. P. burlingtonensis.
Productus aff. P. wortheni.
Brachythyris suborbicularis?
Spirifer centronatus.
Composita humilis.

From the lower division of the Fierro limestone of the Silver City region Paige obtained the following distinctive Mississippian forms identified by G. H. Girty:

Actinocrinus copei?
Dorycrinus lineatus.
Leptaena analoga.
Rhipidomella aff. R. oweni.
Productus mesialis.
Spirifer aff. S. imbrex.
Reticularia cooperensis.

Girty[2] regards the Lake Valley fauna at Silver City as closely related to that found at Fern Glen, Mo., and at other points in that general region.

From the Kelly limestone in the Magdalena Range, Keyes[3] reports *Batocrinus subaequalis* Hall.

From the Mississippian beds in the section east of Alamagordo, Girty[3] obtained the following species:

Triplophyllum sp.
Leptaena analoga.
Schuchertella aff.
S. chemungensis.
Rhipidomella diminutiva?
Schizophoria postsriatula?
Productus gallatinensis.
Productella n. sp. aff. P. pyxidata.
Shumardella? aff. S. missouriensis.
Brachythyris suborbicularis.
Ambocoelia levicula.
Reticularia cooperensis.
Proetus peroccidens.
Spirifer sp. undet.
Platyceras sp. undet.

In 1915 the writer collected from shales about 50 feet above the Fusselman ledge on the north side of Alamo Canyon the following forms identified by G. H. Girty:

Zaphrentis sp.
Rhipidomella dalyana.
Schizoporia? sp.
Spirifer rowleyi.
Spirifer centronatus?
Delthyris novamexicana.
Composita humilis?
Cliothyridina prouti?
Cliothyridina sp.

At the same horizon in the slope near Dog Canyon were collected the following:

Schizoblastus aff. S. roemeri.
Dielasma sp.
Spirifer aff. S. grimesi.
Platyceras aff. P. fissurella.
Platyceras aff. P. paralius.
Platyceras aff. P. equilatera.

Lower Mississippian (Lake Valley) fossils were collected at several localities in the San Andres Mountains. The following forms were identified by G. H. Girty:

San Andres Canyon, in heavy ledge above Percha shale:
Triplophyllum sp.
Schizopophoria aff. S. swallowi.
Productus aff. P. arcuatus.
Spirifer aff. S. grimesi.
Spirifer centronatus.
Brachythyris suborbicularis.

In cherty beds at top of this heavy ledge, in a canyon 3 miles south of San Andres Peak:
Triplophyllum sp.
Spirifer aff. S. pellensis.
Eumetria vera.

In the basal part of the first heavy ledge above the Percha shale on the ridge west of the San Nicolas Spring:
Cystodectya sp.
Chonetes aff. C. logani.
Spirifer sp.

[1] Personal communication.
[2] U. S. Geol. Survey Geol. Atlas, Silver City folio (No. 199), p. 5, 1916.
[3] Am. Inst. Min. Eng. Trans., vol. 39, p. 169, 1909.

MAGDALENA GROUP.

The representatives of the Pennsylvanian series have been studied in detail in many parts of New Mexico, but the following statements refer only to the beds associated with the older formations in southern New Mexico and adjacent parts of Texas.

Cooks Range.—About 40 feet of dark-gray shale lying on the white chert of the Lake Valley limestone high on the slopes on the northwest side of Cooks Peak yielded fossils that appear to indicate the presence of a representative of the Magdalena group, the lowest subdivision of the Pennsylvanian series in New Mexico. Possibly it occurs elsewhere in Cooks Range, but at all other places visited the Gym and Lake Valley limestones are in immediate succession. The fossils in the limy layers in the shale include the following, all determined by G. H. Girty:

Derbya crassa.
Chonetes mesolobus.
Productus semireticulatus.
Pustula nebraskensis?
Marginifera muricata.
Pugnax sp.
Spirifer cameratus.
Spirifer rockymontanus.
Ambocoelia planiconvexa.
Aviculipecten, 2 sp.
Acanthopecten carbonifer.
Lima retifera.
Astartella vera.
Edmondia subtruncata.
Phillipsia scitula.

Silver City region.—As remarked on page 48, the upper part of the Fierro limestone of the Silver City region. as defined by Paige in the Silver City folio, includes beds representing more or less of the Magdalena group. The fossils found in this upper division were determined by Girty as follows:

Fusulina secalica.
Campophyllum torquium?
Zaphrentis sp.
Chaetetes milleporaceus.
Fenestella tenax.
Stenopora sp.
Meekopora? sp.
Prismopora triangulata.
Productus cora.
P. semireticulatus.
Pustula nebraskensis.
Spirifer cameratus.
S. rockymontanus.
Squamularia perplexa.
Composita subtilita.
Cliothyridina orbicularis.

These forms are comprised in the Magdalena fauna in Sierra and Socorro counties.

Mimbres Mountains.—At Kingston, on the east slope of the Mimbres Mountains, according to Gordon,[1] the basal Magdalena strata consist of about 300 feet of dark-blue and gray limestone in thick beds with thin shale partings. The upper part of the group has about the same thickness and consists chiefly of blue and drab shales interstratified with several beds of limestone from 15 to 20 feet thick. Unconformably overlying these beds are red sandstones and shales (Abo sandstone) of the Manzano group. At the Palomas mining camp, 20 miles north of Kingston and 2 miles east of Hermosa, the Palomas Creek canyon has nearly vertical walls, the lower half of limestone and shale in about equal amounts and the upper half of hard, massive gray limestone. About halfway up the cliff a few thin beds of quartzite are interstratified with the other rocks. There is no evidence on which to separate the group into Sandia formation and Madera limestone, as in the region farther east.

Magdalena Mountains.—In the Magdalena Mountains, according to Gordon,[1] the basal member of the Magdalena group is 10 to 15 feet of moderately coarse conglomerate interstratified with dark shale, whose bedding is apparently parallel to that of the underlying Kelly limestone. This conglomerate is overlain by 115 feet of limestone capped by coarse white quartzite or conglomerate in massive ledges separated by thin beds of shale. Next above is a member 80 to 90 feet thick, consisting mostly of limestone, in which are some thin beds of shale and quartzite. The basal part of this member is 6 feet of thick-bedded drab-blue subcrystalline limestone; next above are 25 feet of shale and thin limestone, 2 feet of quartzite, 50 feet of compact bluish earthy limestone, and 410 feet of shale and conglomeratic sandstone or quartzite. The total thickness of these beds (Sandia formation) is about 600 feet. They are overlain by 300 to 500 feet of limestone (Madera), more or less of whose surface has been removed by erosion.

GYM LIMESTONE.

The Manzano group is represented in central and northern New Mexico by the Gym limestone, which crops out extensively in the Flor-

[1] U. S. Geol. Survey Prof. Paper 68, pp. 232, 269, 1910.

ida Mountains, type locality,[1] and also in the Victorio Mountains. In both places it lies unconformably on formations from the El Paso to the Fusselman, for the Percha shale and Lake Valley and Magdalena limestones are absent. In Cooks Range a thin body of the Gym limestone lies on the Lake Valley limestone at most places, but on the northwest slope of Cooks Peak these two limestones are separated by an outlier of shale of Magdalena age. The Gym limestone also appears extensively in the Tres Hermanas Mountains, where it is uplifted and cut by porphyry, and it also crops out in a few small hills rising out of the desert in the south-central part of the county. The formation has not been recognized outside of Luna County, although doubtless it is represented in the Manzano and Hueco sections in other areas.

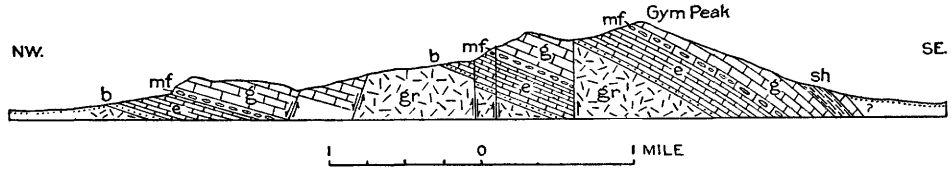


FIGURE 15.—Section across the southern part of the Florida Mountains, Luna County, N. Mex. gr, Granite; b, Bliss sandstone; e, El Paso limestone; mf, Montoya and Fusselman limestones; g, Gym limestone with dark-gray shale member (sh).

In the Florida Mountains the Gym limestone is about 1,000 feet thick, but, as shown in figure 15, it is greatly faulted and the uppermost beds have been more or less deeply removed by erosion. In Cooks Range its thickness is less than 50 feet.

The formation consists almost entirely of light-gray limestone, mostly massive and in part brecciated. An 80-foot member of dark-gray shale is apparently included on the southeast slope of the Florida Mountains, but this may be the Percha shale overlapped, or faulted into its present position. In the Tres Hermanas Mountains part of the Gym limestone is metamorphosed to white marble and there is included a member of 50 to 60 feet of gray to reddish quartzite.

Fossils were collected at several horizons in the Gym limestone at numerous localities. They were determined as follows by G. H. Girty:

Echinocrinus ornatus.
Meekella mexicana?
Productus semireticulatus.
Productus occidentalis.
Productus cora.
Marginifera splendens?
Pugnax utah.
Squamularia perplexa.
Composita perplexa.
Composita subtilita.
Composita mexicana?
Nucula levatiformis.
Nucula levatiformis var. obliqua.
Manzanella elliptica.
Parallelodon politum?
Pinna peracuta.
Monopteria marian?
Plagioglypta canna?
Bellerophon crassus.
Bellerophon majusculus?
Bucanopsis modesta.
Pleurotomaria texana.
Rhynchomphalus obtusispira.
Euomphalus aff. E. pernodosus.
Chonetes playtnotus?
Orthonema socorroense?
Sphaerodoma aff. S. humilis.
Sphaerodoma aff. S. primigenia.
Bulimorpha inornata.

In the San Andres and Sacramento mountains and farther north in New Mexico the supposed equivalent of the Gym limestone is separated from the Magdalena group by a thick series of red beds (Abo sandstone), but these beds are lacking in the southwest corner of the State and also in the region near and east of El Paso.

Most of the fossils in the Gym limestone are doubtless of the Manzano group, but they do not afford a basis for correlation with the rocks of other regions, nor do they indicate how much of the group is represented here. Mr. Girty has called the writer's attention to the fact that *Productus occidentalis* is characteristic of the limestone capping the Sacramento Mountains at Cloudscroft, a bed which is high in the Carboniferous. Some of the gastropods strongly suggest the Hueco fauna, and therefore the formation is believed to represent part of the Hueco limestone.

[1] Darton, N. H., Geology and underground water of Luna County, N. Mex. U. S. Geol. Survey Bull. 618, p. 35, 1916.

HUECO LIMESTONE.

According to Richardson [1] the Carboniferous rocks are represented in the Franklin and Hueco mountains by a massive gray limestone of which 3,000 feet appears, but the total thickness is greater, as more or less of the top has been covered or removed by erosion. Thin bedding is rare, and chert is practically absent. The magnesia content was found to be less than 1 per cent. Locally some beds are black; in the Hueco Mountains most of the limestone is light colored. The Hueco Mountains consist mainly of this formation, and it constitutes the northwestern flank of the Franklin Mountains. The Hueco limestone carries an abundant fauna regarded by Girty as of late Carboniferous age, on account of which at least the upper part of it has been tentatively correlated with the Kaibab limestone of northern Arizona.

GEOLOGIC HISTORY.

The sequence of events in southern New Mexico during the earlier part of the Paleozoic era can be known only in a most general way, for many long intervals of the time are not represented by deposits. It is probable that many beds were laid down that were subsequently removed. Doubtless some of the beds now remaining have been thinned by erosion, and possibly, also, they were formerly much more extensive. Some or all of the pre-Pennsylvanian formations may have covered all of New Mexico. Apparently the uplifts were widespread and not attended by folding, for the attitude of all the Paleozoic formations is the same with a few slight local exceptions.

The first Paleozoic event of which there is evidence was the deposition of sand on beaches of granite and other old rocks in the later part of Cambrian time. There may have been accumulations of earlier Cambrian sediments, but if so they were completely removed. Possibly sedimentation was continuous into early Ordovician time, when the materials of the El Paso limestone accumulated to a thickness of 900 feet or more. The hiatus between the El Paso limestone and the Montoya is a long one, representing all of the Middle Ordovician and the early part of the Upper Ordovician. The hiatus between the Montoya and Fusselman is from late Richmond to probable early Niagara time. Only a small part of later Devonian time is represented by the Percha shale, so during that epoch there was either long emergence of the land or extensive removal of earlier Devonian sediments. During part of early Carboniferous time the region was submerged and the Lake Valley sediments were laid down, but there is only a long hiatus to represent later Mississippian time. Pennsylvanian and Permian time is represented in the main by deposits of the Magdalena and Manzano groups and the Hueco and Gym limestones. The Hueco and Gym are contemporaneous, at least in part, with the Manzano group, which includes 500 to 1,000 feet of red beds (Abo sandstone) that thin out to the south.

[1] U. S. Geol. Survey Geol. Atlas, El Paso folio (No. 166), 1909.

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