New Mexico Geological Society

*Downloaded from:* https://nmgs.nmt.edu/publications/guidebooks/6




# *Geology of the San Andres Mountains*

Frank E. Kottlowski
1955, pp. 136-145. https://doi.org/10.56577/FFC-6.136

*in:*

*South-Central New Mexico*, Fitzsimmons, J. P.; [ed.], New Mexico Geological Society 6th Annual Fall Field Conference Guidebook, 193 p. https://doi.org/10.56577/FFC-6

*This is one of many related papers that were included in the 1955 NMGS Fall Field Conference Guidebook.*

## Annual NMGS Fall Field Conference Guidebooks

Every fall since 1950, the New Mexico Geological Society (NMGS) has held an annual Fall Field Conference that explores some region of New Mexico (or surrounding states). Always well attended, these conferences provide a guidebook to participants. Besides detailed road logs, the guidebooks contain many well written, edited, and peer-reviewed geoscience papers. These books have set the national standard for geologic guidebooks and are an essential geologic reference for anyone working in or around New Mexico.

### Free Downloads

NMGS has decided to make peer-reviewed papers from our Fall Field Conference guidebooks available for free download. This is in keeping with our mission of promoting interest, research, and cooperation regarding geology in New Mexico. However, guidebook sales represent a significant proportion of our operating budget. Therefore, only *research papers* are available for download. *Road logs*, *mini-papers*, and other selected content are available only in print for recent guidebooks.

### Copyright Information

Publications of the New Mexico Geological Society, printed and electronic, are protected by the copyright laws of the United States. No material from the NMGS website, or printed and electronic publications, may be reprinted or redistributed without NMGS permission. Contact us for permission to reprint portions of any of our publications.

One printed copy of any materials from the NMGS website or our print and electronic publications may be made for individual use without our permission. Teachers and students may make unlimited copies for educational use. Any other use of these materials requires explicit permission.

*This page is intentionally left blank to maintain order of facing pages.*

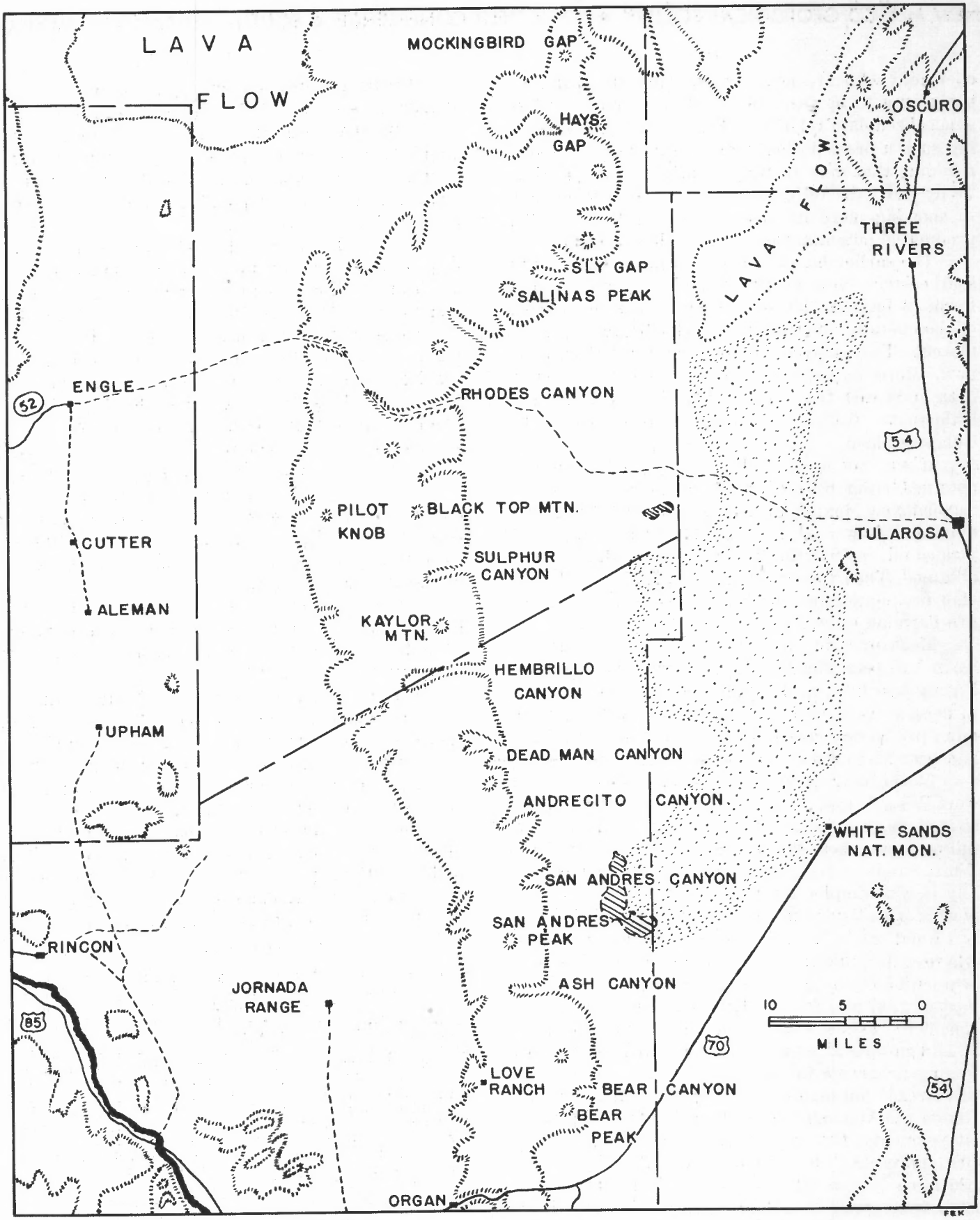



Figure 1. INDEX MAP - SAN ANDRES MTS.

# GEOLOGY OF SAN ANDRES MOUNTAINS

By Frank E. Kottlowski
*New Mexico Bureau of Mines and Mineral Resources*

The San Andres Mountains are one of the most prominent ranges in southern New Mexico and have been a formidable barrier to early and present-day travelers. The range is about 85 miles long, 6 to 17 miles wide, and forms a flat north-south arc concave toward the east (Fig. 1). To the west is the Jornada del Muerto, to the east the Tularosa Basin, at the north Mockingbird Gap (5,260 feet), and at the south San Augustin Pass (5,719 feet). Three peaks rise over 8,000 feet, towering more than 4,000 feet above the Tularosa Basin. San Andres Peak, near the south end, is 8,239 feet above sealevel, Salinas Peak, north of Rhodes Pass, is 8,958 feet and Greer Peak/Silver Top Mountain is about 8,005 feet above sealevel. A typical topographic cross-section (Road log, Fig. 1-2) shows an east scarp capped by Middle Pennsylvanian limestones that form a ridge at elevations of 7,000-8,000 feet; to the west a series of mesas and valleys cut in Upper Pennsylvanian shaly beds and in Hueco, Abo, and Yeso rocks; and a western cuesta capped by San Andres limestones.

About 14 large canyons enter the Tularosa Basin from the range but none cut completely through to the Jornada. The drainage divide is near the west margin of the range reflecting the lower elevations of the Tularosa Basin as compared to the Jornada del Muerto. Along parallels of latitude the lowest points of the Tularosa Basin are 400 to 500 feet below the lowest points of the Jornada. While the major canyons are east-west gashes cut perpendicular to the strike, in many places along fault zones, most of the tributary canyons are strike valleys eroded into the less resistant beds such as the Upper Pennsylvanian and Yeso rocks.

## STRATIGRAPHY

Sedimentary rocks from Precambrian to early Tertiary (?) are well exposed in the San Andres Mountains as indicated on Darton's (1928) reconnaissance geologic map. The beds are chiefly of Paleozoic age and range in thickness from about 6,000 feet near Mockingbird Gap to about 7,000 feet near San Augustin Pass. Only a few isolated outcrops of Cretaceous strata occur in or near the range, therefore, these figures include only a few thousand feet of the Cretaceous; as much as several thousand feet of Cretaceous may be encountered in test wells drilled in the adjoining basins.

Precambrian rocks are chiefly granites with minor amounts of greenish schist near Rhodes Canyon; along the east front of the center of the range from Sulphur to Hembrillo Canyons various metamorphic rocks have been reported (Darton, 1928) and seen. Near San Augustin Pass the Precambrian is again predominantly granite with roof-pendants of schist, gneiss, quartzite, and diorite (Dunham, 1935).

The Bliss sandstone overlies a remarkably even erosional plain cut on the Precambrian, as can be seen at the mouth of Rhodes Canyon. The sandstone in most places forms a dark-brown ledgy cliff (Fig. 2) overlying a slope cut on Precambrian rocks and is present the length of the range. The unit thins northward ranging from 120 feet at the south to about six feet near Mockingbird Gap (Darton, 1928). In the northern part of the range, lenticular, pebbly to conglomeratic sandstones occur at the base. At or near the base Kelley (1951) reported several feet of oolitic hematite. Most of the unit is light-brown, pale reddish-brown, to greenish-gray, glauconitic, calcareous to siliceous, cross-laminated sandstones, although lenses of gray to almost white quartzite occur in the lower part, and arenaceous limestones near the top.

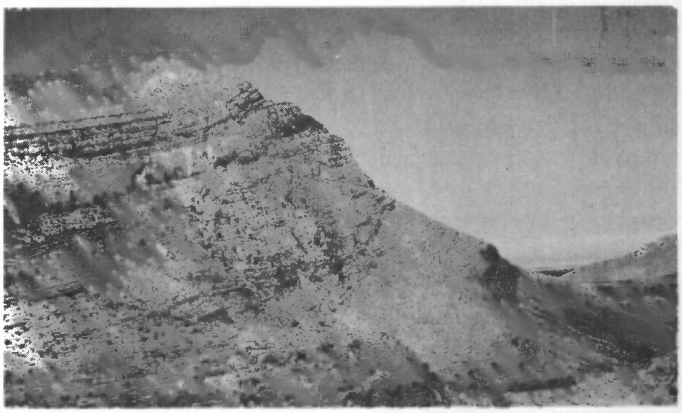


Figure 2. Typical exposures of lower Paleozoic rocks in central part of San Andres Mountains. Lower slope Precambrian outcrops, thin cliff of Bliss sandstone, slope and ledgy cliff of El Paso dolomite, solid cliff of Upham dolomite with Cable Canyon lenses at base, ledgy cliff of Aleman dolomite, top ledgy slope of Cutter-Valmont dolomite.

Differences in published thicknesses of the Bliss and El Paso formations reflect differences of opinion as to where the contact should be placed. Darton (1928) noted gradation from calcareous sandstone into sandy limestone and dolomite of the El Paso; his contact appears to have been drawn chiefly on change in color. Entwistle (1944), at Silver City, used the uppermost glauconitic sandstone as the top of the Bliss. Kelley and Silver (1953) separated the units on the basis of color and topographic expression which they indicated are expressions of the contrasting mineralogy, lithology and bedding of the Bliss and El Paso in the Caballo Mountains. Pray (1954) stated that the El Paso appears to be transitional with the Bliss sandstone and used one of several lenticular, pebbly sandstones as the base of the El Paso in the Sacramento Mountains.

The El Paso formation ranges from about 60 feet near Mockingbird Gap (Darton, 1928) to 750 feet in thickness near the Organ Mountains (Dunham, 1935), and is probably about 300 feet thick in Rhodes Canyon. Throughout much of the range the El Paso is a dolomite-limestone unit, light gray to light brown, with beds forming slabby ledges 2 to 12 inches thick, resulting in an overall steep ledgy slope. Calcareous sandstones and arenaceous dolomites occur near the base; the oolite zone of Flower (1953) is present from San Augustin Pass at least to as for north as Sly Gap.

Kelley and Silver (1952) have treated the El Paso as a group and separated it into two formations, the lower Sierrite and the upper Bat Cave. They measured sections in the San Andres Mountains and noted that the thickness of the Sierrite is irregular, ranging from 60 to 150 feet, while the thickness of the Bat Cave increases southward from about 50 feet near Hays Gap to about 800 feet near San Augustin Pass. This thinning is attributed to post-El Paso erosion. Flower (1953) also noted that post-Canadian erosion has removed variable amounts of the upper part of the El Paso in New Mexico.

The Sierrite is described as typically a cliff-forming sequence of medium-gray to brown, thin-to medium-bedded limestones with numerous irregular brown-weathering chert laminations. The Bat Cave is described as consisting of a lower unit of light-colored slope-forming stromatolitic and detrital limestones and an upper unit of darker, banded, cliff-forming limestone and dolomite.

Much of the El Paso in the San Andres Mountains has been dolomitized. Stromatolitic masses are in most places small and sparsely and irregularly distributed, and the topographic expression varies. The contact of the Sierrite and Bat Cave is, therefore, difficult to pick. The contact of the El Paso and overlying Montoya is, however, a sharp disconformity and locally (as well as regionally) an unconformity.

The Montoya dolomite, as redefined by Kelley and Silver (1952) in the Caballo Mountains is about 60 feet thick near Mockingbird Gap (Darton, 1928), about 225 feet thick in Rhodes Canyon (Kelley and Silver, 1952), and increases to 345 feet thick near San Augustin Pass (Darton, 1928). The four subdivisions proposed by Kelley and Silver (1952), three from the original Montoya (Cable Canyon, Upham, and Aleman) and the upper subdivision from the lower part of the Fusselman (Cutter), occur in the San Andres Mountains and have been noted by Darton (1928) and Dunham (1935). Entwistle (1944) named, and mapped as separate units on a published map, three members of the Montoya dolomite that correspond to the Caballo Mountains units. Pray and Bowsher (1952) noted that the lower Fusselman, as originally defined, contains Ordovician fossils and is lithologically distinct from the upper Fusselman, which contains Silurian faunas. Pray (1953) named this lower Fusselman unit the Valmont dolomite; it correlates with the Cutter dolomite.

The basal bed of the Montoya dolomite is the Cable Canyon sandstone. Darton (1928) noted it as a local sandstone lying on a slightly uneven surface cut on the El Paso, and as much as 11 feet thick. It is a dolomitic to quartzitic sandstone, conglomeratic in part, and white to light-brown. In places it grades up into the overlying Upham dolomite; in other outcrops there is an apparent sharp break.

The Upham dolomite is a massive-bedded, dark-colored, cliff-forming unit. Arenaceous lenses occur in the lower part and scattered to abundant chert nodules in the upper part. The contact with the overlying Aleman is gradational and is in places difficult to pick, especially where chert is abundant in the upper beds of the Upham. Darton (1928) indicated an irregular but general thickening of the Upham southward.

The Aleman dolomite is thinner-bedded and lighter-colored than the Upham and contains much chert in nodules, lenses, stringers, and flakes (Fig. 3). In many places the lower beds of the Aleman form the upper part of the Upham cliff, and the upper Aleman beds crop out as thin ledges (Fig. 2). The thickness of the Aleman is relatively uniform in the range (Darton, 1928) although thinned by post-Ordovician erosion near Mockingbird Gap. Silicified brachiopods are common and indicate a Richmond age (Flower, 1953).



Figure 3. Chert in Aleman dolomite.

The contact between the Aleman and the Cutter-Valmont dolomite is in places sharp and in other outcrops difficult to pick. The Cutter-Valmont dolomite is very light gray, aphanitic to fine-crystalline, and weathers to a ledgy slope; chert is sparse. Darton (1928) reported that it thins northward from the south end of the San Andres Mountains, but thickens in Sulphur Canyon before thinning and pinching out to the north due to post-Ordovician erosion. A shaly silty phase is mentioned by Darton (1928) in Dead Man Canyon.

The Fusselman dolomite, as restricted by Pray and Bowsher (1952), Kelley and Silver (1952), and Pray (1953), is about 80 feet thick near San Augustin Pass but thins northward and pinches out just north of Sulphur Canyon. The unit is a hard, massive, dark-colored dolomite, cherty in places, forming a cliff (Fig. 5) that caps the ledgy slope of the Cutter-Valmont dolomite and is beneath the long slope cut on Devonian beds. The Fusselman rests with a sharp disconformity on the Cutter-Valmont (Fig. 4). The upper surface of the Fusselman dolomite is, in many places, irregular and highly silicified, and forms a reddish-brown shelf below Devonian beds.

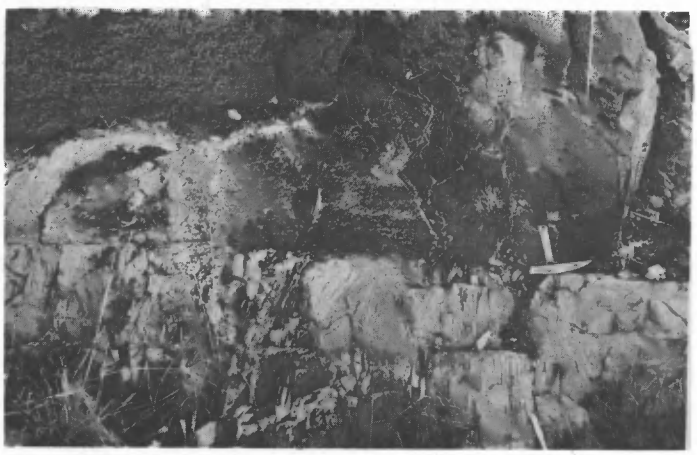


Figure 4. Contact of Fusselman dolomite and underlying Cutter-Valmont dolomite.

Devonian strata overlie earlier Paleozoic beds with a pronounced regional unconformity. At San Augustin Pass and northward to Sulpher Canyon, Devonian beds overlie the northward-thinned wedge of Fusselman dolomite. In Rhodes Canyon, Devonian rocks rest on the Cutter-Valmont dolomite; in Sly Gap on the Aleman cherty dolomites; in Mockingbird Gap on a few feet of Aleman dolomite; and in the southern Oscura Mountains on about 25 feet of the El Paso formation (Darton, 1928).

Beds of Devonian age vary in thickness throughout the San Andres Mountains but pinch out rather abruptly because of Mississippian and Pennsylvanian erosion north of Hays Gap. They are about 100 feet thick near San Augustin Pass (Darton, 1928), about 160 feet thick in Rhodes Canyon (Stevenson, 1945), 35 feet thick in Mockingbird Gap (Laudon and Bowsher, 1949), and about 5 feet thick in the southern Oscura Mountains before pinching out beneath the Pennsylvanian rocks.

Devonian strata in the San Andres Mountains have been studied in considerable detail by Stevenson (1945) and Laudon and Bowsher (1949), and have been subdivided into four lithologic-faunal units. These units, along with the other Lower Paleozoic subdivisions that split up the formations used by Darton (1928) in the San Andres Mountains, are not reasonably mappable on a scale of 1:62,500. The Montoya dolomite, for example, is one of the thickest Lower Paleozoic units near Rhodes Canyon, yet has an outcrop extent of only 0.05 to 0.2 inches on a map with a scale of 1:62,500. Cartographic limitations on that scale prevent subdividing the El Paso, Montoya, Devonian and Mississippian—as well as require a grouping of the Bliss with the El Paso. Until actual field mapping is done on a scale of 1:24,000 or smaller these subdivisions of Richardson's (1909) formations, although quite useful as such, remain chiefly stratigraphic designations. As the Devonian beds form a less steep slope than the rest of the Lower Paleozoic units they have a proportionately wider outcrop (Figs. 5 and 6) but they are rarely exposed, being covered by talus and slope wash formed in place and from above.

The lowest Devonian beds are of the Onate formation of Stevenson (1945), an intergradational sequence of shale, siltstone, fine-grained sandstone, and silty limestone of grayish-brown color. The On-



Figure 5. Upper Ordovician to Pennsylvanian exposures in central San Andres Mountains. Central thin cliff is Fusselman dolomite overlying Cutter-Valmont and Aleman dolomites; above is Devonian slope, thin Mississippian cliffs, Derryan slope, and, capping the mountains, Desmoinesian limestone cliffs.

ate formation is thickest at its type locality in San Andres Canyon where it is 42 or 87 feet thick, depending on where the contact is picked. The formation thins both to the north and to the south from San Andres Canyon and is the five foot thick wedge of Devonian in the southern Oscura Mountains. The Onate rests unconformably on pre-Devonian beds, in many places on an undulating silicified ferruginous surface. Very few geologists pick the same horizon for the contact with the overlying Sly Gap formation.

The Sly Gap formation is the fossiliferous horizon that makes mineralogists turn into fossil collectors. The formation consists of intercalated tan to light-yellow, thin-bedded shales, calcareous siltstones, and silty limestones. Various paleontologists are still finding new species and genera in the extremely abundant fauna dominated by *Atrypa*. The Sly Gap is 60 to 100 feet thick in the north-central part of the San Andres Mountains and thins both to the north and south.

The contact of the Sly Gap and overlying Contadero formation is drawn where gray limestones overlie the tan beds of the Sly Gap. The Contad ero consists of carbonaceous shales and silty nodular limestones, about 70 feet thick at the type locality in Rhodes Canyon, and thins rapidly to the north and to the south being about five feet thick in Dead Man Canyon and absent(?) at Sly Gap.

The Ready Pay member (lower) of the Percha shale is black, fissile, nonfossiliferous shale. Stevenson (1945) believed it absent in Rhodes Canyon, but measured a thickness of about 50 feet in Dead Man Canyon and correlated it with black shales in the Organ and Franklin Mountains. He noted that the Contadero formation may be a facies equivalent in age to the Ready Pay member; if so the combined Ready Pay-Contadero formation would in general thicken southward from Rhodes Canyon and be thin or absent to the north.

Mississippian strata in the San Andres Mountains unconformably overlie Devonian beds and have been divided by Laudon and Bowsher (1949) into the Caballero, Lake Valley, Las Cruces, and Rancheria formations. They thin northward, being about 300 feet thick near Bear Canyon, 200 feet near Hembrillo Canyon, 70 feet in Rhodes Canyon, and 20 feet at Mockingbird Gap (Laudon and Bowsher, 1949). The Mississippian beds form thin cliffs in the north and central parts of the range (Fig. 5) and massive thick cliffs near the south end of the San Andres Mountains (Fig. 6).



Figure 6. Mississippian cliff in southern San Andres Mountains. Above are Pennsylvanian rocks; below in slope of Caballero and Devonian beds terminated on ledgy dip slope of Fusselman dolomite.

The Caballero formation, of Kinderhook age, consists of medium-gray calcareous shale. The formation unconformably overlies various Devonian formations and is overlain unconformably by the Lake Valley formation. The thinner lenticular shaly limestones form a ledgy slope above the low-angle slope of the less resistant Devonian beds and below the Lake Valley cliffs (Fig. 6). The formation is about 65 feet thick in Ash Canyon and thins both to the north and to the south, being absent in the Franklin Mountains and in Rhodes Canyon (Laudon and Bowsher, 1949).

All the six members of the Lake Valley formation, of Osage age, occur, at least sporadically, in the San Andres Mountains, although only three are widespread and typical. The basal Andrecito member, whose type section is in Andrecito Canyon, includes thin-bedded, silty, dark-gray, fossiliferous limestones that crop out as a series of ledges below the massive-bedded, cliff-forming, dark-gray, cherty Alamogordo member. The Andrecito is 105 feet thick in Ash Canyon, but thins both to the north and to the south, only about seven feet being present in Rhodes Canyon. The Alamogordo cliff-forming member (Fig. 6), marked by its distinctive concentrically banded white and black chert nodules, is the most widespread and persistent Mississippian unit in the San Andres Mountains, ranging from about 40 to 70 feet in thickness, overlapping to the north to rest on a thinned Sly Gap formation at Mockingbird Gap.

The Nunn member consists of soft grayish-green marls and nodular crinoidal limestones with scattered bioherms and contains most of the famous Lake Valley fauna. The Nunn member ranges irregularly from 4 to 65 feet in thickness (Laudon and Bowsher, 1949) but averages about 25 feet and is present throughout the range except in the northernmost exposures. The Tierra Blanca member includes medium-bedded, light-gray to light-brown criquina (crinoidal coquina) with scattered to abundant nodules of white to light-gray chert. The member is absent in Bear Canyon, forms bold vertical cliffs, 50 to 100 feet high (Fig. 6), from Ash Canyon to Andrecito Canyon, but northward is only 15 to 25 feet thick (Fig. 5), except where biohermal.

The Arcente member, of soft calcareous siltstones and shales, and the Dona Ana member, of massive cherty criquina, occur only from Andrecito Canyon southward as thin nonpersistent lenses.

The Las Cruces formation, of Meramec age, consists of hard, dense, grayish-black, even-bedded, cherty limestone. The thinned wedge-edge of the formation occurs only in the southern tip of the San Andres Mountains, thickening to the south to its type locality in the Franklin Mountains. The Rancheria formation, of Meramec age, likewise overlaps toward the north and occurs only south of Ash Canyon where it is a sequence of cherty, grayish-black, argillaceous limestones. The Helms formation, of Chester age, is absent in the San Andres Mountains.

Mississippian beds are overlain with pronounced erosional unconformity by basal Pennsylvanian conglomerates and sandstones (Fig. 7). Almost the entire Mississippian section is cut out in places and the spectacular channels filled by angular fragments of Mississippian cherts cemented by greenish-gray reworked silts. Laudon and Bowsher (1949) suggested that the large concentration of reworked chert indicates a source to the west since such conglomerates are of only local extent in the Sacramento Mountains.

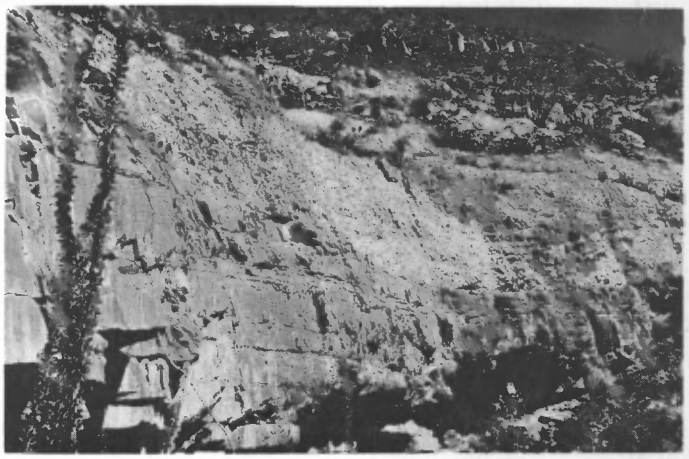


Figure 7. Basal Pennsylvanian conglomerate fill in channel cut through Tierra Blanca and Nunn members and into Alamogordo member of Lake Valley limestone--central San Andres Mountains.

Pennsylvanian rocks in the San Andres Mountains range in thickness from about 3,000 feet in Ash Canyon at the south to about 2,000 feet near Mockingbird Gap. McKee (1951) reported that Wanless measured 2,962 feet of Pennsylvanian strata in Rhodes Canyon. The combined thicknesses of the Derryan, Desmoinesian, and Missourian, however, thin southward, being about 1,300 feet near Mockingbird Gap and 400 feet in Ash Canyon, whereas Virgilian equivalents thicken southward from 800 feet at the north to almost 2,600 feet in Ash Canyon (Thompson, 1942).

Rocks of Derryan age form a ledgy slope (Fig. 5) and typically consist of basal coarse chert-pebble

conglomerates overlain by black shales, hard calcareous siltstones, calcareous sandstones, and calcarenites (Laudon and Bowsher, 1949; Thompson, 1942, 1948). Desmoinesian rocks are those usually thought of as lithologically typical Pennsylvanian or Magdalena—hard, cherty, aphanitic limestones and friable coquinoid limestones, with lesser amounts of nodular argillaceous limestones and thin shales. These beds form the massive to ledgy cliffs (Fig. 5) that cap the east-facing escarpment the length of the San Andres Mountains (Darton, 1928). Beds of Missourian age consist of interbedded shales and argillaceous limestones (Thompson, 1942) that crop out as thin ledges and slopes on top of the west-dipping cuesta cut on Desmoinesian rocks.

Virgilian strata in the San Andres Mountains are lithologically distinct from beds of similar age in the rest of New Mexico. Near Mockingbird Gap they consist of interbedded sandstones and thick limestones, whereas to the south in Ash Canyon they are intercalated dark-gray shales, dark-gray argillaceous limestones, fine-grained calcareous sandstones and gypsum beds (Thompson, 1942). These deposits are typical deltaic to brackish-water clastics and precipitates that outline a narrow, north-south basinal area, extending from about Rhodes Pass south to the Texas-New Mexico line near Newman. Unfortunately, Virgilian beds were almost entirely removed by early Wolfcampian erosion in the Hueco Mountains so that the original extent of the basin to the southeast is not known. Biohermal (Fig. 8) and biostromal reefs (Road log, Figs. 1-4, 1-5) occur within these basinal Virgilian deposits in the northern and central San Andres Mountains (Thompson, 1942; Darton, 1928; Kelley and Silver, 1952) and are similar to those described in the Sacramento Mountains (Pray, 1954) and Hueco Mountains (King, King, and Knight, 1945).



Figure 8. Virgilian bioherms.

Equivalents of the Bursum (?) formation occur in the Rhodes Canyon area (Thompson, 1954), but are apparently absent, due to post-Bursum erosion, at Mockingbird Gap and in Ash Canyon. The Bursum (?) near Rhodes Canyon is about 100 feet thick, and consists of a lower sequence of calcareous sandstones, red shales, and nodular limestones overlain by a massive cliff-forming biostromal limestone. North of Rhodes Spring the Bursum (?) formation is overlain unconformably by a thick lenticular conglomerate, probably equivalent to the basal Powwow conglomerate of the Hueco limestone. At Mockingbird Gap a similar conglomerate, as much as 100 feet thick containing detrital Bursum-type fusulinids, is unconformable on Virgilian strata.

There are several hundred feet of Hueco limestone (Thompson, 1954) at Mockingbird Gap (Hueco?) and in Rhodes Canyon and probably as much as 1,000 feet (Baker, 1920) near San Augustin Pass. The basal Hueco limestone in the southern San Andres Mountains (Thompson, 1954) was referred to by Darton (1928) as the basal massive ledge of his "upper members" which caps the divide ridge from Bear Canyon north to Sulphur Canyon. He noted the alterations of argillaceous limestone and reddish silty shales at the contact of the Hueco with the Abo; also, with Thompson (1942, 1954), the southward intertonguing of the Abo with the Hueco.

The Abo redbeds are about 800 feet thick near Mockingbird Gap and Rhodes Pass (Lee, 1909), but thin to about 300 feet near San Augustin Pass (Darton, 1928). The more resistant calcareous sandy siltstones in the upper parts of the formation form reddish-brown cuestas dipping into the strike valley cut into lower Yeso strata. The Abo and Yeso are gradational so that the contact has been picked at different horizons. Needham and Bates (1943) probably placed the contact just below the lowest limestone in the Yeso, but this would leave in the Abo friable, pinkish and light-gray sands similar to the Meseta Blanca member of the Yeso, which Lee (1909) placed in the Yeso.

The Yeso formation is about 1,260 feet thick in Rhodes Pass (Lee, 1909), about 1,500 feet thick in the southern Oscura Mountains, and thins to about 300 feet near San Augustin Pass (Dunham, 1935). The formation consists of gypsum, light-red, light-gray, and yellowish sandstones and sands, and argillaceous fossiliferous limestones. Lee's (1909) section and fossil collections are from Rhodes Pass, and show the upper fossiliferous limestones of the Yeso which form short cuestas on the west side of the strike valley carved in the basal Yeso beds.

Needham and Bates (1943) located Lee's (1909) type section of the San Andres formation in Rhodes Pass (near STOP NO. 6) where they measured 15 feet of Glorieta sandstone above the Yeso formation and about 595 feet of the San Andres formation beneath the sky. The Glorieta sandstone is atypical at Rhodes Pass, being a friable, yellowish, slope-forming sandstone that grades down into pinkish friable sandstones of the Yeso. The type San Andres limestone is chiefly gray to dark-gray, medium-bedded to massive, fetid, petroliferous limestone containing a considerable cephalopod and brachiopod fauna. Unfortunately, no fusulinids have been found in the type San Andres formation. A thin calcareous sandstone occurs about 100 feet above the base. The formation is probably about 400 feet thick in the southern Oscura Mountains and about 300 feet thick near San Augustin Pass (Dunham, 1935); the total thicknesses do not mean much as the San Andres formation is overlain with great unconformity by Cretaceous beds, or, to the north, by the Triassic Dockum formation.

The large amount of limestone in the upper part of the Yeso at Rhodes Pass suggests that the limestones attributed to the San Andres formation in the southern part of the range may be Yeso limestones. Unfortunately there are only sporadic outcrops of the Yeso and San Andres formations from Andrecito to Ash Canyon; therefore, the beds cannot be walked out along the strike.

The upper contact of the San Andres formation is reported (Darton, 1928) only from the Love Ranch area near the southern end of the San Andres Mountains, where several hundred feet of Cretaceous shale, sandstone, and a thin coal bed crop out; fossils indicate a lower Mancos-Benton age. A few small pedimented outcrops of Cretaceous rocks on the northwest flank of the range, opposite Salinas Peak, are called Dakota(?) sandstone by Darton (1928).

The two Sun Oil Company test wells drilled in the Jornada del Muerto about 20 miles northwest of Rhodes Pass encountered only the basal 200 to 500 (?) feet of Mesaverde sandstones beneath valley fill, a possible 1,100 feet of Mancos shale, 50 to 70 feet of Dakota(?) sandstone, 100 to 170 feet of Triassic Dockum redbeds, and 650 to 700 feet of San Andres limestone.

Consolidated Cenozoic sediments are reported only from the south end of the range near Love Ranch (Darton, 1928; Dunham, 1935), where hundreds of feet of coarse boulder conglomerates and interbedded red siltstones unconformably overlie Mancos strata. The conglomerates are similar to pre-volcanic Tertiary(?) conglomerates in the Organ Mountains and may be a facies of the interbedded red siltstones, gypsum, and local conglomerates in the southern part of the Robledo Mountains. The correlative beds in the Organ and Robledo Mountains, however, rest unconformably on Hueco limestones, not on Cretaceous sandstones and shale.

Several thousand feet of volcanic rocks overlie the Hueco limestone or the pre-volcanic conglomerate in the Organ and Dona Ana Mountains, south and west of San Augustin Pass, but volcanic rocks occur in the San Andres Mountains only on the southwest tip of the range. At that place the Orejon andesite of Dunham (1935) unconformably overlies Hueco limestones.

Intrusive rocks, believed to be of Tertiary age, are, as far as observed, of three types: greenish-gray hornblende andesite sills and dikes intruded chiefly into Lower Pennsylvanian beds; two extensive rhyolite sills, one capping Salinas Peak and adjoining ridges, the other capping Quartzite Ridge south of Love Ranch; monzonite and quartz-monzonite of the Organ Mountains batholith/stock which outcrops just north of San Augustin Pass.

## STRUCTURE

The San Andres Mountains are an elongate tilted fault block, uplifted vertically one to two miles along an east-bounding fault zone with the tilted beds dipping 10 to 20 degrees westward. Relatively minor transverse, oblique, and longitudinal normal faults show displacements ranging from 100 to 700 feet; drag folding of shaly or thin beds along the minor faults occurs at many places. Several small tilted fault blocks occur east of the main east-bounding fault zone. For example, the Henderson Ranch fault block at the mouth of Rhodes Canyon is a miniature San Andres range, a westward tilted fault block with a steep east-bounding fault line scarp; on the west side Virgilian limestones are down-faulted against El Paso dolomites of the main range. At the northern and southern ends of the range some of these smaller eastern frontal blocks are tilted eastward which is the reason for Darton's (1928) statement that the San Andres Mountains are an anticlinal uplift faulted extensively along its east side.

The main east frontal fault zone trends slightly west of north from Ash Canyon to Rhodes Canyon. North of Rhodes Canyon it is offset to the east by oblique faults and trends northeast to Sheep Mountain (northeast of Sly Gap), where the trend is again west of north. The northeastward curve in the range and resulting bulge from Rhodes Pass to Salinas

Peak is due to a series of north-northwest oblique normal faults, and perhaps in part due to the location of the Salinas Peak rhyolite sill/laccolith. The eastward bulge near Bear Canyon in the southern part of the range does resemble parts of a faulted anticline, but may be in part a reflection of the Organ Mountains monzonite stock. The Bliss-Precambrian contact is topographically low near Rhodes Canyon west of the main eastern fault zone and rises both to the northeast and south southeast, indicating a structural sag in the Rhodes Canyon area.

The general north-south trend of the San Andres Mountains continues southward in the Organ and Franklin Mountains although obscured and modified by the Organ Mountains monzonite stock. The range is terminated at Mockingbird Gap by an oblique structural trend which may angle across the northern part of the Tularosa Basin from the northern part of the Sacramento Mountains. At Mockingbird Gap the northern tip of the San Andres Mountains forms the west-dipping limb of a faulted anticline; frontal hills and the Oscura Mountains form the east-dipping limb.

Dunham (1935) reported a high-angle thrust fault near San Augustin Pass with Precambrian granite thrust over lower Pennsylvanian rocks. In places, such as west of Salinas Peak, the oblique normal faults are twisted for short distances, becoming high-angle reverse faults. In the Love Ranch area a sharp north-trending anticline occurs along the west flank of the range in Hueco limestones, and is locally overturned and broken by a high angle reverse fault (Dunham, 1935).

## MINERAL DEPOSITS

The Organ mining district is in the southern San Andres Mountains and northern Organ Mountains. About two million dollars worth of ore has been mined from the district, the principal products being copper, lead, silver, gold, zinc, and fluorite. Small amounts of molybdenum, from molybdenite and wulfenite, were also mined; stannite, not previously known in New Mexico, was recently found in the district by Mr. E. C. Anderson.

Barite-lead-gold prospects occur in the Bear Canyon and San Andres Canyon areas; museum specimens of vanadinite have been collected near Bear Canyon. Small amounts of copper have been shipped from Andrecito and Hembrillo Canyon areas. During the Second World War talc was mined from Precambrian rocks in Hembrillo Canyon. In Grandview Canyon, just north of Hembrillo, crystals of bismuth, bismuthinite, and bismutite have been mined and sold for crystal specimens; copper ores and scheelite were prospected. Small amounts of copper were produced from Sulphur Canyon, Goodfortune Creek (southwest of Salinas Peak), and Mockingbird Gap (Lasky, 1932). Several carloads of ore that contained lead, zinc, and minor silver were shipped from claims at the north end of Mockingbird Gap. Barite-fluorite-galena deposits have been prospected near Mockingbird Gap, Hays Gap, Salinas Peak, Bearden Canyon, and Sulphur Canyon. Oolitic hematite in beds totaling 2 to 3 feet thick occurs (Lasky, 1932; Kelley, 1951) in the basal Bliss sandstone along the eastern scarp area from about Sulphur Canyon to Salinas Peak.

Mineral production has not been significant except from the Organ mining district. Small bodies of minable barite-galena-fluorite, similar to those of the Hansonburg district in the Oscura Mountains (Kottlowski, 1952), might be present, but would be in rugged terrain, far from usable roads, and would probably lack a sufficient supply of water. Large accessible amounts of industrial sedimentary rocks, such as gypsum, limestone, shale, occur but as in most of New Mexico are too far from markets. All mining and prospecting is, of course, banned as long as the San Andres Mountains are part of White Sands Proving Ground.

The sedimentary rocks in the San Andres are not broken by many faults, and except in local areas, have not been shattered and altered like the strata in the Organ and Cuchillo Mountains, the Black Range near Kingston, and the Silver City area. The adjoining basins, therefore, probably contain relatively simple structures that could have trapped oil and gas--structures that have not been too badly broken by faulting and sharp folding so that petroleum accumulation could escape. In the San Andres Mountains, springs, in many places, occur along faults, but only where tributary canyons that contain thick alluvium enter the major east-west canyons. Spring flow seems to be proportional to rainfall; springs along a fault are not at the topographically lowest exposure of the fault. This is evidence that large amounts of groundwater do not seep downward along faults to where it could enter permeable west-dipping horizons and by gravity flow under the Jornada del Muerto. This is also evidence that most of the faults are tight and that oil and gas probably did not escape along the fault zones. The Paleozoic and Mesozoic beds include petroliferous source rocks, reservoir horizons, impermeable beds, and biohermal and biostromal reefs. Lower Paleozoic rocks pinch out northward providing opportunities for stratigraphic as well as fold or fault traps. Neither the Jornada del Muerto nor the Tularosa Basin has been adequately tested for petroleum accumulations.

REFERENCES


Baker, C. L. (1920) Contributions to the stratigraphy of eastern New Mexico: Am. Jour. Sci., 4th ser., v. 49, p. 99-126.

Darton, N. H. (1928)) "Red beds" and associated formations in New Mexico: U. S. Geol. Survey Bull. 794.

Dunham, K. C. (1935) The geology of the Organ Mountains: New Mexico Bur. Mines and Mineral Res. Bull. 11.

Entwistle, L. P. (1944) Manganiferous iron ore deposits near Silver City, New Mexico: New Mexico Bur. Mines and Mineral Res. Bull. 19.

Flower, R. H. (1953) Paleozoic sedimentary rocks of southwestern New Mexico: N. M. Geol. Soc., Fourth Field Conference, p. 106-112.

Kelley, V. C. (1951) Oolitic iron deposits of New Mexico: Am. Assoc. Petrol. Geol. Bull., v. 35, p. 2199-2228.

....., and Silver, Caswell (1952) Geology of the Caballo Mountains: Univ. New Mexico Pub. in Geol., No. 4.

King, P. B., King, R. E., and Knight, J. B. (1945) Geology of Hueco Mountains, El Paso and Hudspeth Counties, Texas: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 36.

Kottlowski, F. E. (1952) Geology and ore deposits of a part of the Hansonburg mining district, Socorro County, New Mexico: New Mexico Bur. Mines and Mineral Res. Cir. 23.

Lasky, S. G. (1932) The ore deposits of Socorro County, New Mexico: New Mexico Bur. Mines and Mineral Res. Bull. 8.

Laudon, L. R., and Bowsher, A. L. (1949) Mississippian formations of southwestern New Mexico: Geol. Soc. America Bull., v. 60, p. 1-88.

Lee, W. T., and Girty, G. H. (1909) The Manzano group of the Rio Grande Valley, New Mexico: U. S. Geol. Survey Bull. 389.

McKee, E. D. (1951) Sedimentary basins of Arizona and adjoining areas: Geol. Soc. America Bull., v. 62, p. 481-506.

Needham, C. E., and Bates, R. L. (1943) Permian type sections in central New Mexico: Geol. Soc. America Bull., v. 54 p. 1653-1667.

Pray, L. C. (1953) Upper Ordovician and Silurian stratigraphy of Sacramento Mountains, Otero County, New Mexico: Am. Assoc. Petrol. Geol. Bull., v. 37, p. 1894-1918.

..... (1954) Outline of the stratigraphy and structure of the Sacramento Mountains escarpment: N. M. Geol. Soc., Fifth Field Conference, p. 92-107.

....., and Bowsher, A. L. (1952) Fusselman limestone of the Sacramento Mountains, New Mexico: Geol. Soc. America Bull., v. 63, P. 1342 (abst.).

Richardson, G. B. (1909) Description of the El Paso District: U. S. Geol. Survey Geol. Atlas, El Paso Folio, No. 166.

Stevenson, F. V. (1945) Devonian of New Mexico: Jour. Geol., v. 53, p. 217-245.

Thompson, M. L. (1942) Pennsylvanian system in New Mexico: New Mexico Bur. Mines and Mineral Res. Bull. 17.

..... (1948) Studies of American fusulinids: Univ. Kan., Paleont. Contrib. No.4, Protozoa, Art. 1.

..... (1954) American Wolfcampian fusulinids: Univ. Kan., Paleont. Contrib. No. 14, Protozoa, Art. 5.