# Geology of the Bear Peak Area Dona Ana County New Mexico

GEOLOGICAL SURVEY BULLETIN 1271-C

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*By* GEORGE O. BACHMAN *and* DONALD A. MYERS

CONTRIBUTIONS TO GENERAL GEOLOGY

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*A study of the southern part of the San Andres Mountains, with emphasis on Paleozoic stratigraphy*

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# GEOLOGY OF THE BEAR PEAK AREA, DONA ANA COUNTY NEW MEXICO

By George O. Bachman and Donald A. Myers

**ABSTRACT**

The Bear Peak area, in south-central New Mexico at the south end of the San Andres Mountains, includes structural elements of both the westward-dipping San Andres Mountains and the Organ Mountain igneous mass.

Rocks exposed in the area range in age from Precambrian to Recent. The Precambrian rocks include schist, quartzite, granite, and associated rocks. Paleozoic rocks, which make up much of the mountain mass, include the Bliss Sandstone of Late Cambrian and Early Ordovician age, the El Paso Formation of Early Ordovician age, the Montoya Dolomite of Middle and Late Ordovician age, the Fusselman Dolomite of Middle Silurian age, and undivided Devonian and Mississippian rocks. The Pennsylvanian System is represented by the Lead Camp Limestone (a new name) and the Panther Seep Formation. The Lower Permian (Wolfcamp) Abo and Hueco Formations interfinger within the area, and the Lower Permian (Leonard) Yeso Formation is present in outliers. Undivided rocks of Cretaceous age are present in a few exposures.

Rocks of Tertiary age are the Love Ranch Formation, which is chiefly conglomerate derived from local sources, and igneous sills and dikes. The sills and dikes are genetically related to the Organ Mountain igneous mass to the south. Alluvium and dune sand of Quaternary age are present along the edge of the mountain uplift.

Normal faults are the most conspicuous structural features in the area, but a major system of reverse faults is present in the southern part of the San Andres Mountains. Movement along this fault system was toward the north, and the reverse faults mark the structural boundary between the San Andres Mountains and the Organ Mountains.

## INTRODUCTION

*Location.*—The area described in this report comprises about 120 square miles in the southern part of the San Andres Mountains, eastern Dona Ana County, N. Mex. (fig. 1). It is the east half of the Bear Peak 15-minute quadrangle and is bounded by the parallels 32°30′ N.

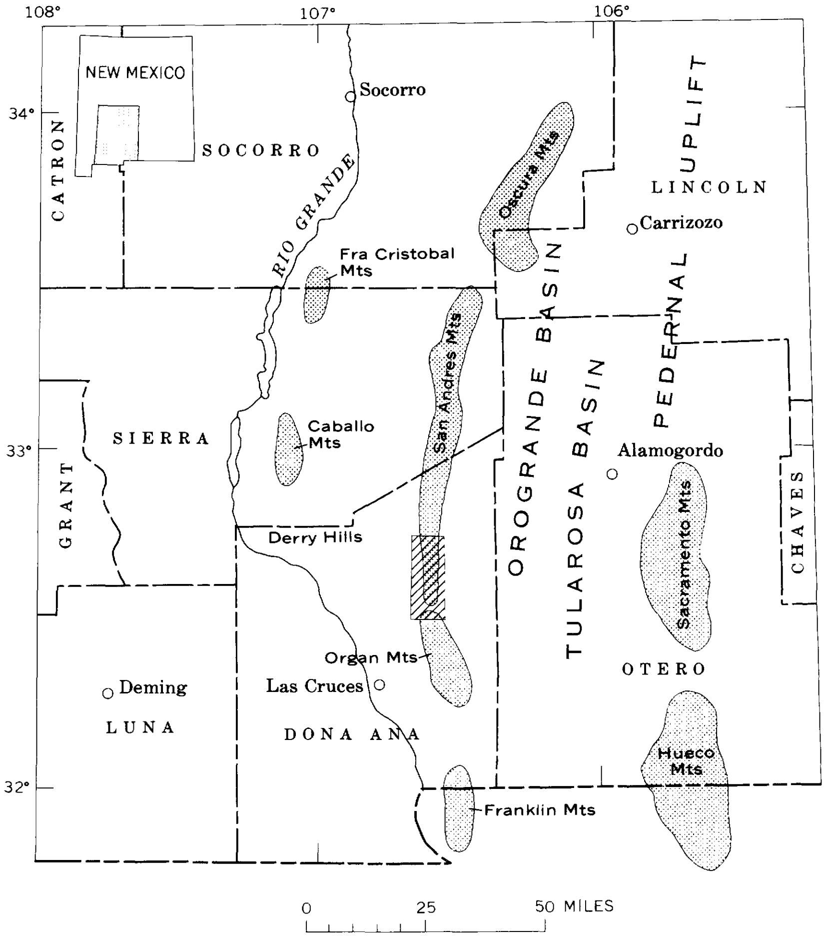



FIGURE 1.—Location of Bear Peak area (crosshatched) and principal geographic and geologic features. Mountain areas are stippled.

and 32°45′ N. and the meridians 106°30′ W. and 106°37′30″ W. (pl. 1). The southwest corner of the area is about 15 miles northeast of the town of Las Cruces.

The area is uninhabited, and almost all of it is within the White Sands Missile Range. Also included within the area are parts of the Jornada Experimental Range of the U.S. Department of Agriculture and the San Andres National Wildlife Refuge of the U.S. Department of the Interior. Access to the area is prohibited to the general public.

Relief in the area is about 3,500 feet. The southwestern part is about 4,700 feet above sea level, and San Andres Peak, in the northeastern part, rises to an altitude of 8,239 feet. The San Andres Mountains tilt

generally toward the west with an average slope of about 15° but they have a steep, and locally precipitous, east front.

*Fieldwork.*—The senior writer first worked in this area in the summer of 1955 while engaged in reconnaissance mapping for a geologic map of New Mexico (Dane and Bachman, 1965). Fieldwork was later undertaken in the area by Bachman and Myers in the spring of 1961 and again by the senior author in the fall of the same year and in 1962.

The geologic map was made in the field on Army Map Service base maps, at a scale of 1:25,000, by triangulation and resection methods. These maps were reduced to 1:62,500 for the present report. Stratigraphic sections were measured by using an Abney level, Jacob's staff, and steel tape. Fusulinids were identified in the laboratory by D. A. Myers.

*Acknowledgments.*—Access to the area was made possible through the cooperative efforts of many people. The writers acknowledge particularly the Commanding General, White Sands Missile Range, and his staff, who coordinated the fieldwork with uses of the range. Mr. Cecil A. Kennedy and Mr. L. Johnson, of the U.S. Fish and Wildlife Service, and Mr. Fred N. Ares, of the Jornada Experimental Range, were helpful in providing information on local geography and facilities.

*Rock formations.*—Rocks in the southern San Andres Mountains range in age from Precambrian to Recent. The main mass of the mountain range is made up of rocks of Paleozoic age, and a composite stratigraphic section of these strata was measured in the vicinity of San Andres Canyon (Bachman and Myers, 1963). The Paleozoic rocks are particularly well exposed in Little San Nicholas Canyon (fig. 2).

## PRECAMBRIAN ROCKS

Metamorphic and igneous rocks assumed to be of Precambrian age are exposed along the eastern front of the San Andres Mountains and south of Bear Canyon as far west as Bear Peak (pl. 1). These rocks consist of schist, gneiss, and granite with minor amounts of other rock types.

Very dark gray amphibolite and hornblende-biotite schist are exposed in the northeastern part of the area. Associated with these are a few layers, as much as 20 feet thick, of quartzite that has retained its original medium- to coarse-grained clastic texture. Discontinuous pods of dark-red gneissic granite are scattered through the hornblende schist; they cannot be traced for more than a few hundred feet. One such pod, in the NE¼ sec. 20, T. 18 S., R. 4 E., is estimated to be 50 feet thick and 300 feet long.

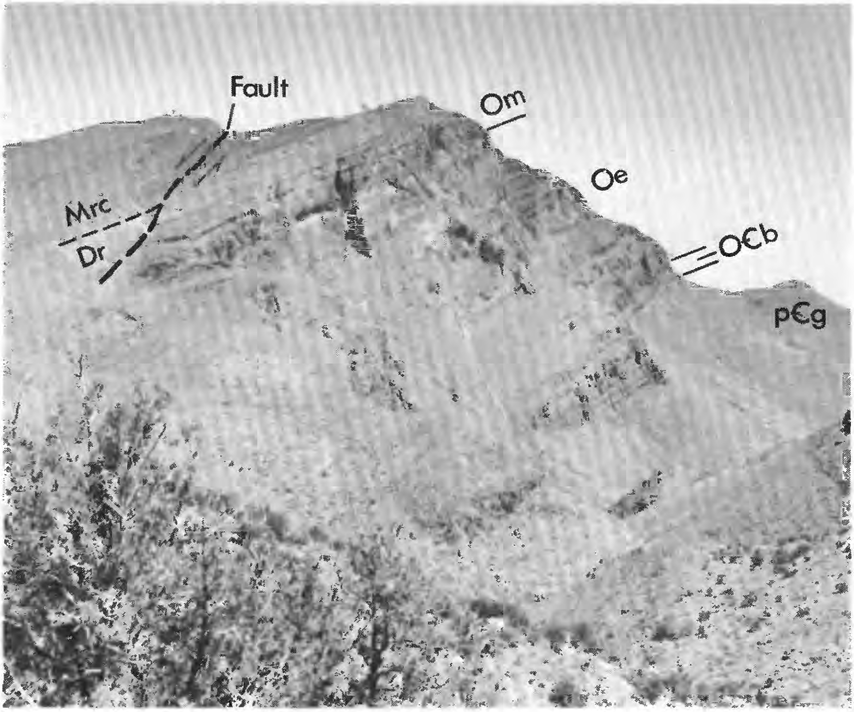



FIGURE 2.—Paleozoic rocks in Little San Nicholas Canyon. View from the south. p€g, Precambrian granite; O€b, Bliss Sandstone; Oe, El Paso Formation; Om, Montoya Dolomite; Dr, Devonian rocks; Mrc, Mississippian rocks.

Granite younger than the metamorphic rocks makes up the larger portion of the Precambrian rocks in the report area. The granite is coarsely crystalline and contains gray and pink feldspar. On the north side of Ash Canyon near its junction with Salt Canyon, the granite is gneissic, and in Little San Nicholas Canyon contains scattered xenoliths of hornblende schist 1–2 feet across. Pods of light-gray pegmatite occur locally in the granite. Some of the larger pods are shown on the geologic map. Locally, bodies of dark-greenish-gray diorite are present among the other Precambrian rocks. The diorite is deeply weathered, and contacts with adjacent rocks can not be observed.

Before deposition of Paleozoic rocks, an extensive erosion surface developed on the Precambrian. This surface must have been remarkably even, for, where observed, it does not have local relief of more than 5 feet.

## PALEOZOIC ROCKS

### CAMBRIAN AND ORDOVICIAN SYSTEMS—BLISS SANDSTONE

The Bliss Sandstone was named by Richardson (1904, p. 27) for exposures in the Franklin Mountains, Tex., about 45 miles south of

the present report area. Darton (1917, p. 33) extended the usage of the term Bliss into the San Andres Mountains.

In the northern part of the Bear Peak area the Bliss consists of two parts. The lower part is light-yellowish-gray quartzite that forms a prominent rounded ledge and weathers reddish brown. The quartzite is fine grained and fairly well sorted, and is apparently cemented by silica. It is well exposed in San Andres Canyon, where it is about 40 feet thick, but is absent in Little San Nicholas Canyon. The lower part is not recognized in all parts of the San Andres Mountains but may be as much as 6 feet thick in the northern part of the range and in the southern part of the Oscura Mountains.

The upper part of the Bliss Sandstone in San Andres Canyon is composed of about 50 feet of interbedded sandstone, quartzite, and shaly sandstone. Individual beds range from about 3 inches to about 18 inches in thickness. The quartz sand grains are fine to medium and subangular to subrounded. The basal 5 feet of this part of the Bliss contains small amounts of quartz-granule conglomerate. The shaly sandstone is dark greenish gray and is glauconitic in places. The Bliss is composed chiefly of quartz grains but also contains scattered grains of microperthite, orthoclase, chlorite, and glauconite.

The Bliss Sandstone thins northward in the San Andres Mountains. It is 115 feet thick in Little San Nicholas Canyon and 90 feet thick in San Andres Canyon. It is 21 feet thick at its northern exposures in the San Andres Mountains and wedges out northward in the Oscura Mountains about 65 miles north of the report area (Bachman, 1961). Northward thinning of the Bliss is mostly a depositional effect and related to northward transgression of the sea across a beveled Precambrian surface.

The upper contact of the Bliss with the overlying El Paso Formation is arbitrary; during the present work it was placed at the top of strata that are composed dominantly of sand. Thus, the Bliss includes some shale and brown-weathering dolomite, but the dolomite in particular is subordinate to other lithologies. From a distance the Bliss appears dark brown to almost black, whereas the El Paso is yellowish brown. The basal beds of the El Paso are thinly laminated sandy dolomite and contrast with the thin beds of sandstone and sandy shale in the upper part of the Bliss.

The age of the Bliss Sandstone has been discussed by Flower (1953) and by Kottlowski, Flower, Thompson, and Foster (1956, p. 16). The fossils collected from the San Andres Mountains by Kottlowski and his associates were from the upper beds of the Bliss and are Early Ordovician in age; however, the lower part of the Bliss Sandstone as exposed in San Andres Canyon may be equivalent to that part of the

Bliss assigned to the Late Cambrian (Franconia) by Flower (1953) elsewhere in New Mexico. The present work did not provide additional evidence for the age of the Bliss in the San Andres Mountains, and the Bliss in that area is assigned to the Cambrian and Ordovician.

## ORDOVICIAN SYSTEM

In the southern San Andres Mountains two formations of Ordovician age are present. In ascending order they are the El Paso Formation and the Montoya Dolomite. Although the two formations are separated by a hiatus, they represent most of Ordovician time.

### EL PASO FORMATION

The El Paso Formation was named by Richardson (1904, p. 2) for exposures in the Franklin Mountains near El Paso, Tex. A stratigraphic section was studied in the Franklin Mountains just outside the corporate limits of El Paso by Cloud and Barnes (1946, p. 72–75, 361–369), and they suggested that this place "would make a good type locality for the El Paso formation." This locality is about 45 miles south of the Bear Peak area. Darton (1917, p. 36) extended use of the name El Paso into the San Andres Mountains and other parts of southern New Mexico.

Kelley and Silver (1952, p. 40–42) proposed that the El Paso in the Caballo Mountains be raised to group status, and they divided the group into the Sierrite Limestone at the base and the Bat Cave Formation at the top. Kottlowski, Flower, Thompson, and Foster (1956, p. 16–22) accepted the group status of the El Paso in the San Andres Mountains but did not recognize the Sierrite and Bat Cave Formations of Kelley and Silver. Instead, they suggested (Kottlowski and others, 1956, p. 16–17) that the El Paso could be divided into "three lithic units of probable formational rank."

During fieldwork in the Bear Peak quadrangle, the present writers mapped the El Paso as a single formation. A yellowish-brown sandy interval at the base may correspond in part to the Sierrite Formation of Kelley and Silver in the Caballo Mountains, but the contact between this interval and the overlying gray carbonate beds is not clearly defined and may be at different horizons in the stratigraphic sequence as the units are traced laterally. The lithic and faunal units described by Kottlowski, Flower, Thompson, and Foster (1956) are not distinctive enough to permit mapping. Therefore, for cartographic reasons, the El Paso is here treated as a single formation.

In the Bear Peak quadrangle the El Paso Formation consists of dolomite, calcitic dolomite, and dolomitic limestone. Gray is the dominant color on fresh surfaces, and crystallization is fine to medium.

Some beds, especially those within 50–100 feet above the base of the formation, are sandy; sand grains, chiefly quartz, are scattered throughout the formation. In some beds minor amounts of chert stand out on weathered surfaces in irregular lacy patterns. The basal 150–170 feet of the El Paso Formation weathers yellowish brown; from a distance it contrasts with the dark brown of the underlying Bliss Sandstone and the medium gray of the upper part of the El Paso. Near at hand, however, where attempts were made to define the interval of color change, it was found that the yellowish hues are gradational with the overlying gray, and that the color change is more subtle than it appears from a distance.

Beds in the basal 50 feet of the El Paso range from 1 to 6 inches in thickness, and some individual beds are very thinly laminated. In the upper part of the formation some beds are as much as 6 feet thick and locally contain stromatolites.

Dolomite is irregularly distributed. Sixteen samples of the El Paso were analyzed for calcium-magnesium molal ratio by J. A. Thomas of the U.S. Geological Survey. Eleven of these were determined to be dolomite, three were calcitic dolomite, and two were dolomitic limestone. Kottlowski, Flower, Thompson, and Foster (1956, p. 19) stated that "in most New Mexico sections dolomitization is local and erratic, but where dolomitization is advanced, the whole of the section is generally affected, and the dolomite beds are not reliable horizon markers."

Insoluble constituents of samples from the El Paso vary in percentage. Insoluble residues consist mostly of fine sand and range from about 60 percent to less than 2 percent of the samples studied. Most of the insoluble constituents are concentrated within the basal 50 feet of the formation, but insolubles compose as much as 30 percent of the sample collected about 170 feet above the base of the formation in Little San Nicholas Canyon. A systematic study of insoluble residues from the entire formation was not undertaken during the present work.

Dolomitization and recrystallization have altered much of the original texture of the El Paso. Pelletal structures are common and are conspicuous on weathered surfaces. In thin sections, however, these structures appear only as a finely crystalline dolomite mosaic surrounded by more coarsely crystalline dolomite. Assumedly, the finely crystalline mosaic with the pelletal structures is the result of dolomitization of an original drusy calcite mosaic. During diagenesis, many of the enclosed sand grains were etched and partially replaced by carbonate minerals.

The El Paso is 760 feet thick in Little San Nicholas Canyon and in Ash Canyon. It thins northward to 670 feet in San Andres Canyon;

and 70 miles farther north, in the Oscura Mountains, it wedges out (Bachman, 1961). Kottlowski, Flower, Thompson, and Foster (1956, p. 21) and the present writers believe that northward thinning is the result of regional erosion of the top of the El Paso before deposition of the overlying Montoya Dolomite, but individual beds at the top of the El Paso are not sufficiently exposed to permit tracing of the bed and substantiation of this premise.

The age of the El Paso has been discussed by Cloud and Barnes (1946, p. 72–75) and by Kottlowski, Flower, Thompson, and Foster (1956, p. 18–22). Fossils were collected from the El Paso during the present work, but they contribute no additional information in regard to the age of the El Paso in the southern San Andres Mountains. These collections were studied by R. J. Ross, Jr., of the U.S. Geological Survey (written commun., 1961), and by Rousseau H. Flower, of the New Mexico Bureau of Mines and Mineral Resources (written commun. to R. J. Ross, Jr., 1961). As discussed by Kottlowski, Flower, Thompson, and Foster (1956, p. 18–22), the El Paso Formation in the southern San Andres Mountains is equivalent to much of the Early Ordovician of Missouri.

During the study of the El Paso fauna, R. J. Ross, Jr., recovered numerous conodonts. These were studied by John W. Huddle, of the U.S. Geological Survey, and the following forms were identified (written commun., 1964):

Colln. D 857 CO, D 863 CO, D 870 CO, D 871 CO. All from horizon 10 feet above the base of the El Paso Formation. North side San Andres Canyon, sec. 17, 18, T. 18 S., R. 4 E.

*Scolopodus gracilis* Ethington and Clark
*S. rex* Lindström
*S. quadraplicatus* Branson and Mehl
*Paltodus spurius* Ethington and Clark
*P.* sp.
*Acontiodus* sp. A
*Drepanodus subarcuatus* Furnish
*D. concavus* Branson and Mehl
*D.* cf. *sculponea* Lindström
*D. homocurvatus* Lindström
*D. lineatus* Furnish
*D. subarcuatus* Furnish
*D.* sp.
*Oneotodus* cf. *variabilis* Lindström
*Oistodus lanceolatus?* Pander
*Scandodus furnishi* Lindström
*S.* sp.
*Acodus* sp.
*Cordylodus* sp.
*Ulrichodina?* sp.

D 858 CO. Horizon 20 feet above the base of the El Paso.
*Acanthodus uncinatus* Furnish
*Acodus* sp.
*Acontiodus* sp.
*Drepanodus lineatus* Furnish
*D. parallelus* Branson and Mehl
*Oneotodus* cf. *variabilis* Lindström
*Paltodus* n. sp. A
*Scandodus* sp.

D 859 CO. Locality at 39 feet above the base of the El Paso.
*Acanthodus uncinatus* Furnish
*Acontiodus* n. sp.
*A.* n. sp. A
*Drepanodus concavus* Branson and Mehl
*D. lineatus* Furnish
*D. subarcuatus* Furnish
*D. subrectus*? (Branson and Mehl)
*D.* sp.
*Oistodus lanceolatus*? Pander
*Oneotodus* cf. *simplex* (Furnish)
*O.* cf. *variabilis* Lindström
*Paltodus* n. sp.
*Scolopodus quadraplicatus*? Branson and Mehl

D 860 CO. Horizon 71 feet above the base of the El Paso.
*Acanthodus uncinatus* Furnish
*Acodus oneotensis*? Furnish
*Acontiodus* sp. A
*A.* sp.
*A.* sp.
*Distacodus* sp.
*Drepanodus concavus* Branson and Mehl
*D.* cf. *deltifer* Lindström
*D. homocurvatus* Lindström
*D. lineatus* Furnish
*D. pandus* Branson and Mehl
*Paltodus* n. sp. A.
*P.* cf. *comptus* Branson and Mehl
*P.* ? sp.
*Oistodus lanceolatus* Pander

D 861 CO. Horizon 115 feet above the base of the El Paso.
*Acontiodus* sp.
*Drepanodus* cf. *deltifer* Lindström
*D. homocurvatus* Lindström
*D. proetus*? Lindström
*D.* sp.
*Drepanodus*?
*Distacodus* sp.
*Oistodus contractus* Lindström
*O. inaequalis* Pander
*Oneotodus variabilis*? Lindström
*Paltodus variabilis* Furnish

*Scolopodus quadraplicatus* Branson and Mehl
*S. rex* Lindström

D865 CO. Horizon 221 feet above the base of the El Paso.
*Acodus* sp.
*Acontiodus staufferi* Furnish
*Drepanodus cyranoicus* Lindström
*D. homocurvatus* Lindström
*D.* aff. *proetus* Lindström
*Oistodus contractus*? Lindström
*Paltodus jeffersonensis* Branson and Mehl
*P. Paltodus* sp.
*Scolopodus pseudoquadratus* Branson and Mehl
*S. rex* Lindström

D872 CO. Locality at 508 feet above the base of the El Paso.
*Acontiodus* sp.
*Drepanodus* sp.
*Scolopodus rex* Lindström
*S. robustus*? Ethington and Clark

D873 CO. Locality at 669 feet above the base of the El Paso.
*Drepanodus concavus*? Branson and Mehl
*D. pandus* Branson and Mehl
*Drepanodus*? sp.
*Oistodus inaequalis* Pander
*O. lanceolatus* Pander
*Oneotodus*? sp.
*Scolopodus filosus* Ethington and Clark
*S.* sp.

### MONTOYA DOLOMITE

The "Montoya limestone" was named by Richardson (1909, p. 4) for "about 250 feet of limestone lying between the El Paso and Fusselman limestones" in the Franklin Mountains about 45 miles south of the report area. Darton (1917, p. 39) extended the usage of the name Montoya into the San Andres Mountains. Kelley and Silver (1952, p. 57) proposed raising the Montoya to group status in the Caballo Mountains and named four formations to be included in the proposed group. These formations are recognizable as lithologic units in the southern San Andres Mountains but are treated here as members of the Montoya, as they are not mappable at scales used during the present work. In ascending order, the members of the Montoya are the Cable Canyon Sandstone, Upham Dolomite, Aleman, and Cutter Members.

In the southern San Andres Mountains the Montoya Dolomite is a distinctive sequence of rocks and is easily separated from adjacent formations. From a distance the Cable Canyon Member appears as a yellowish-gray band at the base of the Montoya. The overlying Upham Member weathers light gray and forms a massive cliff. The Aleman

Member is medium dark gray, and its basal contact with the Upham Member is marked by a distinct color change. In places, particularly along joints, the Aleman is subject to deep-pitted weathering that characteristically forms miniature caverns in cliffs. The Cutter Member is light gray and relatively thin bedded, and it forms slopes or steplike ledges below the overlying massive Fusselman Dolomite.

The Cable Canyon Sandstone Member, at the base of the Montoya Dolomite, is medium gray and weathers brown. It consists chiefly of medium to coarse, subangular to subrounded quartz grains, some of which are pale blue. Cement composition is variable and includes silica as well as carbonate minerals. The thickness of the member is also variable and is without apparent geographic pattern within the report area. The member is 10 feet thick in Little San Nicholas Canyon, 14 feet thick on the divide between Salt and Ash Canyons, and 11 feet thick in Ash and San Andres Canyons. It grades upward into the Upham Member. At many exposures the Cable Canyon forms a topographic notch.

The Upham Dolomite Member is the most persistent member of the Montoya in the San Andres Mountains. It forms a distinctive series of medium-dark-gray ledges or a cliff. Beds average about 4–5 feet thick, and the weathered surfaces are deeply pitted. The member consists chiefly of medium- to fine-crystalline dolomite in a mosaic of subhedral to anhedral grains. The basal 2 or 3 feet may be very sandy. Quartz grains, which show minor etching by dolomite, are sparsely distributed and range from about 0.10 to 1.0 mm in diameter. Fossils are common at some localities. Regionally, the Upham is relatively pure dolomite with small amounts of insoluble matter (Kottlowski, 1957, p. 12–13). The Upham Dolomite is about 90 feet thick in the southern San Andres Mountains. It is also present to the north in the Oscura Mountains, where it wedges out 60–65 miles north of the Bear Peak area.

The Aleman Cherty Member of the Montoya consists of interbedded dolomite and chert. The dolomite is medium dark gray and forms a very fine crystalline mosaic. Crystal grains range from 0.06 to 0.1 mm in diameter and are subhedral to anhedral. There is some clayey cement. Beds average 1–6 inches thick. Interbedded chert is medium gray, and beds average about 1–2 inches thick. Chert content of the Aleman is variable, and numerous visual estimates of relative chert content were made in the field. The lower 50-foot interval of the member was estimated to contain from 30 to 50 percent bedded chert within the quadrangle. The chert content decreases upward in the member, and the upper 75-foot interval contains less than 15 percent chert. At

one place chert in the upper part of the member is concentrated in the upper 30 feet of the member. The Aleman is about 180 feet thick in the southern part of the San Andres Mountains. It wedges out to the north and is absent north of Sheep Mountain, about 35 miles north of the report area.

Contacts are placed on the basis of the presence of bedded chert. The basal contact of the Aleman is placed at the base of the lowermost bedded chert in the member. The upper contact is more arbitrary, as scattered chert nodules are present in the overlying Cutter Member. Where marly beds are present in the overlying Cutter, the top of the Aleman is placed at the base of the marly beds.

The Cutter Dolomite Member occurs along the eastern front of the San Andres Mountains. It ranges in thickness from 180 feet on the divide between Salt and Ash Canyons to 147 feet in San Andres Canyon. The contact with the overlying Fusselman Dolomite is sharp and irregular and has at least 2 feet of relief. The light-gray thin-bedded Cutter and the darker gray massive Fusselman contrast strongly.

The Cutter Member, as used in this report, was included as a lower member of the Fusselman Dolomite of Silurian age by Darton (1928, p. 186) and other earlier workers. Darton (1928, p. 320), however, questioned the assignment of his lower member to the Fusselman. Kelley and Silver (1952, p. 62–64) collected Ordovician fossils from the base of this member and named it the "Cutter Formation" of the Montoya Group in the Caballo Mountains.

The Cutter consists of a marly interval at the base and thin-bedded dolomite in the upper part. The member weathers light gray to white and forms a slope between the Aleman Member of the Montoya and the overlying dark ledge-forming Fusselman Dolomite. The marl at the base of the member is rarely exposed. The dolomite occurs in even beds that range from about 6 to 18 inches in thickness. It is a sparry mosaic of subhedral to anhedral dolomite crystals that average 0.02–0.04 mm in diameter. Chert is not common. Fossils are common at a few places in the marly part of the member, but none were observed in the bedded dolomite.

Fossils were collected by R. J. Ross, Jr., of the U.S. Geological Survey, and the writers in San Andres Canyon in the marly interval near an abandoned mine adit. As identified by R. J. Ross, Jr. (written commun., 1964), these fossils included (USGS colln. D886 CO):

Kelplike forms of algae (?)
*Hebertella* sp.
*Strophomena* sp.

The following pelecypods from the same collection were identified by John Pojeta, Jr., of the U.S. Geological Survey (written commun. to R. J. Ross, Jr., 1964):

*Ambonychia* sp.
*Deceptrix* sp.
*Modiolopsis* sp.
Cyrtodontids

*Age and correlation.*—Kottlowski, Flower, Thompson, and Foster (1956, p. 24) considered the Cable Canyon and Upham Members to be in the same depositional unit and of Middle Ordovician age; they assigned (1956, p. 26) the Aleman and Cutter Members a Late Ordovician age.

## SILURIAN SYSTEM—FUSSELMAN DOLOMITE

The Fusselman "limestone" was named by Richardson (1909, p. 4) for exposures in the Franklin Mountains, Tex., about 55 miles south of the Bear Peak area. Darton (1917, p. 42; 1928, p. 185–186) used the name Fusselman in the San Andres Mountains. Kelley and Silver (1952, p. 62) and Pray (1953) recognized that the lower part of the Fusselman (as used by Darton) was Ordovician in age, and they removed that part from the Fusselman. Kelley and Silver named it Cutter Formation in the Caballo Mountains; Pray named the correlative unit Valmont Formation in the Sacramento Mountains. The name Cutter has priority on the basis of publication date. The Fusselman is therefore now restricted to the dolomite of Silurian age.

The Fusselman Dolomite forms a prominent ledge in the southern San Andres Mountains. It is medium dark gray, thick to massive bedded, and very cherty. The basal 5- to 10-foot interval is slightly sandy, especially in Bear Canyon. The chert ranges from light gray to medium dark gray. The dolomite that forms most of the formation is a finely crystalline mosaic of anhedral to subhedral grains and weathers olive gray.

The Fusselman is well exposed in the Sacramento Mountains, about 35–40 miles east of the San Andres Mountains. Pray (1961, p. 46–48) described the Fusselman Dolomite in the Sacramento Mountains in detail. There, the writers noted at least two distinctive lithologies—a relatively noncherty medium-gray dolomite at the base and an overlying medium-dark-gray cherty dolomite. In Alamo and Dog Canyons in the Sacramento Mountains this break in lithology is irregular and is not on a bedding plane. At some places in the Sacramento Mountains only the basal medium-gray dolomite is present. In the southern San Andres Mountains, though, lithologies occur that are similar to the upper medium-dark-gray very cherty dolomite of the

Sacramento Mountains, but the basal, medium-gray noncherty dolomite is not commonly present.

The Fusselman is present throughout the southern San Andres Mountains. Owing to disconformities both at the base and at the top of the formation, its thickness varies within short distances. In Bear Canyon it is about 75 feet thick. In Little San Nicholas Canyon it is 105 feet thick, and in San Andres Canyon it ranges from 65 to 80 feet in thickness within a lateral distance of 300 yards. The Fusselman Dolomite thins northward in the San Andres Mountains and pinches out about 30 miles north of San Andres Canyon (Kottlowski and others, 1956, p. 27).

Fossils were not collected from the Fusselman during the present field study, but the formation has generally been regarded as Middle Silurian (Niagara) by other workers (Richardson, 1908, p. 480; Darton, 1928, p. 186; Swartz and others, 1942). Pray (1953, p. 1913) suggested an Early Silurian (Alexandrian Series, Illinois) age for the Fusselman (?) Formation in the Sacramento Mountains, to the east.

## DEVONIAN SYSTEM

The name Percha Shale as used by many workers is synonymous with rocks of Late Devonian age in south-central New Mexico. Stevenson (1941, 1945) divided the rocks of Middle and Late Devonian age in southern New Mexico into four formations: in ascending order, the Onate, Sly Gap, Contadero, and Percha Formations. However, assigning formational rank to such units as Onate and Sly Gap is impractical, as they are not usually mappable at standard map scales. During the present work no attempt was made to divide the Devonia in the southern San Andres Mountains, although an effort was mad to recognize the stratigraphic units discussed by Stevenson (1945).

Rocks of Devonian age are present throughout most of the San Andres Mountains, but exposures are generally poor, as the shale that composes much of the interval weathers to form a rubble-covered slope. This slope is a distinctive feature of the Devonian in the mapped area.

The best exposures of Devonian rocks in the mapped area are in San Andres Canyon. Stevenson (1945, p. 222) gave the name Onate Formation to rocks exposed on the north side of the canyon and wrote that

> The Onate formation consists of a variable and intergradational series of shale, siltstone, fine sandstone, and limestone. Identification of these sediments for correlation purposes is complicated by lateral transitional changes, such as gradations from a shale to a siltstone to an arenaceous limestone in a distance of a few hundred feet. Additional difficulties arise from the lack of sufficient index fossils, and the absence of strong color contrasts between the beds.

During the present fieldwork the type section of the Onate Formation was studied, and fossils were collected from it. The Onate Formation was interpreted by the writers to be that interval of Devonian strata between the Fusselman Dolomite and a prominent ledge of gray fine-grained sandstone and siltstone that weathers bright yellow to orange. This bright-colored ledge is believed to be the basal bed of the Sly Gap Formation of Stevenson. Although strata adjacent to this bed are not distinctive, this bed is prominent in many exposures of the Devonian in the southern part of the San Andres Mountains and is the only bed exposed in some areas where the rest of the Devonian interval is covered.

The Onate Formation was measured by the writers in San Andres Canyon, where it consists of 67 feet of dark-gray shale and olive to yellow shale and some interbeds of limestone and fine-grained sandstone.

The Sly Gap Formation of Stevenson (1941) consists of interbedded shale, siltstone, and sandstone and minor thin layers of limestone. The dominant color is gray, and, except for the basal orange-weathering unit, the beds are not lithologically distinct from the underlying Onate Formation. In the southern San Andres Mountains, fossils are sparse, and none were collected.

Stevenson (1945, p. 226, fig. 6) indicated that the Onate, Sly Gap, and Percha (Ready Pay Member) are present in San Andres Canyon. Laudon and Bowsher (1949, p. 46, fig. 20) indicated that rocks of Mississippian age rest on the Sly Gap Formation; they showed only the Onate and Sly Gap—the Percha is presumably absent. This interpretation is similar to that of Kottlowski, Flower, Thompson, and Foster (1956, p. 31) for exposures in Ash Canyon, although they suggested that the Percha might be represented there. Because these Devonian strata are difficult to distinguish by means of their lithologic characteristics, the present writers do not advocate their use as formational units.

On the north side of San Andres Canyon, rocks of Devonian age are about 160 feet thick; on the south side of the canyon they are about 120 feet thick. On the west-facing spur between Salt and Ash Canyons the Devonian is no more than 70 feet thick. In Little San Nicholas Canyon, where the entire interval is covered, the Devonian is about 165 feet thick.

During the present investigation fossils were collected systematically only at exposures on the north side of San Andres Canyon. There, fossils are most abundant in the lower strata exposed (the Onate

Formation). They include the following forms that were identified by J. T. Dutro, Jr., of the U.S. Geological Survey:

| | *Field Locality* | | | |
|---|---|---|---|---|
| | *6126* | *6127* | *6128* | *6129* |
| Echinoderm debris | | | | × |
| *Sulcaretopora* sp | | | × | × |
| *Leptrostrophia* sp | | | × | -------- |
| *Chonetes* cf. *C. aurora* (Hall) | × | × | × | -------- |
| *Leiorhynchus* sp | | × | × | -------- |
| *Atrypa* sp | | | × | × |
| *Crurithyris* sp | × | ---------- | × | -------- |
| *Warrenella* ? sp | | | | × |

Dutro commented (written commun., 1961) that

these * * * collections from the Onate reflect the distinctive faunal assemblages found in this unit in the San Andres and Sacramento Mountains. *Chonetes aurora* (Hall) is a common form in the Tully Formation of New York, and the other species from the lower three collections also resemble Tully forms. The large *Atrypa* and large spiriferoid *Warrenella* may represent earliest Late Devonian faunas. The age of the Onate is, then, either latest Middle Devonian or earliest Late Devonian. Quite possibly the formation straddles the series boundary. This fossil assemblage is quite different from that of the overlying Sly Gap, which has a definite early Late Devonian affinity.

## MISSISSIPPIAN SYSTEM

Rocks of Mississippian age in southern New Mexico have been studied by Laudon and Bowsher (1941, 1949), who divided them into six formations. One of these formations, the Lake Valley, was subdivided into six members. The nomenclature proposed by Laudon and Bowsher is based on distinctive lithologic characteristics that are generally recognizable in the field. However, these formations are too thin to be shown separately on the geologic map (pl. 1). Three formations, as defined by Laudon and Bowsher (1949) in the San Andres Mountains, are present in the Bear Peak area. In ascending order, these are the Caballero, Lake Valley, and Rancheria Formations. Lithologic units present in the quadrangle are shown in table 1, and their stratigraphic relationships are shown in figure 3.

### CABALLERO FORMATION OF LAUDON AND BOWSHER (1941)

The Caballero Formation was named by Laudon and Bowsher (1941, p. 2114) for Caballero Canyon in the Sacramento Mountains about 30 miles northeast of the Bear Peak area. There it "consists of soft, gray, silty limestone beds that weather to rounded, nodular, rubbly chunks on fresh exposures" (Laudon and Bowsher, 1941, p. 2114).

TABLE 1.—*Classification of Mississippian rocks in the Bear Peak area*

[Modified from composite lithologic section of Laudon and Bowsher (1949, p. 11). Members of Lake Valley were newly named in Laudon and Bowsher report]

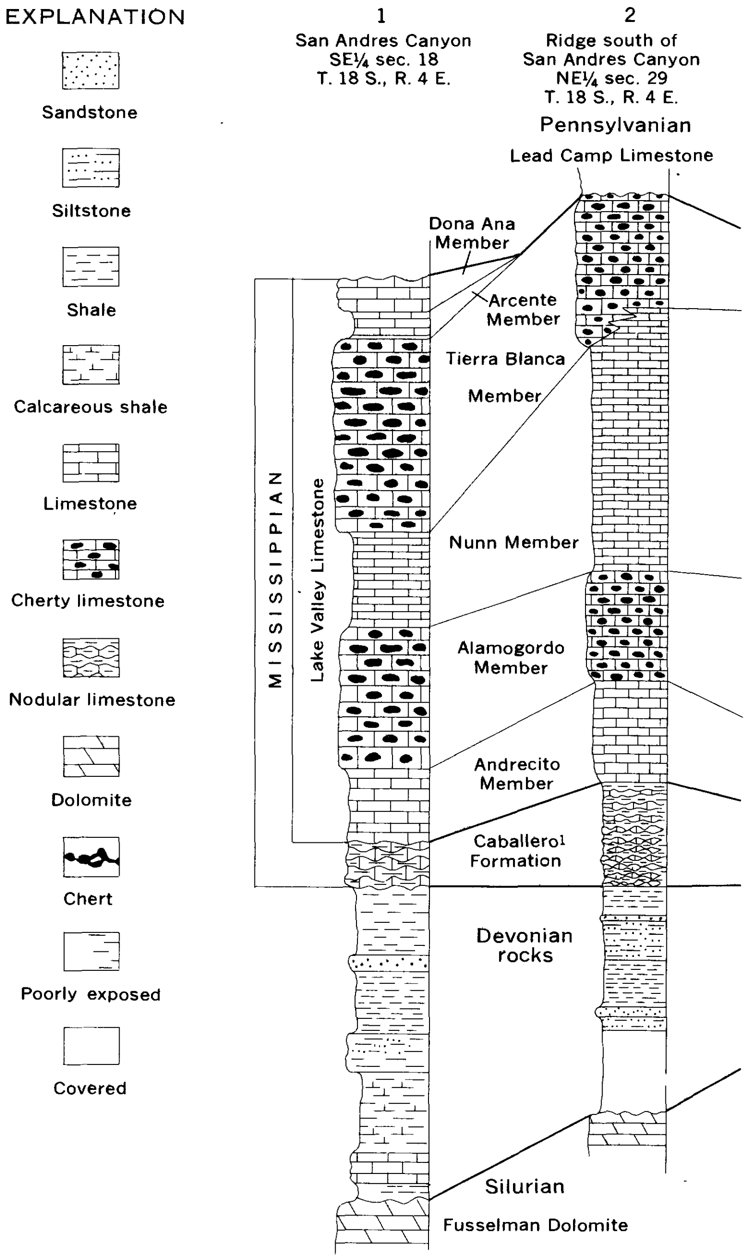
| System | Mississippi Valley Series | Formation | Member | Thickness (ft) | Distinctive characteristics |
|---|---|---|---|---|---|
| Mississippian | Meramec | Rancheria | | 0–185 | Thin-bedded black silty limestone. Cherty. One bed of black chert about 5 ft thick within 5 ft of base. |
| | Osage | Lake Valley | Dona Ana | 0–5 | Gray cherty limestone. Forms ledge. |
| | | | Arcente | 0–55 | Dark-gray calcareous siltstone and limestone; thin bedded. Forms slope. |
| | | | Tierra Blanca | 0–200 | Gray limestone; very cherty. Chert white to light gray. Forms cliff or ledge. |
| | | | Nunn | 0–50 | Medium-gray limestone; marly; very crinoidal. Weathers to slope or notch. |
| | | | Alamogordo | 0–75 | Even-bedded black silty limestone; very cherty with black concentrically banded chert nodules. Forms prominent ledge. |
| | | | Andrecito | 0–25 | Even-bedded black limestone. Beds about 1 ft thick (avg). Noncherty. Some shale partings. *Taonurus* sp. common on some bedding planes. |
| | Kinderhook | Caballero | | 15–65 | Interbedded nodular limestone and gray shale. |

In the southern San Andres Mountains the Caballero Formation is lithologically similar to the formation at its type locality. It consists of interbedded medium-gray shale and nodular limestone. The nodules, some of which contain crinoid fragments, weather yellowish gray to light medium gray, are from 3 to 6 inches long, and average 2 inches thick. In the Bear Peak quadrangle the formation ranges from 33 to 55 feet in thickness and thins northward.

A sample of crinoidal limestone nodule collected about 25 feet above the base of the formation contained 8.8 percent insoluble residues. The calcium-magnesium molal ratio was 23.46, which indicates that the sample was dolomitic limestone.

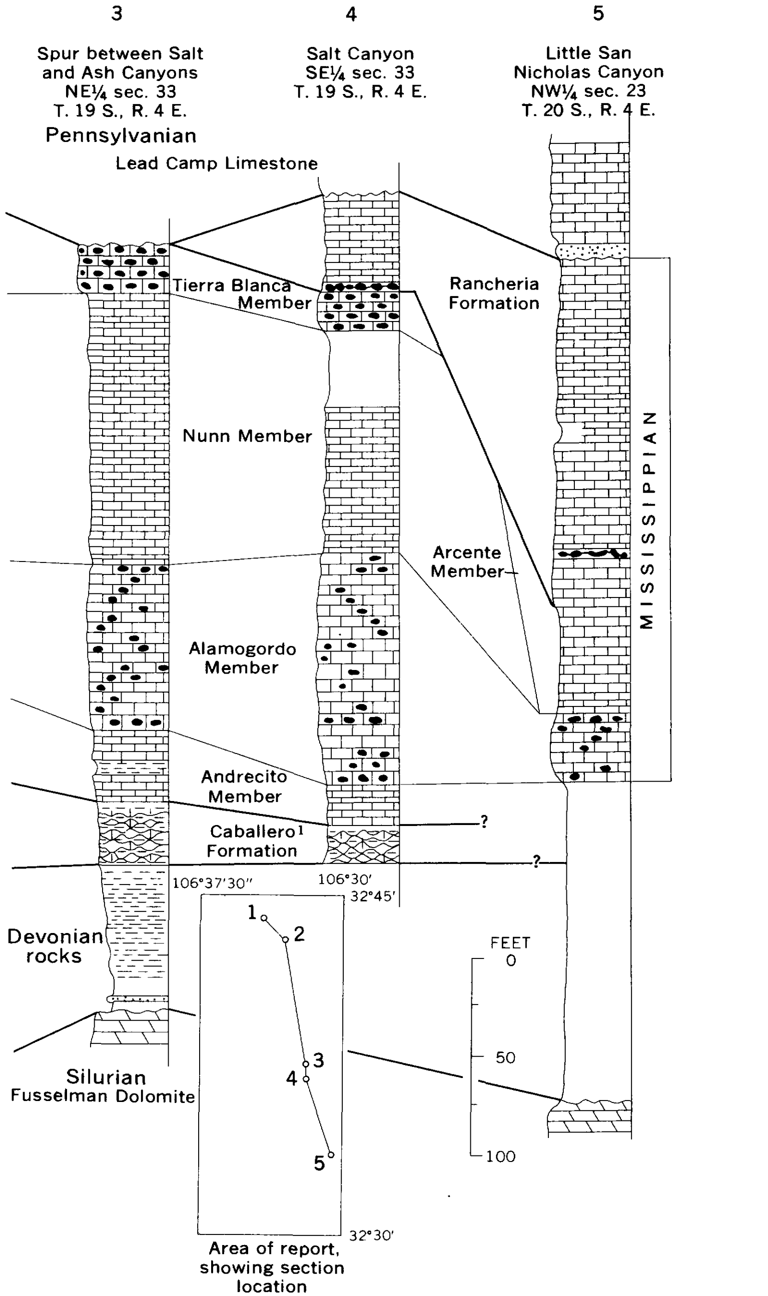
### LAKE VALLEY LIMESTONE

The name Lake Valley Limestone was first applied to rocks of Mississippian age in the Lake Valley mining district, Sierra County, N. Mex., about 50 miles west of the southern San Andres Mountains (Cope, 1882, p. 214). Darton (1917) used the name in the San Andres Mountains. Laudon and Bowsher (1949) divided the Lake Valley Formation in the southern San Andres Mountains into six lithologic-




[1]Of Laudon and Bowsher (1941).

FIGURE 3.—Columnar sections of Devonian and




Mississippian rocks in the Bear Peak area.

ally distinct members: in ascending order, the Andrecito, Alamogordo, Nunn, Tierra Blanca, Arcente, and Dona Ana Members. The Tierra Blanca Member wedges out toward the south in the mapped area and overlies the Arcente Member. The Nunn Member is absent from the southern part of the mountain range.

Rocks of Mississippian age in San Andres Canyon are divided as indicated by Laudon and Bowsher (1949, p. 45–47). Southward from San Andres Canyon, near Ash and Salt Canyons, however, facies changes make subdivision of the Lake Valley Limestone difficult. In San Andres Canyon the Tierra Blanca Member is a very prominent cliff-forming limestone about 100 feet thick. On the high ridge south of San Andres Canyon (secs. 28, 29, and 33, T. 18 S., R. 4 E.), the Tierra Blanca Member thins to about 50 feet and apparently grades into thin-bedded limestone of the Nunn Member.

In Ash and Salt Canyons the Andrecito, Alamogordo, and Nunn Members are not easily distinguished from one another. In Salt Canyon a limestone sequence about 200 feet thick may contain equivalents of all three members (fig. 3). Laudon and Bowsher (1949, p. 43) indicated that they too had difficulty drawing contacts in Ash Canyon. The contacts used during the present work are based on the tracing of members between Ash and Salt Canyons, but locally the nomenclature of these rock units is conjectual. Farther to the south, in Little San Nicholas and Bear Canyons, formations and members as described by Laudon and Bowsher (1949) are easily distinguished.

The Andrecito Member consists of about 50 feet of medium-gray limestone beds that range from about 1 to 2 feet in thickness. The limestone is finely crystalline and has markings of *Taonurus* sp. on some bedding planes. At some exposures, especially in the vicinity of Salt Canyon, it is lithologically similar to the overlying Alamogordo but does not contain chert nodules.

The Alamogordo Member consists of medium-dark-gray ledge-forming limestone that weathers medium olive gray. It is cryptocrystalline and contains dark-gray to black concentrically banded chert lenses and nodules that range from about 3 inches to slightly more than 1 foot in thickness. The basal contact of the Alamogordo with the underlying Andrecito Member is gradational and is placed at the lowest occurrence of dark-gray chert. The Alamogordo Member ranges from about 35 to about 120 feet in thickness in the area.

The Nunn Member, which overlies the Alamogordo Member, is a poorly exposed slope-forming unit that ranges in thickness from a feather edge at the south to about 135 feet in Salt Canyon. It consists of poorly consolidated crinoidal debris with interbeds of marl. The

contact with the overlying Tierra Blanca Member is gradational, and the two members interfinger between Ash and San Andres Canyons. The Nunn is poorly consolidated and has sparse chert, compared with the overlying Tierra Blanca Member.

The Tierra Blanca Member, which overlies the Nunn in the northern part of the quadrangle, is composed chiefly of limestone and forms prominent ledges or cliffs. Individual beds range from 10 to 15 feet in thickness. It is medium gray and in places contains large crinoid columnals. A distinctive feature is the presence of very light gray to white chert nodules. The member is about 100 feet thick in San Andres Canyon and thins toward the south; it is absent south of Salt Canyon.

In San Andres Canyon, at the north end of the mapped area, the Arcente Member rests on the Tierra Blanca. This member was named originally by Laudon and Bowsher (1941, p. 2116) for exposures in Arcente Canyon (sec. 3, T. 17 S., R. 10 E.) in the Sacramento Mountains about 40 miles east of the Bear Peak area. The Arcente is present to the south in Little San Nicholas Canyon but is absent in the central part of the mapped area. In the vicinity of Salt and Ash Canyons the relation of the Arcente to other members of the Lake Valley is not clear. The Arcente consists of dark-gray very finely crystalline silty limestone. It is thinly and irregularly bedded in plates that average about one-half inch thick. It weathers to a slope and is poorly exposed at many places. The Arcente is about 15 feet thick in San Andres Canyon and 55 feet thick in Little San Nicholas Canyon.

The Dona Ana Member of the Lake Valley also is exposed in San Andres Canyon. It was named originally by Laudon and Bowsher (1941, p. 2116) for Dona Ana County. Its type locality, however, was designated in Deadman Canyon, sec. 3, T. 17 S., R. 10 E., in the Sacramento Mountains about 40 miles east of the Bear Peak area. In San Andres Canyon the Dona Ana is represented by a thin remnant of medium-gray crinoidal cherty limestone. Chert nodules are elongate and average about 2 or 3 inches thick and range from 6 inches to 1 foot in length. The member weathers to a ledge.

#### RANCHERIA FORMATION OF LAUDON AND BOWSHER (1941)

In the southern part of the area the Rancheria Formation forms the top of the Mississippian sequence. The Rancheria is thin-bedded dark-gray cherty limestone. The beds average about 1 foot in thickness and are evenly bedded at most places. However, at one locality (N½ sec. 26, T. 20 S., R. 4 E., pl. 1) foreset bedding was observed. The chert in the formation is dark gray, but that in the upper part weathers light brown. The Rancheria is about 180 feet thick in Little San Nicholas

330-225 O—69——4

Canyon but is only 50 feet thick in Salt Canyon and is absent northward from Salt Canyon.

*Age and correlation.*—New evidence concerning the age and correlation of Mississippian formations in the San Andres Mountains was not found during the present work. Loudon and Bowsher (1949) indicated that the Caballero Formation is of Kinderhook age, the Lake Valley is of Osage age, and the Rancheria is of Meramec age. Rocks of Chester age are believed to be absent in the San Andres Mountains.

## PENNSYLVANIAN SYSTEM

Rocks assigned to the Pennsylvanian crop out in a north-trending band 1–2¼ miles wide that extends westward from the crest of the San Andres Mountains. The more resistant beds in the lower part of the Pennsylvanian interval cap the crest of the range and form a westerly dip slope. The lower beds, the Lead Camp Limestone, consist of massive cliff-forming cherty limestone. The upper beds, the Panther Seep Formation, consist of dark-colored shale containing thin beds of limestone and sandstone. The total thickness of the Pennsylvanian ranges from about 2,785 feet at Ash Canyon (Kottlowski and others, 1956, p. 7) to about 3,200 feet at the north end of Lead Camp Canyon.

### LEAD CAMP LIMESTONE

The massive cliff-forming cherty limestone beds that unconformably overlie the Mississippian and underlie the rocks of the Panther Seep Formation are here named the Lead Camp Limestone. The name is taken from Lead Camp Canyon in the northern part of the Bear Peak area. The type section is designated as those exposures near the junction of Lead Camp and San Andres Canyons on the north side of San Andres Canyon (NW¼ sec. 19, T. 18 S., R. 4 E.). The following section was measured at this locality:

| | Thickness (feet) |
|---|---|
| Pennsylvanian System: | |
| Panther Seep Formation (part): | |
| 64. Limestone, medium-gray; weathers medium gray to olive gray; calcarenite; beds 3–6 in. thick | 4 |
| 63. Covered | 7 |
| 62. Limestone, medium-gray; weathers olive gray; calcarenite; bedding laminated; beds about 1/4 in. thick; poorly exposed | 3 |
| 61. Covered | 5 |
| 60. Limestone, medium-gray; weathers light yellowish gray to olive gray; calcarenite | 2 |
| 59. Covered | 5 |
| 58. Limestone, medium-gray; weathers olive gray; fine calcarenite; beds about 1 in. thick; forms weak ledge; contains elliptical bodies that may be altered fusulinids | 7 |

| | Thickness (*feet*) |
|---|---|
| Pennsylvanian System—Continued | |
| Panther Seep Formation (part)—Continued | |
| 57. Limestone, medium-gray; weathers light brownish gray; calcarenite; beds about 1 ft thick; forms weak ledge | 3 |
| 56. Covered | 5 |
| Total Panther Seep Formation | 41 |
| Lead Camp Limestone: | |
| 55. Limestone, medium-gray; weathers olive gray; calcarenite; some beds crinoidal; chert nodules in upper 10–15 ft; beds from 2 to 5 ft thick; forms massive ledges; contains *Triticites* cf. *T. nebraskensis* Thompson 18 ft below top | 68 |
| 54. Limestone, medium-gray; weathers yellowish brown; calcarenite; shaly partings; beds 3 in.–1 ft thick; forms slope; poorly exposed; contains *Marginifera* sp.; some beds crinoidal | 12 |
| 53. Limestone, medium-gray; weathers olive gray; calcarenite; beds 2–5 ft thick; contains light-gray nodules chert as much as 1 ft in diameter; forms ledge | 10 |
| 52. Limestone, medium-dark-gray to medium-gray; weathers olive gray; calcarenite; beds 4–6 in. thick in basal 10 ft, 1–2 ft thick in upper 9 ft; upper 9 ft forms ledges; contains a few brachiopods | 19 |
| 51. Covered. Forms slope. Probably thin-bedded limestone | 10 |
| 50. Limestone, medium-gray; calcarenite; very cherty; chert in irregular light-brown-weathering masses | 4 |
| 49. Conglomerate, limestone-pebble; pebbles ½–1 in. in diameter at base, 2–3 in. in diameter in upper 1 ft; forms ledge | 2 |
| 48. Limestone, medium-gray; weathers light gray; fine to medium calcarenite; beds 2 in.–1 ft thick; wavy bedded and locally nodular; forms poorly developed ledges; contains highly fluted *Fusulina* sp. 3 ft below top | 15 |
| 47. Limestone, medium-gray; weathers light gray to light dusky yellow: fine to medium calcarenite; scattered medium to very light gray chert nodules and stringers that weather light gray to light dusky yellow; beds 1–6 ft thick; petroliferous odor on freshly broken surfaces; forms strong ledge | 67 |
| 46. Limestone, medium-gray; weathers olive gray to dusky yellow; fine to medium calcarenite; very cherty, medium-gray nodules and stringers weather dusky yellow; contains highly fluted *Fusulina* sp. Line of section moved. Traced bed south to base of bed 47 in bottom of arroyo. Crossed two small faults of less than 5 ft displacement | 3 |
| 45. Limestone, medium-gray; weathers light gray; fine to coarse calcarenite; contains nodules of medium-gray chert 6 in.–1 ft in diameter; forms massive ledge | 37 |
| 44. Limestone, medium-gray; weathers medium gray to olive gray; fine calcarenite; nodular limestone partings; beds 6 in.–1 ft thick; chert nodules 2–3 in. in diameter; forms weak ledges | 30 |

| | Thickness (feet) |
|---|---|
| Pennsylvanian System—Continued | |
| Lead Camp Limestone—Continued | |
| 43. Limestone, medium-gray; weathers medium to olive gray; fine to medium calcarenite; nodular limestone partings; beds 6 in.–2 ft thick; sparse chert nodules 2–3 in. in diameter forms weak ledges; contains *Fusulina* sp., *Wedekindellina* sp. | 10 |
| 42. Covered | 5 |
| 41. Limestone, medium-gray; as in bed 43 | 11 |
| 40. Limestone, medium-gray; weathers light gray; calcarenite; beds 3–6 ft thick; contains zones of nodular and lenticular chert; forms massive ledges and cliffs; scattered horn corals between 60 and 65 ft above base | 105 |
| 38, 39. Limestone, medium-gray; weathers light to olive gray; calcarenite; chert nodules and lenses weather dark brown; forms ledge | 27 |
| 37. Limestone, medium-gray; weathers medium gray to dusky yellow; calcarenite; chert beds about 1 ft thick; contains *Fusulina* sp., *Wedekindellina* sp | 16 |
| 36. Covered | 5 |
| 35. Limestone, medium-gray; weathers light gray; medium calcarenite; porous, upper 1/3 mottled; much nodular chert; beds 6–10 ft thick; forms strong rounded ledge. Walked top of bed WSW to get around fault | 25 |
| 34. Limestone, medium-gray; calcarenite; chert nodules; poorly exposed | 25 |
| 33. Limestone, medium-gray; calcarenite; abundant chert nodules and stringers parallel to bedding; forms ledge | 10 |
| 32. Covered; forms slope; may be thin-bedded limestone | 10 |
| 31. Limestone, medium-gray; weathers medium light gray; argillaceous calcarenite; scattered nodules and stringers of medium-gray chert that weathers dark gray to black; beds 2–3 ft thick; forms weak ragged ledges and slopes | 32 |
| 30. Limestone, medium-gray; weathers olive gray; calcarenite; abundant chert beds and nodules; forms ledge; lenticular, wedges out north and south within 300 ft; contains *Fusulinella* sp. at top of bed | 18 |
| 29. Limestone, medium-gray; weathers light to olive gray; calcarenite; medium- to dark-gray chert nodules and stringers; forms ledge; contains crinoid debris, spiriferoid brachiopods, *Prismopora* sp., *Fusulinella* aff. *F. devexa* Thompson near top of bed | 13 |
| 28. Covered, forms slope | 13 |
| 27. Limestone, medium-gray; weathers light gray; fine to medium calcarenite; freshly broken surfaces have petroliferous odor; thin shale interbeds; chert nodules; basal bed 3 ft thick, upper beds 6 in.–1 ft thick; forms ragged ledge; crinoid debris | 9 |
| 26. Limestone and shale, interbedded, medium-gray; medium to coarse calcarenite; beds 2–4 in. thick; poorly exposed; forms slope; crinoid debris | 5 |
| 25. Covered | 35 |

| Pennsylvanian System—Continued<br>Lead Camp Limestone—Continued | Thickness (*feet*) |
| --- | --- |
| 24. Limestone, medium-gray; calcarenite; lenticular, wedges out 300 ft north | 12 |
| 23. Covered | 13 |
| 22. Limestone, medium-gray; calcarenite; iron stained; contains crinoid debris | 3 |
| 21. Covered | 7 |
| 20. Limestone, medium-gray; weathers light to olive gray; calcarenite; forms ledge; very crinoidal | 6 |
| 19. Covered; forms slope; may include gray shale and nodular limestone | 10 |
| 18. Limestone, medium-gray; weathers reddish to yellowish brown; calcarenite; wavy bedded; beds 3 in.–1 ft thick; gray shale partings; forms weak ledges; contains abundant shell fragments, productid brachiopods, corals, echinoid spines, abundant crinoid stem fragments | 8 |
| 17. Limestone, medium-gray; calcarenite; locally completely replaced by rusty-brown chert; forms blocky ledge | 11 |
| 16. Covered, forms slope | 20 |
| 15. Sandstone, light- to medium-gray; weathers light brown; coarse subangular quartz grains; locally granule-to-pebble conglomerate; forms rounded ledge | 6 |
| 14. Covered | 32 |
| 13. Limestone, medium-gray; weathers light gray; calcarenite; sparse chert nodules; forms ledge; contains *Millerella* cf. *M. marblensis* Thompson | 13 |
| 12. Covered, forms slope | 8 |
| 11. Limestone, medium-gray; calcarenite; mostly replaced by chert | 2 |
| 10. Covered, forms slope | 8 |
| 9. Limestone, medium-gray; weathers light gray; calcarenite; abundant medium-gray chert; weathers rusty; crinoidal | 4 |
| 8. Covered, forms slope | 6 |
| 7. Limestone, medium-gray; weathers light to yellowish gray; coarse calcarenite; rusty-weathering stringers of medium-gray chert common; small-scale crossbedding; forms ledge; contains crinoid debris and other unidentifiable fossil debris | 4 |
| 6. Covered | 7 |
| 5. Sandstone, medium-brownish-gray; locally quartz-granule conglomerate; crossbedded; apparently not continuous along strike more than 300–400 yd; forms ledge | 12 |
| 4. Covered, forms slope | 13 |
| 3. Conglomerate; dark- to reddish-gray chert cobbles as large as 6 in. thick and 1 ft across in a matrix of coarse to granule angular quartz grains; forms weak ledge; not persistent | 3 |
| 2. Covered | 2 |
| Total Lead Camp Limestone | 861 |

| | Thickness (feet) |
|---|---|
| Mississippian System: | |
| Lake Valley Formation: | |
| Dona Ana Member: | |
| 1. Limestone, medium-gray; medium calcarenite; contains nodules 6 in.–1 ft long and 2–3 in. thick of light-gray chert; crinoidal | 15± |

The Lead Camp Limestone, mostly massive cliff-forming limestone, caps the southern San Andres Mountains and forms a dip slope from the crest of the range westward. It contains about 75 percent limestone, of which more than half is cherty; about 21–24 percent shale; and minor amounts of sandstone and conglomerate. The width of its outcrop ranges from about 1,000 feet to about 1¼ miles.

The limestone is medium to dark gray and weathers medium gray to brown. It is clastic and ranges from fine grained to limestone-pebble conglomerate. Many of the beds are thick to massive, and some form cliffs as much as 100 feet high. Chert is common as nodules and lenses and replaces some intervals of limestone 4–5 feet thick.

The shale mostly underlies soil-covered slopes on the lower part of the formation. It occurs in beds as much as 35 feet thick and as partings of gray shale in the thick-bedded limestone. Most of the shale is calcareous, and some beds contain marine fossils.

The sandstone and conglomerate are in the lower part of the formation. At many places the basal bed of the formation is composed of 3–10 feet of rounded to angular cobbles of light-gray chert in a coarse sand matrix. The sandstone consists of reddish- to brownish-gray medium to coarse quartz sand and is found as discontinuous beds near the base of the formation.

The Lead Camp Limestone is 861 feet thick at the type section near the north end of the mapped area. It thins southward and is 432 feet thick in Salt Canyon and about 320 feet thick in Little San Nicholas Canyon (SE¼ sec. 15, T. 20 S., R. 4 E.). This thinning may be a local characteristic, because about 50 miles to the south, in the Franklin Mountains rocks considered by the writers to be of equivalent age are about 1,600 feet thick (Nelson, 1940).

*Age and correlation.*—The limestone beds in the lower 85 feet of the type section contain the fusulinid *Millerella* cf. *M. marblensis* Thompson. This fusulinid, although not diagnostic, suggests a possible Morrow age for the lower part of the formation.

The overlying 188 feet of rocks, mostly limestone with minor amounts of shale, contains the fusulinids *Fusulinella* aff. *F. devexa* Thompson and *Fusulinella* spp. These fusulinids indicate deposition during Atoka time. In Little San Nicholas Canyon, where the Lead Camp Limestone is about 320 feet thick, fusulinids transitional between *Fusulinella* and *Fusulina* are present 228 feet above the base of

the formation. These specimens are poorly preserved and have not been studied thoroughly, but they indicate that the boundary between the Atoka and Des Moines faunas in Little San Nicholas Canyon may be stratigraphically near this horizon.

These rocks are overlain by about 100 feet of non-fusulinid-bearing limestone and shale interbeds, which in turn are overlain by about 50 feet of limestone containing an assemblage of the fusulinid genera *Fusulina* and *Wedekindellina*. These fusulinids resemble those found in the lower part of the Des Moines. From the rocks containing the *Fusulina-Wedekindellina* assemblage to about 125 feet below the top of the formation, the limestone beds contain strongly fluted specimens of the genus *Fusulina*. The stratigraphically highest forms of *Fusulina* from the type section of the Lead Camp are as advanced as those found in the Capps Limestone Member of the Mineral Wells Formation of the Strawn Group in north-central Texas.

The presence of fusulinids that resemble *Triticites nebraskensis* Thompson near the top of the uppermost limestone bed indicates final deposition of the Lead Camp Limestone during early Missouri time.

In summary, the Lead Camp Limestone includes rocks that were deposited during Morrow(?), Atoka, Des Moines, and early Missouri time. This formation is in part the stratigraphic equivalent of the Sandia Formation and the lower gray limestone member of the Madera Formation in central New Mexico (Read and others, 1944) and of the La Tuna, Berino, and Bishops Cap Members of the Magdalena Formation of Nelson (1940) in the Franklin Mountains to the south. It may include rocks equivalent in part to both the Red House and Nakaye Formations of Kelley and Silver (1952) in the Caballo Mountains and the Gobbler and Beeman Formation of Pray (1961) in the Sacramento Mountains.

Thompson (1942, p. 26–30) named strata of Pennsylvanian age in the Derry Hills, about 8 miles south of the Caballo Mountains, the "Derry Series." At the type locality the Derry is mainly limestone and is approximately equivalent to the Red House Formation in the Caballo Mountains. Kelley and Silver (1952, p. 96) observed that "the Red House formation may thin to the south and southeast of the Caballo Mountains by downward intertonguing of the massive limestone units of the Nakaye formation." The senior writer has observed interfingering of the Nakaye downward into the Red House along the western scarp of the Caballo Mountains.

It is here suggested that the type section of the "Derry series" is a calcareous facies of the Red House Formation. The downward intertonguing of limestone into the clastic facies toward the south in both the Caballo Mountains and the San Andres Mountains indicates that

limy seas encroached on the area from the south. These seas, during their earliest encroachment, may have been largely confined to the region that developed into the Orogrande basin during Late Pennsylvanian time. The "Derry series" in other parts of New Mexico is of varied lithology, and Thompson (1942, p. 28) observed that "it is composed largely of marine limestones, shales, conglomerates, and coarse sandstones."

### PANTHER SEEP FORMATION

Rocks that overlie the Lead Camp Limestone were named the Panther Seep Formation by Kottlowski, Flower, Thompson, and Foster (1956, p. 42) for exposures in the vicinity of Panther Seep and were designated a type section in Rhodes Canyon (sec. 14, T. 13 S., R. 3 E., and sec. 12, T. 13 S., R. 2 E.), about 35 miles north of the Bear Peak area. In the Bear Peak area, the base of the Panther Seep Formation is at the top of the massive cliff-forming cherty limestone that forms the upper part of the Lead Camp Limestone. The Panther Seep lies conformably upon the Lead Camp, and the two formations may interfinger locally.

The Panther Seep Formation is mostly a slope- and valley-forming unit containing a few ledge-forming beds of limestone and sandstone. Its outcrop pattern ranges in width from about three-fourths mile to about 1½ miles. Its thickness ranges from about 2,370 feet at Lead Camp Canyon to about 2,640 feet at Salt Canyon. It is 2,390 feet thick at Ash Canyon (Kottlowski and others, 1956, p. 7). The formation is 15–22 percent sandstone and siltstone with minor amounts of conglomerate; 59–63 percent shale; 17–21 percent limestone; and 1–2 percent gypsum.

The sandstone and siltstone beds are brown to yellowish brown; many are cross-laminated and have ripple marks. Much of the sandstone is coarse-grained to pebbly or conglomeratic and lenticular and appears to represent channel-fill deposits. Some of the sandstone contains fragments of fossil plants. These clastic beds are most common in three zones in the formation. The lowermost zone includes beds that lie between 600 and 1,200 feet above the base of the formation. The beds consist of thick- to thin-bedded crossbedded olive-gray calcareous quartz sandstone as much as 33 feet thick. The second zone includes strata that lie between 280 and 480 feet below the top of the formation. This zone consists of thick- to thin-bedded feldspathic brown to reddish-brown crossbedded sandstone and, locally, conglomerate in beds as much as 70 feet thick, but mostly 3–5 feet thick. The third zone is between the top and 160 feet below the top of the formation. Rocks in this zone consist of more thinly bedded calcareous gray quartz sandstone and minor amounts of conglomerate.

The shale in the Panther Seep, including concealed beds that may contain siltstone and shaly limestone, comprises the bulk of the formation. The exposed rocks are mostly medium- to dark-gray sparsely fossiliferous to nonfossiliferous shale. Locally, brachiopods and other marine megafossils were noted.

The limestone, which includes some calcitic dolomite in the upper part of the formation, is all clastic, and some beds are cross-laminated. Most of the limestone is olive to dark gray and weathers yellowish brown to yellowish orange. Beds are as much as 35 feet thick, although most of the beds are less than 5 feet thick.

The upper part of the Panther Seep Formation contains some thinly and unevenly bedded siliceous limestone beds (fig. 4) that contain algal mounds 3 to 4 inches high. Many of these mounds are contorted between bedding planes and form minute overturned and recumbent folds. Associated fragmentation of algal material suggests that the distortion of the beds is the result of wave or current action immediately after the time of deposition. The algal material in the limestone resembles that illustrated by Johnson (1963, pl. 34, fig. 1; pl. 18, fig. 10) as *Shermanophycus* and *Eugonophyllum*.

Locally, in the vicinity of the north end of Lead Camp Canyon, a 1-foot-thick bed of spherical to cylindrical algal balls lies about 170 feet below the top of the formation. These balls, ¼–½ inch in diam-

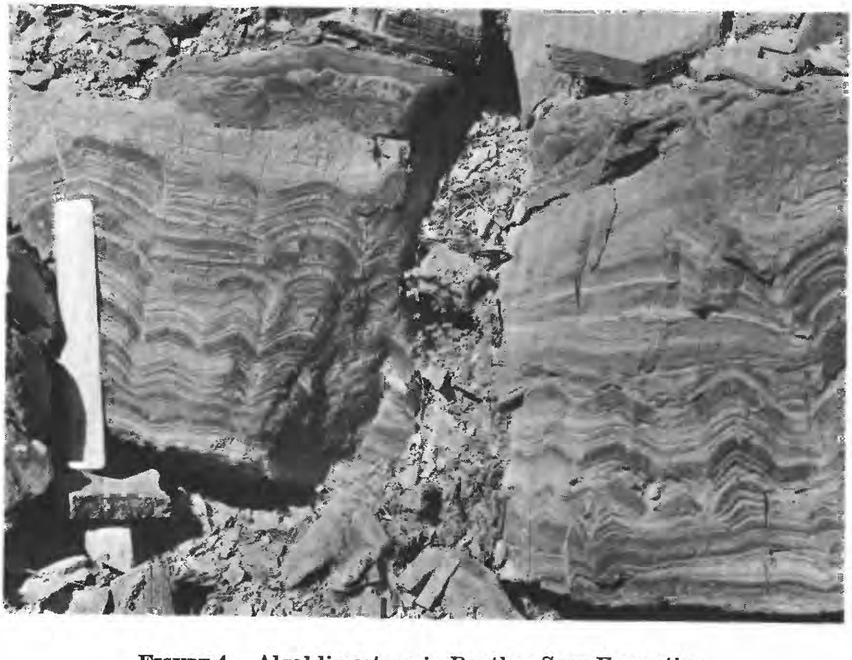


FIGURE 4.—Algal limestone in Panther Seep Formation.

eter, are composed of algae that resemble *Osagia* and small Foraminifera that have accreted around the tests of megafossils.

Gypsum is present in at least two beds in the central part of the Bear Peak area. The lower bed was traced for only about 3 miles along exposures between Ropes Draw and Ash Canyon; it is absent in the northern part of the area. This bed, as much as 32 feet thick, lies about 230 feet below the top of the formation. The lower few feet consists of gypsiferous limestone. The upper bed of gypsum, about 210 feet below the top of the formation, is as much as 15 feet thick and consists of alternating light and dark bands of gypsum; interbeds of dark-gray limestone are present in the upper part.

*Age and correlation.*—Fossils, other than algae in the limestone and fragments of fossil wood in some of the sandstone beds, are generally scarce. A collection of marine invertebrate fossils was made from a gray to black impure limestone west of the northern part of Lead Camp Canyon about 1,450 feet above the base of the formation. The following forms were identified by Mackenzie Gordon, Jr. (written commun., 1964), in U.S. Geological Survey collection 21620–Pc:

Lophophyllidiid coral, gen. and sp. indet. (immature)
*Hystriculina* cf. *H. texana* Muir-Wood and Cooper
*Pugnoides* sp.
*Crurithyris* cf. *C. planiconvexa* (Shumard) (pedicle valve)
*Aviculopecten* sp.
*Ianthinopsis*? sp. indet.
*Meekospira*? sp. indet. (broken section)
*Metacoceras* sp.
*Glaphyrites millsi* (Miller and Cline) ?

Gordon stated that "the faunal assemblage in this collection is not incompatible with Virgil age; it is merely not proof of it."

Kottlowski, Flower, Thompson, and Foster (1956, p. 47, pl. 1) reported species of *Triticites* and the fusulinid genus *Dunbarinella*, which are characteristic of Virgil age, from the Panther Seep Formation. The writers, however, found no fusulinids in the Panther Seep in the Bear Peak area.

On the basis of reported fusulinids and on stratigraphic position, the Panther Seep Formation is mostly of Virgil age. The lower few hundred feet, however, may be of middle and late Missouri age, and the beds that overlie the upper gypsum beds may be of Wolfcamp age.

The Panther Seep was probably deposited contemporaneously with the arkosic limestone member of the Madera Formation (Read and others, 1944) in central New Mexico. It is correlative with the Bar B Formation of Kelley and Silver (1952) in the Caballo Mountains to the west and is correlative, at least in part, with the Holder Formation of Pray (1961) in the Sacramento Mountains to the east. Pray (1961,

fig. 24) indicated that the Beeman Formation is of Missouri age and correlative with part of the Panther Seep Formation.

## PERMIAN SYSTEM

Rocks of Permian age in the Bear Peak area include the Hueco, Abo, and Yeso Formations. The Hueco and Abo Formations interfinger in the quadrangle, and, generally, two major tongues of each formation are present. At the base of the Permian is a marine tongue of the Hueco that thickens southward. This is overlain by a lower tongue of the Abo Formation that thins and wedges out toward the south within the quadrangle. Where the Abo Formation wedges out, the upper tongue of the Hueco Formation merges southward with the lower tongue and forms a single body of Hueco lithology in the southern part of the quadrangle. The upper tongue of the Abo Formation is present along the entire western slope of the San Andres Mountains within the area. The Yeso Formation overlies the Abo along the foot of the western slope of the mountains.

### HUECO FORMATION

The name Hueco Formation was used by Richardson (1904, p. 32–38) for strata that he believed to be of Pennsylvanian age. These strata that he called "Hueco," however, are now known to include rocks at least of Mississippian, Pennsylvanian, and Permian ages. King (1934, p. 741–748) discussed and redefined the term "Hueco," and in the present report the term is used for rocks of the same general lithology that are believed to be correlative with part of the Hueco Formation of Early Permian age in the Hueco Mountains, Tex.

In the southern San Andres Mountains the Hueco Formation rests disconformably on the Panther Seep Formation. The Hueco consists of limestone, shale, and sandstone. The dominant color is gray, but some sandy beds weather light brown or yellow. Some beds of shale and sandstone within the Hueco, as mapped (pl. 1), are medium brownish red. These are thin tongues of the Abo Formation that can be traced southward to their wedge edges in the main body of the Hueco Formation. The sandstone is fine grained and consists largely of quartz. Both the sandstone and the shale are generally calcareous, but fossils, except for ostracodes in some shale beds, are not common. The Hueco, together with the Abo Formation, is as much as 2,200 feet thick in the Bear Peak area.

In the southern San Andres Mountains the base of the Hueco Formation is marked by a prominent ledge of limestone that can be traced through much of the mapped area. The limestone is at least 40 feet thick and has individual massive beds as much as 12 feet thick. It is

usually olive gray clastic limestone of variable texture and fabric. Some parts are very algal and biohermal, and other layers are coquinoid. The clastic debris is relatively free of insoluble material and may contain algal and other fossil fragments. One sample of ostracode coquina was digested in hydrochloric acid and was found to be composed of 92.5 percent soluble calcareous matter. The same sample had a calcium-magnesium molal ratio of 23.53 percent, which indicates that it is a magnesian limestone (Guerrero and Kenner, 1955, p. 46).

North of Ropes Draw a fossil log 8 inches in diameter and more than 6 feet long was observed in a limestone bed (NE¼ sec. 36, T. 18 S., R. 3 E.). Other fossil wood fragments were observed in limestone beds. The writers assumed that the wood floated out to sea from a nearby coastal area, became waterlogged, and sank into the calcareous mud that later became limestone.

*Age and correlation.*—Some limestone beds in the Hueco Formation are very fossiliferous. Beds in parts of Goldenberg Draw (NE¼SW¼ sec. 35, T. 18 S., R. 3 E.) contain ostracodes. The ostracodes have been examined by I. G. Sohn, of the U.S. Geological Survey, who reported the following (written commun., 1961):

*Bairdia* spp.
*Orthobairdia* sp.
*Rectobairdia*? sp.
*Bairdiacypris* sp.
*Silenites*? sp.
*Kellettina* sp.
Kirkbyid gen. and sp. indet.
*Aurikirkbya* sp.
*Microcheilinella*?

These genera are regarded by Sohn as typically marine. Ostracodes were observed at other places and at other horizons in the Hueco, and they may indicate types of depositional environments. However, time was not available to collect the many specimens needed to reach conclusions in regard to facies and environments of the intertonguing Hueco and Abo Formations.

Fusulinids were collected from various localities in the basal part of the Hueco Formation. West of Lead Camp Canyon, at a locality 35 feet above the base of the formation, the Hueco contains *Schwagerina* cf. *S. andresensis* Thompson and *Pseudoschwagerina* cf. *P. texana* Dunbar and Skinner. In the vicinity of Little Wells, collections from 290 feet above the base of the Hueco contained *Schwagerina* cf. *S. andresensis* Thompson, *Pseudoschwagerina* cf. *P. uddeni* (Beede and Knicker), and *Triticites* sp. West of the divide between Bear Creek and San Nicholas Canyon, the fusulinids *Pseudoschwagerina?* sp. and

*Schwagerina* aff. *S. grandensis* Thompson were collected near the base of the Hueco Formation.

*Intertonguing of the Abo and Hueco Formations.*—Intertonguing of the marine Hueco and the nonmarine Abo Formations in the southern San Andres Mountains is so intricate that all minor tongues cannot be delineated on the geologic map. For cartographic purposes both the Hueco and the Abo have been divided into two tongues. These intertonguing relationships are shown diagrammatically in figure 5.

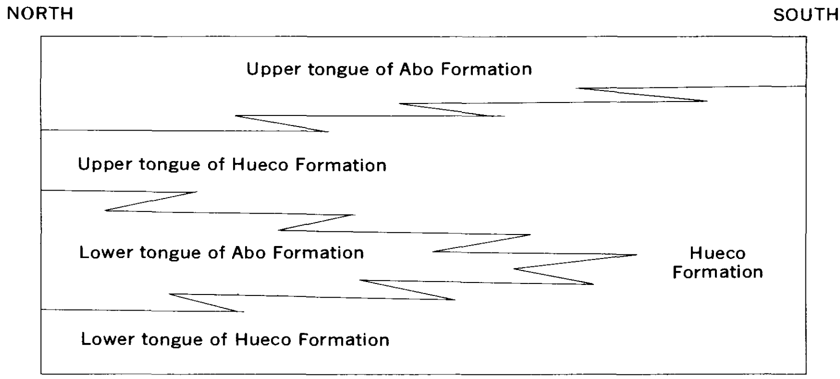



FIGURE 5.—Interfingering relationship of Hueco and Abo Formations in the report area.

In the Oscura Mountains about 55 miles to the north of the Bear Peak area the Abo Formation interfingers with the Bursum Formation of earliest Wolfcamp age. The Bursum thickens toward the south in that region, but rocks of Bursum age were not recognized in the Bear Peak area. Locally, warping during earliest Wolfcamp time caused hiatuses to develop, and the Bursum may have been stripped away, or not deposited, in the southern San Andres Mountains.

In the Bear Peak area, interfingering of the Abo and Hueco Formations is readily observable, and individual beds of Abo or Hueco lithology can be traced from their wedge edges into the main body of the formation. Some interfingering is quite gradual and beds must be traced for several miles, but at other places, including an area about 1 mile south of Ropes Draw (sec. 12, T. 19 S., R. 3 E.), interfingering is abrupt, and a bed may lose its identity within hundreds of yards. This interfingering may be attributed to filling of the Pennsylvanian to Permian Orogrande basin by periodic influxes of sediments eroded from adjacent highlands while marine beds were being deposited during recurrent encroachment of Permian seas.

**ABO FORMATION**

Lee (in Lee and Girty, 1909, p. 12) named the Abo Sandstone as part of the "Manzano group." Needham and Bates (1943, p. 1654) designated a type locality for the Abo Formation in Abo Canyon at the south end of the Manzano Mountains about 120 miles north of the Bear Peak area.

In the southern part of the San Andres Mountains the Abo Formation is reddish-brown sandstone, siltstone, and silty to sandy shale that contrast with the gray limestone and light-brown or yellow sandy beds of the intertonguing Hueco Formation. Some thin beds of gray shale and limestone are included, but these gray beds are minor tongues of the Hueco Formation that are too thin to map separately from the Abo. The sandstone beds are cross-laminated and commonly calcareous, and they form weak ledges. Some pebble conglomerate is present, but conglomeratic beds are much less common than in the northern part of the San Andres and Sacramento Mountains. Two major tongues of the Abo were mapped on the west slope of the mountains in the Bear Peak area. The lower tongue wedges into the Hueco Formation and could not be traced southward from the latitude of Ash Canyon. The upper tongue was traced to Bear Canyon, where it is terminated by a system of faults.

*Thickness of the Abo and Hueco Formations.*—The total thickness of the Hueco and Abo sequence at the north end of the area is about 2,200 feet. The lower tongue of the Hueco Formation in the vicinity of Lead Camp Canyon is about 1,160 feet thick. Overlying this lower tongue is a sequence of intertonguing red beds and marine limestone and shale. The red beds have been assigned to the Abo Formation; the marine limestone and shale, to the Hueco Formation. West of Lead Camp Canyon, four tongues of Abo are present. They range in thickness from about 120 feet to about 260 feet. These Abo tongues are interlayered with three tongues of Hueco that range in thickness from 20 to 125 feet. This section of intertonguing Abo and Hueco has an exposed thickness of about 900 feet. An estimated additional 100–150 feet of section is believed to be concealed beneath dune sand below the base of the overlying Yeso Formation.

The total thickness of the Hueco and Abo interval in the central part of the area is about 2,220 feet. In the vicinity of Little Wells (SW¼ NE¼ sec. 31, T. 19 S., R. 4 E.) the lower tongue of the Hueco is about 910 feet thick. As to the north, the lower tongue is overlain by a sequence of red beds and marine limestone and shale. Here, however only two main tongues of Abo are present. The lower tongue of the Abo is about 100 feet thick; the upper about 520 feet thick. The upper tongue of Hueco is about 600 feet thick. The top of the Hueco and Abo

sequence is concealed beneath colluvium and probably includes another 100 feet of section beneath the base of the Yeso Formation.

In the southern part of the area, in the vicinity of Love Ranch, the thickness of the Hueco Formation is not known, owing to structural complications. The Abo Formation, represented by a single tongue on top of the Hueco, is about 375 feet thick.

### YESO FORMATION

The Yeso Formation was named by Lee (in Lee and Girty, 1909, p. 12). A type locality was designated by Needham and Bates (1943, p. 1657) near Mesa del Yeso, 12 miles northeast of Socorro, N. Mex., and about 100 miles north of the Bear Peak area. The Yeso Formation includes gypsum, dolomite, limestone, shale, siltstone, and fine-grained sandstone in central New Mexico. The gypsum and carbonates are gray and the shale, siltstone, and sandstone range from yellowish gray to salmon red in central New Mexico. In south-central New Mexico the entire Yeso is dominantly gray.

In the Bear Peak area the Yeso Formation is exposed in outliers along the western slope of the southern San Andreas Mountains and in fault blocks near Bear Canyon. In most places in the mapped area the base of the formation is concealed beneath alluvium. In the northern part of the San Andres Mountains and in the Oscura Mountains the Abo-Yeso contact is apparently gradational. The Yeso is dominantly dolomitic limestone and gypsum, but it includes thin beds of fine-grained sandstone where exposed on the north side of Bear Canyon. One bed of gypsum about 30 feet thick is exposed in an outlier near the mouth of Ropes Draw (NW¼ sec. 2, T. 19 S., R. 3 E.).

At the south end of the San Andres Mountains, rocks of Cretaceous age rest on the Yeso Formation. In the vicinity of Love Ranch a minor fault separates the Yeso Formation and the Cretaceous rocks. Owing to faulting or poor exposures, the thickness of Yeso cannot be accurately measured at any locality within the report area, but in the vicinity of Love Ranch at least 250 feet of Yeso strata are preserved.

The Yeso Formation in the southern San Andres Mountains has been interpreted to thin southward, owing largely to loss of gypsum beds (Kottlowski and others, 1956, p. 59). The present writers interpret the thinning of the Yeso Formation in the southern San Andres Mountains as being due to regional beveling during pre-Late Cretaceous time. The present work indicates that Cretaceous strata rest on the Yeso Formation in the southern San Andres Mountains and that the Glorieta and San Andres Formations of Permian age are absent in that area.

Fossils collected from limestone beds in the Yeso Formation in the NE¼ sec. 3, T. 19 S., R. 3 E., and identified by E. L. Yochelson (written commun., 1964) of the U.S. Geological Survey, include (colln. 19780–PC):

Fenestrate bryozoan fragment
Echinoid spines
Scaphopod genus indet.
"*Pseudorthoceras*" sp. indet.
*Nucula* sp. (abundant)
Parallelodont pelecypod
Pectenoid pelecypod fragments, indet.
*Euphemites* sp. indet.
*Knightites* (Retispira) sp. indet.
Bellerophontacean gastropod fragments, indet.
*Amphiscapha* (*Amphiscapha*) sp. indet.
*Straparollus* (*Euomphalus*) cf. *S.* (*E.*) *kaibabensis* (H. Chronic)
"*Worthenia*" cf. "*W.*" *arizonica* Winters (abundant)
*Stegocoelia* (subgenus one) sp. indet. (abundant)
*Stegocoelia* (subgenus two) sp. indet.
*Goniasma*? sp. indet. (abundant)
*Cibecuia*? sp. indet. (very abundant—this is possibly *Orthonema socorroense* Girty)
Neritacean gastropod—new genus
*Paleostylus* (*Pseudezygopleura*) sp. indet.
New genus allied to *Orthonema*
High-spired gastropod aff. *Orthonema*
*Soleniscus* sp. indet.
*Cylindritopsis*? sp. indet.
Rodlike holes etched into shells

## SUMMARY OF PALEOZOIC DEPOSITIONAL HISTORY

During Precambrian time sediments were deposited in the region of the southern San Andres Mountains. The sedimentary rocks were altered to schist and quartzite by regional metamorphism that was probably accompanied by intrusion of granite stocks and mafic dikes. Near the end of Precambrian time an extensive erosion surface developed.

The Bliss Sandstone was deposited during Late Cambrian and earliest Ordovician time in a sea that transgressed from the west (Kelley and Silver, 1952, p. 55) onto the Precambrian erosion surface. The abundant quartz grains in the Bliss were probably derived from reworking of sedimentary debris on the eroded Precambrian surface. Local currents in the depositional environment are indicated by the presence of numerous cross-laminated sandy beds.

The sea in which the Bliss had been deposited continued to transgress eastward and continued to be an environment of deposition

during Early Ordovician time. During this time the El Paso Formation was deposited as a bioclastic limestone in shallow seas that contained abundant marine life. The formation was dolomitized after deposition of the sediments and probably before deposition of the overlying Montoya Dolomite.

At the close of El Paso time the region was tilted about 10 feet per mile southward along a northeast-trending hinge line that lies about 60 miles north of the Bear Peak area. This tilting is indicated by a regional disconformity between the El Paso and Montoya Formations. The magnitude of the disconformity increases toward the north in the San Andres Mountains (Kelley and Silver, 1952; Bachman, 1965).

The Montoya Dolomite was deposited in Middle and Late Ordovician time in a sea that transgressed northward across the tilted surface of the El Paso Formation. In the southern San Andres Mountains the Cable Canyon Sandstone Member of the Montoya marks the base of the formation and may represent sand reworked by the advancing Montoya sea. Most of the Montoya was deposited as fine-grained calcareous mud that was dolomitized soon after deposition. The presence of numerous fossils indicates that marine life was abundant in the Montoya sea. At the close of Montoya time southward tilting occurred that was similar to that at the close of El Paso time. It may not have exceeded 10 feet per mile.

During Middle Silurian time the Fusselman Dolomite was deposited in a marine environment in south-central New Mexico. The Silurian sea may have transgressed the region from the south and southeast; the record of Silurian deposition to the west is too incomplete to indicate the original extent of Silurian rocks in that direction. Southward tilting occurred again during Late Silurian time.

During Late Devonian time shallow seas spread across southern New Mexico. Nearshore deposition is suggested by the abundance of terrigineous material in the rocks, and by the paucity of limestone. The nature of the contact between Devonian strata and overlying Mississippian strata is not clear. At most localities the contact is concealed, and where observed in the area it is gradational.

Rocks that make up the Mississippian System in south-central New Mexico are mostly limestone. Many of the units are persistent and are very similar lithologically throughout much of the San Andres Mountains and the Sacramento Mountains about 35 miles to the east. The seas in which these strata were deposited were probably shallow and supported abundant marine life, especially crinoids.

During Pennsylvanian time structural axes developed along generally north-south trends in orogenic belts adjacent to marine basins. During Early(?) Pennsylvanian time sandstone, shale, and near-

shore limestone were deposited on an irregular erosional surface. During Late Pennsylvanian time the Orogrande basin developed in the general region of the southern San Andres Mountains and the Tularosa Basin. This basin received sediments from the Pedernal highland to the east and was filled near the end of Pennsylvanian time. Gypsum was deposited in a shallow sea that persisted in the general region of the southern San Andres Mountains near the end of Pennsylvanian time.

During Early Permian (Wolfcamp) time the Hueco sea invaded the region from the south. The marine transgression was oscillatory, and the depositional environment varied from one of open sea (Hueco Formation) to nearshore continental (Abo Formation). During Yeso (Leonard) time seas were more widespread and were highly saline, as gypsum was deposited in association with marine limestone and shale.

### PERMIAN-CRETACEOUS UNCONFORMITY

In the Bear Peak area, rocks of Late Cretaceous age rest on the Yeso Formation of Permian (Leonard) age. Near Love Ranch a fault separates the Cretaceous rocks from the Yeso Formation, but north of Love Ranch (NW1/4 sec. 18, T. 20 S., R. 4 E.) the depositional contact is well exposed. Rocks of Late Permian, Triassic, Jurassic, and Early Cretaceous ages are absent in this area.

The basal part of the Cretaceous is sandy, but conglomeratic rocks are not common, and there is no evidence of major local uplift. The hiatus that separates the Permian from the Cretaceous rocks in this area reflects regional beveling during Triassic and Jurassic time that was probably the result of epeirogenic tilting. The distribution and facies of Triassic and Jurassic rocks elsewhere in the Southwestern United States and northern Mexico suggest that tilting was probably toward the north.

## MESOZOIC AND CENOZOIC ROCKS

### CRETACEOUS SYSTEM

Rocks of Cretaceous age were first reported within the Bear Peak area by Darton (1928, p. 191–192). He wrote that "100 feet or more of shale and sandstone * * * including a thin bed of coal that has been worked to a small extent" contains fossils that belong to the Benton fauna and indicate a horizon in the lower part of the Mancos Shale. He did not give these exposures a formal name, however. Kottlowski, Flower, Thompson, and Foster (1956, p. 63) assigned these beds to the Sarten Formation, Dakota(?) Sandstone, and "Mancos–Eagle Ford beds."

These rocks are exposed in the southwestern part of the mapped area on the north side of Bear Creek and as outliers northward along the western slope of the mountains to the latitude of Lion Den Canyon. They are isolated from other bodies of Cretaceous rock and for this reason are of interest to students of regional Cretaceous stratigraphy; but since exposures are limited in extent, the present writers do not consider that they merit a new formational designation.

Cretaceous rocks in the area consist of medium-gray medium- to coarse-grained sandstone and gray to black shale. Some of the sandstone beds weather yellowish gray to brown and are cross-laminated. Other beds include sandy shale and black carbonaceous shale. A prospect pit west of Love Ranch may be the place where "a thin bed of coal * * * has been worked to a small extent" (Darton, 1928, p. 191), but coal was not observed during the present fieldwork. The most conspicuous rock unit is a well-sorted fossiliferous marine sandstone near the middle of the exposures northwest of Love Ranch.

The thickness of the Cretaceous rocks is only approximately known owing to poor exposures, structural complications, and an irregular contact with overlying Tertiary rocks. Kottlowski Flower, Thompson, and Foster (1956, p. 119–120) measured about 700 feet of Cretaceous strata in the vicinity of Love Ranch. This thickness is greater than that measured by the writers, but it is not excessive in view of the difficulty of measuring the exposures. The writers measured 350 feet of Cretaceous rocks in one hillside north of Love Ranch (sec. 19, T. 20 S., R. 4 E.), and at least 100 feet of strata may be added to this thickness at exposures in a saddle west of Love Ranch.

*Age and correlation.*—Fossils are common in the Cretaceous beds in the southern part of the mapped area. Collections from an interval about 100–170 feet above the base of the Cretaceous were studied by W. A. Cobban, of the U.S. Geological Survey. He identified the following species (written commun., 1960) from USGS collections 2493, 2494, 2495, 2496:

*Inoceramus* cf. *I. incertus* Jimbo
*Ostrea* sp.
*Lopha* aff. *L sannionis* (White)
*Laturnula* sp.
*Tellina* sp.
*Lima utahensis* Stanton
*Veniella* sp.
*Cardium pauperculum* Meek
*Cardium* sp.
*Baculites* cf. *B. besairei* Collignon
*Prionocyclus reesidei* Sidwell
*Proplacenticeras stantoni* (Hyatt)
*Bostrychoceras* cf. *B. elongatum* (Whiteaves)

Cobban regards this fauna as "very late Carlile" in age. The presence of *Inoceramus* cf. *I. incertus* and *Prionocyclus reesidei* indicates late Turonian age, and this fauna is correlative with the basal part of the Austin Chalk in western Texas (Freeman, 1961).

## TERTIARY SYSTEM

### LOVE RANCH FORMATION

The Love Ranch Formation was named by Kottlowski, Flower, Thompson, and Foster (1956, p. 69) for "exposures northwest of Love Ranch" in sec. 30, T.20 S., R. 3 E. They noted that the "Love Ranch Formation is distinctive among Tertiary sedimentary units in southern New Mexico in containing only eroded fragments of pre-Tertiary rocks. Except for a thin lens of andesite tuff-breccia, no volcanic rocks, or clastic fragments thereof, occur in the conglomerates or in the cementing sandstones." They described only the basal 408 feet in detail but estimated that the formation may be as much as 2,100 feet thick. They observed that the formation is involved in thrust faulting that caused the total measured thickness to be uncertain.

The basal part of the Love Ranch Formation is well exposed in the type locality and consists of interbedded conglomerate and reddish-brown fine-grained calcareous clastic rocks. The conglomerate beds are well cemented at most places, whereas the fine-grained beds are poorly consolidated and are eroded to slopes. The basal bed is a massive poorly sorted cobble conglomerate composed of calcareous debris. It rests on an uneven erosional surface on rocks of Cretaceous age northwest of Love Ranch. Some boulders more than 14 inches in diameter were measured in the basal bed, but the average diameter is about 8 inches. In the lower beds of the formation the average diameter of cobbles and pebbles decreases upward within each bed.

At localities along the south edge of Love Ranch (NW¼ sec. 25, T. 20 S., R. 3 E.) angular limestone fragments of Hueco Formation more than 3 feet across are present in the Love Ranch Formation. Two very large blocks of limestone were detached from the main body of Hueco and have slid onto beds of the Love Ranch Formation. These are shown on the geologic map (pl. 1, NW¼ sec. 25, T. 20 S., R. 3 E.) as exotic blocks in the Love Ranch Formation. The increasing coarseness of constituents toward the south is evidence that the Love Ranch Formation was derived from that direction.

Because fossils have not been found in the Love Ranch Formation, its age is not known. It was deposited after the Cretaceous rocks in the area and probably before major intrusion of the Organ Mountain igneous complex. Fragments of igneous rocks from the Organ Mountains have not been found in the formation. Owing to its lack of fossils and

its local extent, the Love Ranch should only tentatively be correlated with formations in adjacent areas. The writers believe that it is of early Tertiary age.

### IGNEOUS ROCKS

A sill, or sequence of complex sill injections, underlies Quartzite Mountain in the southern part of the Bear Peak area. The rock is light gray and finely crystalline and contains quartz (much of which appears to be secondary), sericitized orthoclase, and minor amounts of biotite. These sills were intruded into the locally brecciated Hueco Formation on Quartzite Mountain, and into the Panther Seep Formation east of Quartzite Mountain. South of the mapped area, sills are numerous, constitute a large part of the rock column, and are related genetically to the Organ Mountain igneous complex. The sills in the Bear Peak area may be equivalent to the "quartz-feldspar porphyry sills and dikes" of Dunham (1935, p. 84–86).

Basic dikes, as much as 12 feet thick, are present in the mapped area north of Bear Mountain (pl. 1). The dikes, apparently diorite, are deeply weathered and poorly exposed. A nearly vertical acidic dike, probably genetically related to the sills of Quartzite Mountain, crops out in the southern part of the mapped area (SE¼ sec. 27, T. 20 S., R. 4 E.).

Dunham (1935, p. 68) related the emplacement of the Organ Mountain intrusive mass to the Late Cretaceous–early Tertiary period of intrusive activity. The emplacement "was completed before the initiation of the Santa Fe cycle of erosion in Miocene time." The quartz-feldspar porphyry sills and dikes at the north end of the Organ Mountains represent a late phase of the Organ Mountain intrusion (Dunham, 1935, p. 147).

### QUATERNARY DEPOSITS

Alluvium covers most of the region surrounding the mountains. It may grade downward into deposits of the Santa Fe Group (Miocene to Pleistocene(?) age), but these were not seen at the surface. The alluvium includes clay, sand, and gravel deposited as fans by intermittent streams from the mountains. Modern arroyos cut into some of these deposits, and the sediments are characteristically poorly sorted and form lens-shaped beds.

The alluvial deposits are poorly consolidated and are easily reworked by the wind to form dunes. Sand dunes are prominent features in the northern part of the area. Sand derived from this area has been carried up the western dip slope of the range by the prevailing southwesterly winds and deposited locally in Lead Camp Canyon on the lee side of the steep cliff at the base of the Hueco Formation (fig. 6).

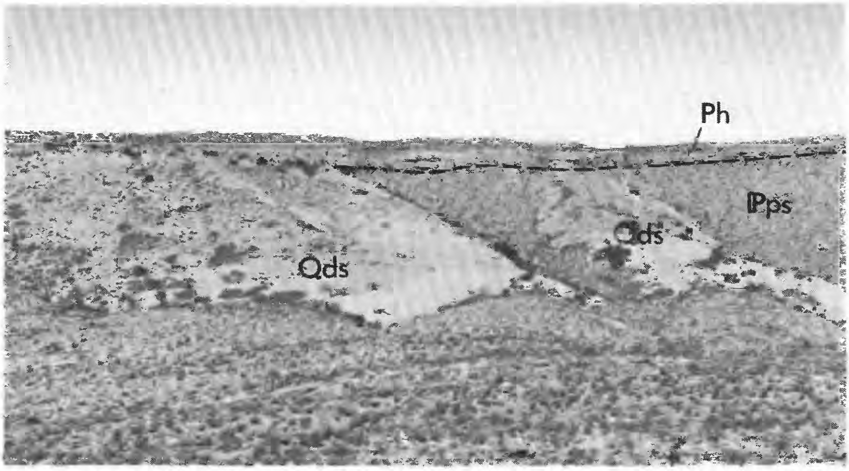



FIGURE 6.—Sand dunes on the lee side of limestone cliff of Hueco Formation. View is westward across Lead Camp Canyon. IPps, Panther Seep Formation; Ph, Hueco Formation; Qds, dune sand.

## GEOLOGIC STRUCTURE

The main part of the San Andres Mountains is a westward-dipping block-faulted mountain range about 65 miles long. Beds strike generally north over the southern two-thirds of the range and northeast in the northern part.

In the southern part of the San Andres Mountains the beds have an average dip of about 15° W. Locally some beds are contorted, dip more steeply, and are overturned in a few places.

Structurally, the San Andres Mountains terminate in the southern part of the Bear Peak quadrangle at Bear Canyon. South of Bear Canyon, igneous intrusions and numerous closely spaced normal and reverse faults related to the Organ Mountain uplift characterize the geologic structure.

On the western slope of the San Andres Mountains, near the latitude of Ash Canyon, beds in the upper part of the Panther Seep Formation and the basal part of the Hueco Formation are sharply folded into an anticline whose north-south axis was traced nearly 4 miles (fig. 7). Along the west side of the anticline, beds are vertical and locally overturned (pl. 1). Other minor folds are present between Ash Canyon and Ropes Draw and in the northern part of Lead Camp Canyon. These are not continuous structural features, although Dunham stated (1935, p. 142) that on the west side of the San Andres Mountains "a sharp fold, with which thrust faulting is associated, extends from Little Well on the Jornada Range to San Andrecito Canyon [T. 18 S., R. 4 E.], a distance of 12 miles."

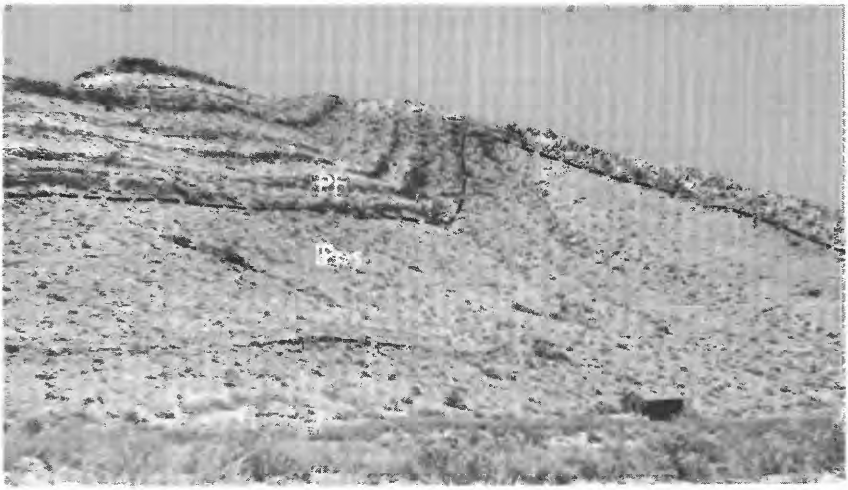


FIGURE 7.—Flexure in Panther Seep and Hueco Formations. View looking southwest near Little Wells. Pps, Panther Seep Formation; Ph, Hueco Formation.

Most faults in the Bear Peak area are normal faults. However, thrust faults occur south of Bear Canyon. Dunham (1935, p. 142–144) reported thrust and reverse faults in the Organ Mountains at the head of Black Prince Canyon, about 6 miles south of Bear Canyon. During the present work, fault systems were not traced into Black Prince Canyon from the mapped area, but, by projection, it is believed that the system of north-south faults west of Bear Peak is part of the system observed by Dunham in Black Prince Canyon.

In the southeastern part of the Bear Peak area, Precambrian granite is thrust northward across the Hueco Formation. Along the eastern boundary of the granite, a north-trending fault, probably a tear fault, was traced from the south edge of the area to Bear Canyon. Steep dips, folds, and breccia characterize the Hueco Formation adjacent to this latter fault. The fault is arcuate in plan and curves toward the west parallel to Bear Canyon. It separates into several faults, here named the Bear Canyon fault system, along the north side of Bear Peak. The north-trending tear fault in the southeastern part of the Bear Peak area merges with the Bear Canyon system. Beds in the Hueco Formation north of the fault dip steeply toward the north or are vertical. In Bear Canyon this fault system splays into numerous minor faults, many too small to be mapped, and cuts through rocks of Ordovician, Silurian, Devonian, and probably Mississippian ages. The Bear Canyon fault system may continue toward the northwest into the vicinity of Love Ranch, but if present in that area it is concealed. Rocks of Cretaceous age and the Love Ranch Formation

of early Tertiary age dip steeply toward the north, or are overturned, probably as a result of northward stresses along the Bear Canyon fault system.

Near the southern exposures of the Love Ranch Formation (center sec. 25, T. 20 S., R. 3 E), the Hueco Formation rests on the vertical Love Ranch. The contact between the two formations is poorly exposed, but it is believed to be a reverse fault that dips about 60° S. A sliver of Love Ranch Formation is present below the Hueco and overlies the Cretaceous at one locality (NW¼SE¼ sec. 25, T. 20 S., R. 3 E.). Conglomerate debris in the Love Ranch Formation is derived from the Hueco Formation, and some angular fragments of limestone from the Hueco are present near the fault contact. Near this same locality there are other small faults in the Love Ranch Formation.

From observations during the present work the following interpretations are made:

1. The relatively simple composition and the limited distribution of the Love Ranch Formation suggests that the constituents were derived locally.
2. The Love Ranch Formation accumulated from an uplifted area along an active fault zone. The fault zone is part of the Bear Canyon fault system, and the uplifted area was south of Love Ranch and probably in the vicinity of Quartzite Mountain.
3. Faulting was intermittent and continued after deposition of the Love Ranch Formation began.
4. Faulting was the result of compressional forces, probably from the south.

## MINERAL DEPOSITS

Numerous prospect pits and abandoned adits indicate previous interest in the mineral deposits of the eastern part of the Bear Peak area. The largest underground working within the mapped area is an abandoned lead mine in San Andres Canyon. Dunham (1935, p. 255–257) stated that the mine was developed between 1900 and 1904 and that no work has been done since 1904. He also stated that there may have been a small production of galena concentrates, but data on amounts shipped were not available. Dunham did not regard the property to be of economic value. Only scattered fragments of galena were observed around the mine workings by the present writers, and Dunham's estimate that the galena content does not exceed 3 percent was probably realistic.

Nonmetallic mineral deposits including building stone, sand, gravel, and gypsum are present in the report area. These deposits are all within the confines of White Sands Missile Range and may not be

developed under present conditions. They are available for local use within the missile range, but access is difficult owing to the rugged terrain. Abundant sand and gravel are available along some of the arroyos on either side of the San Andres Mountains.

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