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Stratigraphic Studies of the San Andres Mountains, New Mexico

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Abstract

The San Andres Mountains (fig I), in south central New Mexico, expose a section of Paleozoic sedimentary rocks unrivaled in New Mexico in length of continuous outcrop and in completeness of existing time-lithologic units. The thickness, lithology, and extent of the Paleozoic strata concealed in the nearby basins can be estimated accurately from the sections in the San Andres Mountains and from known sections in more accessible areas.

The Bliss sandstone, El Paso group, Montoya group, Fusselman dolomite, Devonian formations, Mississippian formations, Pennsylvanian beds, Bursum formation, Hueco formation, Abo redbeds, Yeso formation, San Andres formation, Dockum formation, Sarten formation, Dakota (?) sandstone, Eagle Ford or Mancos formation, and Love Ranch formation were measured and described in detail in Rhodes, Hembrillo, and Ash Canyons. Rhodes Canyon, the most accessible in the range, contains the northernmost complete section. Hembrillo Canyon, though difficult of access, is in the center of the range. Ash Canyon is the southernmost accessible canyon in which the formations have escaped intense deformation and metamorphism associated with intrusion of the Organ Mountains batholith.

Paleozoic sedimentary rocks measured a total of 7,065 feet in Rhodes Canyon, 6,519 feet in Hembrillo Canyon, and 7,130 feet in the Ash Canyon-Love ranch area. Pre-Pennsylvanian sedimentary rocks thicken southward from 858 feet in Rhodes Canyon, and 1,380 feet in Hembrillo Canyon, to 1,918 feet in Ash Canyon. Eighteen miles north of Rhodes Canyon, in Sly Gap, pre-Pennsylvanian strata are 674 feet thick. Pennsylvanian sedimentary rocks thicken and thin southward, and Permian beds thin, as do combined thicknesses of Pennsylvanian and Permian strata (see table 1). The Abo redbeds thin markedly southward, where they interfinger with marine beds of the Hueco formation. Triassic beds occur only north of Rhodes Pass. Rocks of Jurassic age are not present anywhere in or near the San Andres Mountains. Upper Cretaceous sedimentary rocks in the adjoining basins thin southward, though Lower (?) Cretaceous rocks, absent near Hembrillo Canyon and northward, appear near Love ranch (see fig 1), and thicken south of the range.

The porous dolomites and dolomitized limestones of pre-Devonian age thin northward beneath a relatively uniform blanket of impervious Devonian shales and siltstones, but still are 509 feet thick in Sly Gap, near the north end of the range. The lower part of the Pennsylvanian strata, from Derryan to Missourian in age, thickens southward to Hembrillo Canyon, but thins abruptly in Ash Canyon; south and east of the San Andres Mountains (in the Franklin and Sacramento Mountains) it again thickens, but remains relatively thin to the west (in the Robledo Mountains). The thick Virgilian sequence of the Pennsylvanian, named the Panther Seep formation in this report, thickens southward and is lithologically different from rocks of correlative age outside of the range. Biohermal and biostromal reefs are common in the upper part of the Panther Seep beds north of Ash Canyon.

Precambrian rocks are chiefly reddish-brown and gray granites, with minor amounts of schist, near Rhodes and Ash Canyons, though a thick sequence of metamorphic rocks crops out near Hembrillo Canyon.

TABLE 1. THICKNESSES OF SIGNIFICANT PARTS OF MEASURED SECTIONS (in feet)

	Rhodes Canyon	Hembrillo Canyon	Ash Canyon Area
Pre-Devonian	613	1,087	1,385
Pre-Pennsylvanian	858	1,380	1,918
Derryan to Missourian	1,048	1,209	435
Virgilian	1,458	1,825	2,390
Pennsylvanian	2,506	3,034	2,825
Hueco and Bursum	685	402	1,355
Abo redbeds	835	613	325
Permian	3,701	2,105+	2,387
Pennsylvanian to Permian	6,207	5,139+	5,212
Paleozoic	7,065	6,519+	7,130
Mesozoic	92+	–	707

The Bliss sandstone ranges from 46 to 105 feet in thickness from Rhodes to Ash Canyons, the thickness depending in part on where the contact with the El Paso group is picked. The Bliss is a light- to dusky-brown, grayish-green to dusky-red, glauconitic, calcareous sandstone; oolitic hematite lenses occur near or at the base; arenaceous limestones are present in the upper part. Flower believes the Bliss sandstone in the San Andres Mountains to be of earliest Ordovician age.

The El Paso group, of Lower Ordovician age, consists of medium dark- to light-gray dolomites and limestones that weather blue gray or light brown and crop out as a ledgy slope. The lower beds, transitional into the Bliss sandstone, are arenaceous and glauconitic; oolitic and arenaceous beds occur 250-300 feet above the base. The group thickens southward, ranging from 306 to 760 feet in thickness from Rhodes to Ash Canyons.

The Montoya dolomite, of Middle and Upper Ordovician age, which thickens southward, is 260, 400, and 424 feet thick in the three canyons, north to south. The four formations of the Montoya group vary irregularly in thickness (see fig 2), reflecting lateral and vertical lithologic changes. The basal Cable Canyon sandstone is light gray, pebbly, and dolomitic in Rhodes Canyon, shaly and silty in Hembrillo Canyon, thick and quartzitic in Ash Canyon. The crinoidal Upham dolomite is medium dark gray and forms the lower massive cliffs. The Aleman dolomite is medium to dark gray, massive- to medium-bedded, and extremely cherty. The upper unit, the Cutter dolomite, is light to medium gray, thin- to medium-bedded, and dense.

The Fusselman dolomite, of Silurian age, as restricted by Pray and Bowsher (1952, p 1342) and Kelley and Silver (1952, p 62), pinches out about 6 miles south of Rhodes Canyon, but thickens southward to 95 feet in Ash Canyon. The Fusselman is a medium- to dark-gray, massive, cliff-forming dolomite, with scattered chert nodules; the beds weather gray to dark brown.

Sedimentary rocks of Devonian age vary irregularly in thickness (85-211 feet) and vary laterally and vertically in

lithology; the faunas are not completely known, although they have been the subject of much study. The basal beds are of the Onate formation, dark olive-gray to tan, hard, calcareous siltstones and shales, 10-32 feet thick. Above is the Sly Gap formation, abundantly fossiliferous, consisting of dark-gray to pale olive-gray calcareous shales and calcareous yellowish-brown siltstones, 31-75 feet thick. The Contadero formation is 45-51 feet thick from Rhodes to Hembrillo Canyons, but absent in Ash Canyon; it includes olive-gray calcareous shales, with lenses of brown siltstone and silty limestone. About 7o feet of the uppermost dark- to grayish-olive calcareous shales and siltstones in Rhodes and Hembrillo Canyons is referred to the Percha formation.

Mississippian sedimentary rocks vary in thickness, as shown by our measurements and by those of Laudon and Bowsher (1949, p 35); they thin northward from Hembrillo Canyon but are thicker in the southern part of the San Andres Mountains. The lowermost Mississippian (Caballero) formation is about 6o feet thick in Ash Canyon but pinches out south of Hembrillo Canyon and consists of silty calcareous shales, with nodules and lenses of silty limestone. The four lower members of the Lake Valley formation, Andrecito, Alamogordo, Nunn, and Tierra Blanca, occur in or near all three canyons; the upper two members, Arcente and Dona Ana, are present only south of San Andres Canyon. The silty, dark-gray limestones and shales of the Andrecito member form a broken cliff or ledgy slope below the cliff of the massive, cherty, dark-gray limestones of the Alamogordo member. The fossiliferous, argillaceous limestones and shales of the Nunn member form a notch above the Alamogordo member cliff and below the massive ledges of cherty, crinoidal Tierra Blanca limestones. The Arcente member consists of calcareous siltstones and silty limestones. The Dona Ana member is massive, light-gray crinoidal coquinoid limestone.

Pennsylvanian sedimentary rocks overlie the Mississippian beds with pronounced erosional unconformity; in places almost the entire Mississippian section was cut out, and channels were filled by Pennsylvanian chert-pebble conglomerates. Strata containing Pennsylvanian fusulinids range from 2,506 to 3,034 feet in thickness, with the thickest section near Hembrillo Canyon. On the basis of lithologic differences and Thompson's fusulinid studies these beds have been subdivided into Derry, Des Moines, Missouri, and Virgil series. Derryan beds, which may include Morrowan equivalents at the base, consist of basal chert-pebble conglomerates and calcareous to quartzitic sandstones, arenaceous and silty limestones, and carbonaceous shales, ranging from 107 to 344 feet in thickness. Strata of Desmoinesian age are massive- to medium-bedded, cherty or coquinoid limestones, with arenaceous calcarenites in the lower part and argillaceous limestones near the top; the thickness averages about 600 feet but thins abruptly near Ash Canyon to about 183 feet. Missourian sedimentary rocks, 145-271 feet thick, are interbedded, argillaceous limestones and calcareous shales, with medial, massive, cherty limestones.

Rocks of Virgilian age in the San Andres Mountains area are lithologically different from beds of similar age in the rest of New Mexico. They are named herein the Panther Seep formation because they constitute a distinct mapping unit. The beds are typical deltaic to brackish-water elastics and precipitates that were deposited in a narrow, north-south elongated basin extending from about Rhodes Canyon southward into Texas. Ranging in thickness from 1,460 feet near Rhodes Canyon to 2,390 feet in Ash Canyon, the Panther Seep strata consist of silty brownish shales, dark carbonaceous shales, dark-gray argillaceous limestones, silty calcarenites, silty calcareous sandstones, and lenses of massive biostromal limestones. Two thick gypsum beds occur in the upper part of the formation near Ash Canyon; near Rhodes and Hembrillo Canyons are numerous biohermal reefs.

Argillaceous silty limestones, gray to purplish shales, and arenaceous calcarenites, with basal conglomerates and sandstones, have been referred to the Bursum formation. At the top of the unit in Rhodes Canyon is a massive biostromal cliff-forming limestone. The formation is about 265 feet thick in Rhodes Canyon, perhaps 75- 100 feet thick near Hembrillo Canyon, and absent (?) in Ash Canyon.

The Hueco formation, which ranges from 325 to 1,355 feet in thickness, thickens rapidly southward from Hembrillo Canyon in the area where it intertongues with and replaces the lower part of the Abo redbeds. The Hueco formation consists chiefly of argillaceous limestones, cherty fossiliferous limestones, silty calcarenites, and gray fossiliferous shales, with reddish shales and calcareous siltstones near the top. In the Ash and Hembrillo Canyon areas this formation also contains a basal massive biostromal limestone.

The Abo redbeds thin southward from 835 feet near Rhodes Pass to 325 feet near Love ranch. The lower beds grade southward into Hueco beds. A typical southward transition is from grayish-red calcareous siltstones into pink and olive-gray calcareous siltstones, and then into silty, light-gray calcarenites of the Hueco formation. The Abo consists of dusky-red to dark reddish-brown shales and calcareous siltstones, with a few lenses of silty, fine-grained sandstone.

The Yeso formation thins southward from 1,580 feet at Rhodes Pass to about 325 feet near Love ranch. The formation consists of a basal friable, nonresistant, pale-red to orange sandstone, the Meseta Blanca (?) sandstone member, and overlying interbedded, gray, orange, pale-red, friable sandstone, gypsum, calcareous siltstone, and silty fossiliferous limestone. Near Rhodes Pass the Torres member, Canas gypsum, and Joyita sandstone, in ascending order, can be differentiated. The Canas gypsum member disappears south of Rhodes Canyon, and no gypsum is present even in the Torres (?) member in the Love ranch area.

Beds resembling the Glorieta sandstone occur at the base of the San Andres formation, where they are lenses of friable yellowish-brown sandstone. The San Andres formation thins southward from 600 feet at Rhodes Pass to 384 feet near Ash Canyon. At both Rhodes and Hembrillo Canyons the upper contact is not exposed, but in the Sun Oil Co. test wells drilled 20 miles northwest of Rhodes Pass the San Andres formation is 650-700 feet thick beneath Dockum redbeds. The San Andres formation consists of gray to dark-gray, medium-bedded to massive, fetid, fossiliferous, petroliferous limestones.

North of Rhodes Pass, near Cain ranch (see fig 5), the San Andres formation is overlain by 52 feet of poorly exposed, pale reddish-brown calcareous shale, claystone, and siltstone here referred to the Dockum formation. These redbeds are absent south of Rhodes Pass. Near Cain ranch the Dockum is overlain by more than 4o feet of Dakota sandstone, top eroded. Near Love ranch the San Andres formation is overlain unconformably by the Sarten formation, of possible Lower Cretaceous age. The Sarten consists of intercalated yellowish-brown to purplish silty sandstones, gray sandy fossiliferous shale, brown fossiliferous calcareous sandstone, coquinoid in part, olive-gray glauconitic sandstones, and black carbonaceous shales; total thickness about 96 feet.

In the Love ranch-Ash Canyon area the Sarten formation is overlain unconformably by a quartzitic, crossbedded, light-gray, ledge-forming sandstone lithologically similar to the Dakota (?) sandstone elsewhere in New Mexico and about 185 feet thick, including interbedded silty, greenish-gray, nonresistant sandstones. Above the Dakota (?) sandstone is a sequence of intercalated olive-gray calcareous sandstones and carbonaceous shales containing numerous plant imprints, a coal lens, and lenses of calcarenite and silty limestones bearing a marine Eagle Ford-Mancos fauna. These Upper Cretaceous beds are at least 425 feet thick and are overlain with pronounced erosional unconformity by several thousand feet of interbedded boulder conglomerates and reddish siltstones, named the Love Ranch formation in this report and considered to be of Tertiary age. Tertiary volcanic rocks overlie the Love Ranch beds in the Organ Mountains. Tertiary intrusives are of three types: ( ) hornblende andesite sills and dikes, (2) thick rhyolite sills, (3) monzonite and quartz monzonite of the Organ Mountains batholith and associated dikes.

In order to provide a comparison between the detailed sections measured in the San Andres Mountains and the records of petroleum test wells in the adjacent region, data on 21 wells were examined and reinterpreted. Some of these wells not only show changes in the aspect of the measured formations but also reveal faults, disturbed blocks, intrusive rocks, and thick sections of Cenozoic volcanic rocks and valley fill.

Insoluble residues were prepared by the Midland Residue Research Laboratory from samples of pre-Pennsylvanian rocks taken from all three measured sections. For some of the formations the results of the residue studies provide close agreement with field and laboratory data in the selection of formational boundaries.

An interpretation is made of the sedimentary and tectonic record revealed by the stratigraphic sections in order to present a graphic evaluation of the geologic history of the region of the San Andres Mountains. In spite of the thickness of the section (as much as 12,700 ft) only parts of the great periods of geologic time are represented. The carefully studied sections emphasize the breaks in the geologic record and reveal breaks which would not be apparent in a less careful examination. Major erosional breaks occur at the base of deposits of Devonian, Pennsylvanian, Mesozoic, and Tertiary age. Pre-Devonian strata thin northward and are chiefly carbon ate rocks. Devonian beds are the oldest sequence of fossiliferous lithified muds; they grade upward into the Mississippian shelf limestones. Pennsylvanian and Permian rocks record deposition of a thick sequence of sediments on an unstable marine shelf area. Lateral gradation from continental redbeds into marine limestones is shown by the intertonguing of the Abo and Hueco formations. The succeeding Yeso formation exhibits alternations from continental and shoreline elastics to marine limestones and gypsum. Mesozoic rocks are mainly continental and shoreline deposits, which in places have been removed partly or entirely by Cenozoic erosion. Tertiary and Quaternary deposits are continental elastics interbedded with volcanic rocks. Major folding and faulting in the San Andres Mountains (except for the Precambrian) is of Cenozoic age and is of the Basin and Range block-faulting type of deformation. Scarps cutting alluvial fans record Recent continuation of this block faulting.

Many features of the stratigraphic succession in the San Andres Mountains are favorable to the occurrence of petroleum in nearby areas where structures are suitable. The section contains units similar in age and lithology to horizons that are prolific producers of oil and gas in southeastern New Mexico. Source beds, reservoir rocks, and impermeable "cap" rocks occur throughout the Paleozoic section. Possible stratigraphic traps are suggested by northward pinching out of the relatively porous carbonate rocks of pre-Devonian age beneath the impervious shaly Devonian strata. Numerous permeable horizons and carbonaceous shales are contained in the thick Pennsylvanian and Lower Permian marine sequence, and in the area between Rhodes and Hembrillo Canyons these formations contain many biohermal limestones which are sources of petroleum production in other areas. Petroliferous limestones as well as porous and permeable beds are included in the San Andres and Yeso formations. Permeable beds occur in the Dakota (?) sandstone and in the Eagle Ford formation, where they are closely associated with dark marine shales. The sedimentary rocks exposed in the range are not deformed to a prohibitive extent nor are they metamorphosed except close to the Organ Mountains batholith.

The stratigraphic sections measured in the San Andres Mountains are shown in the columnar sections (figs 2-4, 8-14; pl I). Data on each distinctive unit are provided in descriptions of the measured sections, which have been condensed from much more detailed descriptions on file with the New Mexico Bureau of Mines and Mineral Resources.

Introduction

LOCATION

The San Andres Mountains, in central southern New Mexico, are bounded on the east by the Tularosa Valley, and on the west by the Jornada del Muerto plains; they are terminated on the north by Mockingbird Gap, and on the south by San Augustin Pass (fig). The range is about 85 miles long, north to south, and 6-17 miles wide; 14 large east-west canyons offer access to measurable sections. Sections were measured in Rhodes Canyon, near the north end of the range, in Hembrillo Canyon, at the middle, and in and near Ash Canyon, close to the south end.

The San Andres Mountains lie almost entirely within the restricted area of the White Sands Proving Ground and may be entered only with the permission of the commanding officer. Rhodes Canyon is traversed by former N. Mex. Highway 52, a well-kept gravel road from Engle to Tularosa. A partly abandoned, sandy road leads from Rincon 3o miles to Hembrillo Canyon; a ranch road from the U. S. Department of Agriculture Jornada Experimental Range goes to the upper reaches of Ash Canyon.

Rhodes Canyon was the site of Eugene Manlove Rhodes' ranch, and his final resting place is on a 10-acre plot atop Rhodes Pass. Rhodes, long acclaimed as the outstanding writer of authentic Western stories, was one of the first homesteaders in the San Andres Mountains. His books, among which are "Paso Por Aqui," "Proud Sheriff," "Beyond the Desert," and "Trusty Knaves," are based on actual everyday events that occurred in the wild and woolly New Mexico of 1880-1906, and were read widely in the Saturday Evening Post.

PURPOSE OF REPORT

The three representative measured sections described in this report were studied as an aid to the understanding of surface and subsurface geology for the regions to the west and east. Exploration for oil and gas in the adjoining basins will be guided in part by the sedimentary sections so well exposed throughout the San Andres Mountains.

PREVIOUS WORK

Significant previous geologic articles on the San Andres Mountains, although not numerous, contain considerable stratigraphic information—if one can check the outcrop to see which interpretation is more nearly correct. Shumard (1859) early commented on the rocks in the range, and Herrick (1898) described copper-lead deposits in "Carboniferous" beds just above the Precambrian in the northeastern part of the range. Lee and Girty (1909) named the San Andres formation and listed a relatively accurate section measured near Rhodes Pass. Baker (1920) noted the facies change of Abo red-beds into Hueco limestones in the southern part of the range; also the Mancos-Eagle Ford beds and Love Ranch conglomerates and red siltstones near Love ranch. Darton (1928) made a reconnaissance map of the San Andres Mountains, measured eight sections of Lower Paleozoic rocks, and briefly described the formations. Thompson (1942) measured four sections of Pennsylvanian and lower marine Permian rocks in the range. Needham and Bates (1943) relocated, measured, and described the type San Andres formation. Stevenson (1945) measured and described the Devonian formations; Laudon and Bowsher (1949), the Mississippian formations. Kelley and Silver (1952) listed thicknesses of Lower Paleozoic units from the range, and Thompson (1954) measured and described lower marine Permian strata. The New Mexico Geological Society's Sixth Annual Field Trip traversed Rhodes Canyon in 1955; the field trip guidebook contains a road log by Kottlowski, Foster, and Sandeen (pp 14-23), and a generalized summary of the geology of the range (Kottlowski, pp 126-145).

METHOD OF STRATIGRAPHIC STUDIES

The greater part of the stratigraphic studies on which this report is based was carried out under a research contract in which three major oil companies, the Standard Oil Co. of Texas, the Humble Oil & Refining Co., and the Gulf Oil Corp., agreed to defray the expenses. The State Bureau of Mines and Mineral Resources secured permission to work within the restricted area of White Sands Proving Ground and completed the work stipulated in the contract by August 1955. Some further investigations, together with the original report, form the basis of the current study.

Suitable measurable sections were located through reconnaissance of the areas and through walking out individual beds and contacts. Sections were measured by hand level and tape, and 5-foot intervals were painted and labeled on the outcrop. Each lithologic unit, generalized to one-half foot, was described, and samples representative of each 5-foot interval were collected. Forty sections totaling 22,600 feet were measured, and almost 4,000 samples taken. Both megafossils and microfossils (fusulinids) were collected from the sections or from recognizable lateral extensions of the beds; these were added to the collections in the paleontologic laboratory of the Bureau in Socorro.

One half of each rock sample was crushed to resemble drilling cuttings. "Cuttings" from samples of pre-Pennsylvanian rocks were sent to E. W. Vanderpool for insoluble-residue analyses. The cuttings and rock samples were examined under binocular microscope, and detailed lithologic descriptions compiled; for this report the descriptions have been generalized and condensed into five continuous sections. Thinsections made of selected rocks were studied petrographically. Fossils were identified as closely as the incomplete studies of New Mexico Paleozoic faunas allow. Almost 2,400 polished sections and about 35o thinsections were made of fusulinid-bearing rocks. Columnar sections based on faunas and lithology were prepared, and stratigraphic descriptions written. Other sections in the San Andres Mountains and in other outcrop areas of south central New Mexico were examined for comparison with the herein listed sections. As part of the subsequent geologic mapping of Black Top Mountain and Sowell quadrangles several key horizons were traced from Rhodes to Hembrillo Canyons.

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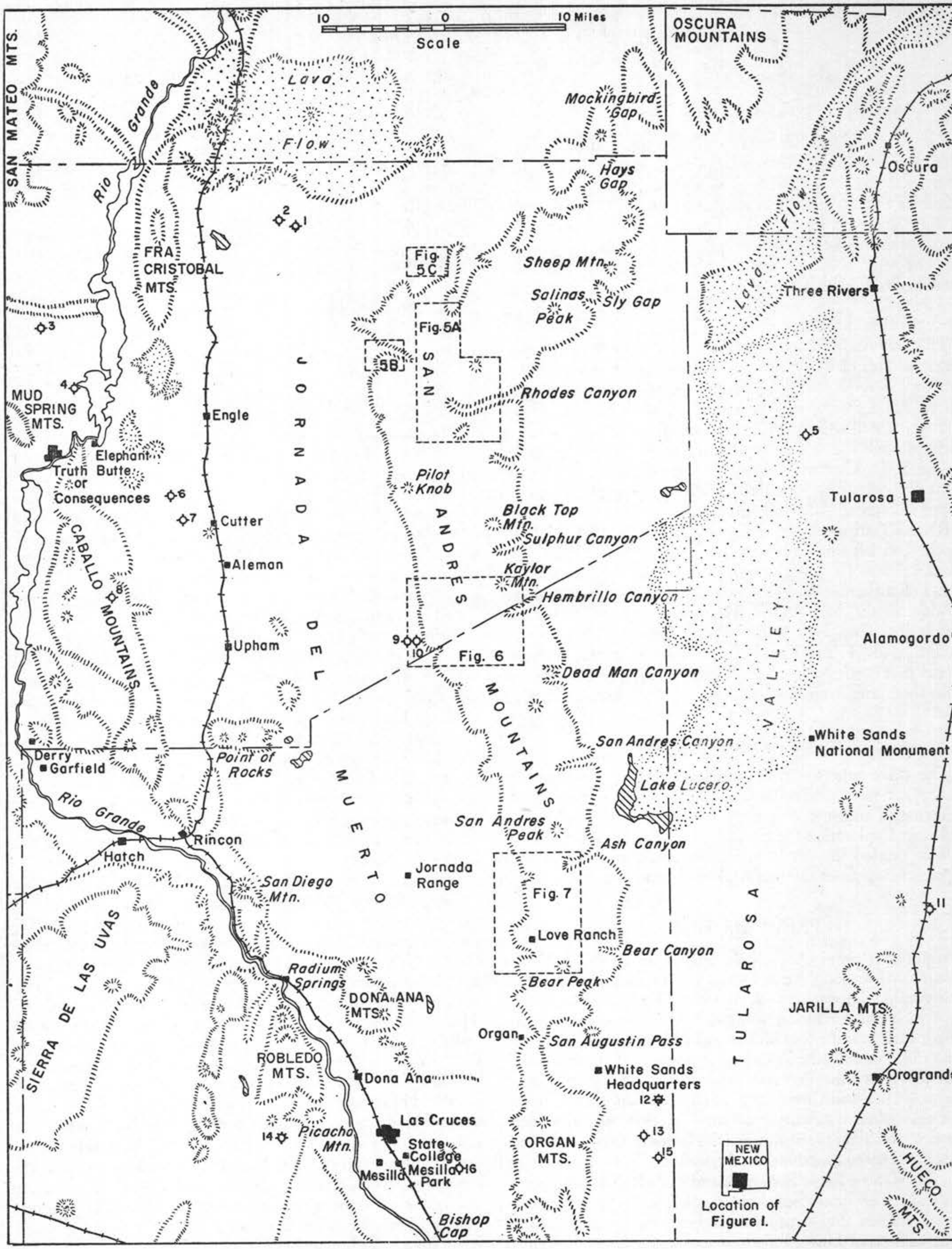

INDEX MAP OF SAN ANDRES MOUNTAINS

Numbered oil tests described in Table 6; areas covered by Figures 5-7 shown with dashed outlines

Figure 1

terms employed to describe lithology is inserted in this report before the descriptions of the measured sections.

ACKNOWLEDGMENTS

The authors are particularly grateful to the oil companies for the financial aid and the impetus which made this project possible. The work could not have been done without the permission of the Commanding General, White Sands Proving Ground; the cooperation of the military authorities is gratefully acknowledged.

The project was under the general direction of Eugene Callaghan, director of the Bureau. F. E. Kottlowski, of the Bureau staff, was party chief and compiled the report, blending written material and the observations and opinions of the four participants. Kottlowski and R. W. Foster, Bureau staff member, measured and made field descriptions of the sections, studied the rock samples in the laboratory, wrote out the detailed lithologic descriptions, drafted the preliminary columnar sections, and studied the well cuttings. R. H. Flower, also of the Bureau staff, measured the Devonian section in Rhodes Canyon and collected, identified, and zoned the megafossils of the Lower Paleozoic formations and of the Yeso and San Andres formations in Rhodes Canyon. M. L. Thompson, of Kansas University, who collected many of the fusulinids and made all of the fusulinid identifications, measured and described the Mockingbird Gap section of Pennsylvanian rocks (pl 1). Alexander Stoyanow, of the University of California in Los Angeles and Arizona University, identified the Cretaceous fossils. E. W. Vanderpool and May-Ion Baker, of the Midland Residue Research Laboratory, made the insoluble-residue analyses. R. V. Shull, K. E. Sorensen, R. N. Cowles, and Byron Nixon, New Mexico Institute of Mining and Technology students, collected most of the rock samples, crushed one set of samples, and assisted the Bureau staff in the field and laboratory.

Special appreciation is due Eugene Callaghan for his guidance and critical reading of the manuscript. At many points the text has profited from his criticism and suggestions. The writers are also grateful for the assistance of Edmund H. Kase, Jr. in the painstaking preparation of the manuscript for final publication.

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Topography and Physiographic Setting

The San Andres Mountains form a narrow, flat north-south arc concave toward the east (see fig 1). A typical cross-section shows an east scarp rising about 3,00o feet above the Tularosa Valley and capped by Desmoinesian Pennsylvanian limestones at elevations of 7,000-8,000 feet. To the west a series of cuestas and strike valleys are cut in upper Pennsylvanian shaly beds and in Hueco and Abo rocks; then come a prominent strike valley in lower Yeso sandstones and a western cuesta capped by San Andres limestones, which dip westward under the Jornada del Muerto plains. Three peaks rise over 8,000 feet: Greer Peak or Silver Top Mountain (8,005 ft), Salinas Peak (8,958 ft), and San Andres Peak (8,239 ft).

About 14 large canyons enter Tularosa Valley from the range, but none cuts completely through to the Jornada plains. The drainage divide is near the west edge of the range owing to the lower elevations of the Tularosa Valley as compared to the Jornada plains. Along parallels of latitude the lowest points of the Tularosa Valley are 400-500 feet below the lowest points of the Jornada plains, and points along the foot of the eastern escarpment of the range are 800-1,300 feet lower than points along the west edge of the mountains. Streams form a rectangular drainage pattern, with major canyons as east-west gashes cut perpendicular to the strike, in many places along fault zones, and with most of the tributary canyons as north-south strike valleys eroded from less resistant beds.

The drainage divide is highest near Salinas Peak; lowest, surprisingly, at the north end of the range; and generally decreases south of Rhodes Pass. Altitudes of passes, from north to south, are: Mockingbird Gap, 5,28o feet; Hays Gap, 5,240 feet; Thoroughgood Canyon (Lava Gap), 5,270 feet; Rhodes Pass, 6,533 feet; Cottonwood Canyon, 6,3 1 o feet; Sulphur Canyon, 5,92o feet; Hembrillo Pass, 5,790 feet; Dead Man Canyon, 5,740 feet; San Andres Canyon, 5,35o feet; Ash Canyon, 5,82o feet; Bear Canyon, 5,795 feet; and San Augustin Pass, 5,719 feet.

The San Andres Mountains are in the Basin and Range physiographic province, in the easternmost part of the Mexican Highland section. The range is a westward tilted fault block in which sedimentary beds dip westward into the Jornada del Muerto syncline. The range is bounded on the east by a major fault zone which closely follows the escarpment overlooking the downdropped Tularosa Basin. Mockingbird Gap, at the north end of the range, is a broad pass in a downfaulted anticlinal axis of which adjacent parts of the San Andres and Oscura Mountains are respectively the west and east limbs. San Augustin Pass, at the south end, is in a coarse-grained, less-resistant phase of the Organ Mountains monzonite batholith.

West of the Jornada are north-south tilted fault-block ranges and graben valleys up to the edge of the Mogollon volcanic plateau. On the east side of the Tularosa Valley is the Sacramento physiographic section of gently tilted fault-block plateaus; beyond are the Great Plains. Southward the north-south trend of the range continues in the Organ and Franklin Mountains but is abruptly terminated at El Paso, where the trend of the basins and ranges becomes northwest-southeast. Northward the general north-south trend continues in the Sierra Oscura and Chupadera Mesa, but these northern fault blocks dip eastward and are bounded on the west by a fault-line scarp.

Stratigraphy

Sedimentary rocks of Precambrian to Tertiary (?) age are well exposed in the San Andres Mountains and range in thickness from about 7,200 feet near Rhodes Pass to about o,000 feet near Ash Canyon. Pre-Tertiary strata, as exposed in the range, are about 7,200 feet thick. In the adjoining basins pre-Tertiary sedimentary rocks may range from 7,200 to 12,700 feet in thickness, south to north. Pre-Pennsylvanian beds thicken southward from 86o feet in Rhodes Canyon to 1,920 feet in Ash Canyon. Pennsylvanian and Permian strata thin southward from 6,200 feet near Rhodes Pass to 5,200 feet near Ash Canyon.

Formations exposed in the range are: Bliss sandstone of Cambro-Ordovician age; the El Paso group of Lower Ordovician age; the Montoya group, composed of Cable Canyon sandstone and Upham dolomite of Middle Ordovician age, and Aleman and Cutter dolomites of Upper Ordovician age; Fusselman dolomite of Silurian age; the Onate formation of late Middle Devonian age; the Sly Gap, Contadero, and Percha formations of Upper Devonian age; the Caballero and Lake Valley formations of Lower Mississippian age, Kinderhookian and Osagian, respectively; the Las Cruces and Rancheria formations of Upper Mississippian, Meramecian, age; Pennsylvanian beds referred to the Derry-Bend series, Des Moines-Strawn series, Missouri-Canyon series, and Virgil-Cisco series; the Bursum formation of lowest Wolfcampian, Permian age; the Hueco and Abo formations of middle and upper Wolfcampian age; the Yeso formation of Leonardian age; the San Andres formation of Leonardian-Guadalupian age; the Dockum formation of Triassic age; the Sarten formation of Lower (?) Cretaceous age; the Dakota (?) sandstone and Eagle Ford formation of Upper Cretaceous age; and the Love Ranch formation of early Tertiary (?) age.

The adjoining structural depressions contain in addition considerable thicknesses of the Mancos, Mesaverde, and McRae formations of Upper Cretaceous age, as well as bolson sediments, volcanic rocks, and volcanic sediments of Tertiary age.

The measured sections and their descriptions should be viewed in proper perspective; each represents just one specific locality and may not show significant lateral changes. Units must be mapped in detail and outcrops walked out to insure that all changes are recorded. The Devonian, Pennsylvanian, Permian, and Cretaceous sedimentary rocks are especially variable within short lateral distances. As a consequence, the writers take the liberty of pointing out regional characteristics of formations which may apply well beyond the confines of the three sections measured in the San Andres Mountains.

PRECAMBRIAN ROCKS

Precambrian rocks crop out in a large area along the lower part of the east-bounding escarpment of the San Andres Mountains. Near the mouth of Ash Canyon pinkish microdine granite predominates, with inclusions and roof-pendants of greenish mica schists. Pegmatite dikes cut the pink granite, as do large, irregular bodies of coarse reddish-brown granite. At the mouth of Rhodes Canyon light-gray orthoclase-microdine granite is most abundant, with included masses of greenish biotite-hornblende schists and black biotite-quartz-feldspar schists cut by unzoned pegmatites and diabase dikes. A coarse phase of the gray granite is marked by large (15-mm) oligoclase phenocrysts. Small masses of pale reddish-brown granite occur not far below the base of the Bliss sandstone.

From Sulphur Canyon to south of Hembrillo Canyon a thick series of metamorphic rocks is exposed, consisting of quartz-feldspar schists and quartzites (both with relic cross-lamination), amphibolite schists, amphibolites, green phyllites, talc, talc schists, and talc argillite. These metamorphic beds were intruded by diabase and felsite dikes and by small masses of gray granite and coarse reddish-brown granite. Foliation of the metamorphic series trends N. 30° W., and dips about 6o° E. In places, just below the Bliss sandstone, a thin light-gray quartzite, with bedding almost parallel to that of the Bliss, overlies the other metamorphic rocks with pronounced angular unconformity. This whitish quartzite was intruded by the pale-pink felsite which in nearby outcrops is truncated by the Bliss sandstone. As the Bliss sandstone in the area is regarded as of earliest Ordovician age, this whitish quartzite possibly may be of Cambrian or late Precambrian age.

The lithologic variation of the Precambrian rocks, especially in the Hembrillo Canyon area, would make magnetic and gravity surveys of adjoining basins difficult to appraise.

Typical of the schists exposed in all three areas, but most common near Rhodes and Ash Canyons, is a fine-grained to aphanitic biotite-hornblende schist, medium-gray to olive-gray, with tiny moderate reddish-orange specks of iron oxides and indistinct, continuous, and undulating foliation. In thin-section an average mineral count is: sodic oligoclase, 41 percent; quartz, 23 percent; biotite, 21 percent; hornblende, 11 percent; sphene, 2 percent; ilmenite, magnetite, apatite, and muscovite, 2 percent. The feldspar averages Ab 82 and is much altered to sericite; minor parts of the green to brown biotite are altered to chlorite; some of the magnetite octahedra are rimmed by hematite. Minerals are crudely alined parallel to foliation. They range from 0.25 to 0.05 mm in length (average about 0.20 mm) and are mostly laths or elongate prisms. The mafic minerals, hornblende, biotite, and iron oxides, tend to cluster together into elongate clots. Sphene, with diamond-shaped crystals common, and apatite are scattered throughout; tiny needles of apatite are especially abundant within quartz crystals.

The light-gray to light-brown granite (pl 5-F) that constitutes most of the Precambrian outcrop near Rhodes Canyon is composed of: microcline, 48 percent; quartz, 24 percent; orthoclase, 13 percent; sodic andesine, 12 percent; and muscovite, 3 percent. Minor amounts of mafic minerals occur as widely scattered clots, chiefly of biotite and hornblende altered to chlorite, calcite, and iron oxides. The feldspars, especially the andesine, are altered in part to sericite and clay minerals. The microperthitic potash feldspars contain tiny short lenses of oligoclase. Quartz occurs as anhedral crystals, as myrmekitic intergrowths in andesine, and as tiny, rounded poikilitic crystals in potash feldspars.

The porphyritic phase of the gray granite near Rhodes Canyon contains large euhedral crystals of calcic oligoclase,

TABLE 2. GEOLOGIC FORMATIONS MEASURED IN SAN ANDRES MOUNTAINS

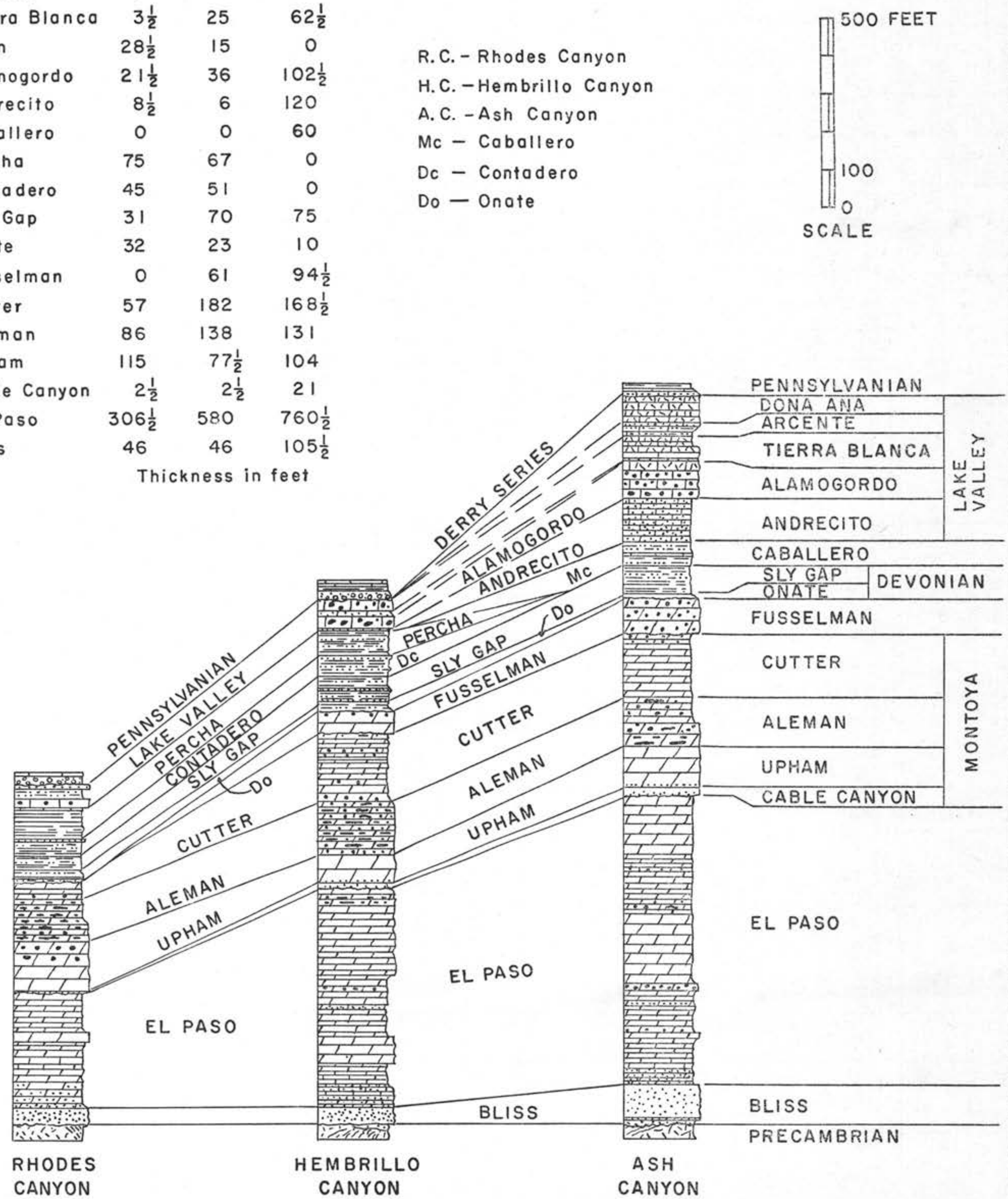
Age	Formation and Member	Thickness (feet) Rhodes Canyon	Hembrillo Canyon	Ash Canyon	Lithology and Remarks
Tertiary (?)	Love Ranch formation	0	0	408-2,100	Interbedded boulder conglomerates and red siltstones
	Angular Unconformity				
Upper Cretaceous	Eagle Ford-Mancos formation	——	——	425	Interbedded and gradational calcareous sandstones and carbonaceous silty shales, olive-gray, with numerous plant imprints and a coal lens; lenses of silty limestones and calcarenites; marine fossils
Upper Cretaceous	Dakota (?) sandstone	40+	——	186	Quartzitic crossbedded light-gray sandstones speckled by limonitic silt; silty greenish-gray nonresistant sandstones
	Angular Unconformity				
Lower Cretaceous (?)	Sarten (?) formation	0	0	95	Intercalated yellowish-brown to purplish silty sandstone, sandy gray fossiliferous shale, fossiliferous brown highly calcareous sandstone, olive-gray calcareous glauconitic sandstone, and black carbonaceous shale
	Angular Unconformity				
Triassic	Dockum formation	52	0	0	Pale reddish-brown calcareous shale, claystone, and siltstone
	Angular Unconformity				
Permian: Guadalupian	San Andres formation Glorieta (?) sandstone	602+	198+	384	Gray to dark-gray, medium-bedded to massive, fetid, petroliferous fossiliferous limestones; friable yellowish sandstone lenses at base may be Glorieta sandstone; near Ash Canyon includes much siltstone and silty sandstones
Permian: Leonardian	Yeso formation	1,579	892	323	Interbedded pale-red, orange, and gray friable sandstones, gray gypsum, calcareous siltstones, and silty fossiliferous limestones; in Rhodes Canyon divisible into, in ascending order, Meseta Blanca (?) sandstone, Torres member, Canas gypsum, and Joyita sandstone
Permian: Wolfcampian	Abo redbeds North / South	835	613	324	Dusky-red to dark reddish-brown shales and calcareous siltstones; lenses of silty fine-grained sandstone; grayish-red calcareous siltstones grade southward into pink to olive-gray calcareous siltstones and then into silty light-gray calcarenites of Hueco formation
Permian: Wolfcampian	Hueco formation	417	325	1,355	Argillaceous limestones, cherty fossiliferous limestones, silty calcarenites, and gray fossiliferous shales; to south basal massive biostromal limestone; reddish shales and calcareous siltstones near top
	Unconformity				
Permian: Wolfcampian	Bursum formation	267	76	0?	Argillaceous silty limestones, gray to purplish shales, and arenaceous calcarenites; at base pebble-conglomerate or conglomeratic sandstone; at top, in Rhodes Canyon, a massive biostromal limestone
	Unconformity				

Pennsylvanian	Virgilian	Panther Seep formation	1,458	1,825	2,390	Silty brown shales, dark carbonaceous shales, dark argillaceous limestones, massive biostromal limestones, silty calcarenites, silty calcareous sandstones; near Ash Canyon two gypsum beds in upper part; near Rhodes and Hembrillo Canyons numerous biohermal reefs
		Disconformity				
	Missourian	Missouri series	195	271	145	Argillaceous limestones and calcareous shales, with medial massive cherty limestones
		Disconformity				
	Desmoinesian	Des Moines series	622	593	183	Massive to medium-bedded, cherty or coquinoid limestones; arenaceous calcarenites at base; argillaceous limestones in upper part
		Disconformity				
	Derryan	Derry series	230	344	107	Calcareous and quartzitic sandstones, arenaceous and silty limestones, and carbonaceous shales; basal chert-pebble conglomerates
		Angular Unconformity				
Mississippian	Osagian	Lake Valley formation: Dona Ana	0	0	70	Massive medium- to light-gray crinoidal coquinoid
		Lake Valley formation: Arcente	0	0	33	Calcareous siltstone and gray limestone
		Lake Valley formation: Tierra Blanca	3½	25	62	Cherty crinoidal limestone
		Lake Valley formation: Nunn	28½	15	0	Silty argillaceous fossiliferous limestones and calcareous shales
		Lake Valley formation: Alamogordo	21½	36	102	Massive cherty dark-gray limestone
		Lake Valley formation: Andrecito	8½	6	120	Silty dark-gray limestone and calcareous shales
		Unconformity				
	Kinderhookian	Caballero formation	0	0	60	Silty calcareous shale, with nodules and lenses of silty limestone
		Disconformity				
Devonian	Upper Devonian	Percha formation	75	67	0 ?	Dark- to grayish-olive calcareous shales and siltstones
		Contadero formation	45	51	0 ?	Calcareous shale, olive-gray; lenses of brown siltstone and silty limestone
		Sly Gap formation	31	70	75	Dark-gray to pale-olive calcareous shale, calcareous yellowish-brown siltstone, abundant fossils
	Middle Devonian	Onate formation	32	23	10	Dark olive-gray to tan calcareous siltstone and shale
		Unconformity				
Silurian		Fusselman dolomite	0	61	94	Massive dolomite, cherty in part
		Unconformity				
Ordovician	Cincinnatian	Montoya group: Cutter dolomite	57	182	168	Light- to medium-gray thin- to medium-bedded dense dolomite
		Montoya group: Aleman dolomite	86	138	131	Medium- to dark-gray cherty dolomite
	Mohawkian	Montoya group: Upham dolomite	115	77	104	Medium dark-gray massive crinoidal dolomite
		Montoya group: Cable Canyon sandstone	2½	2½	21	Light-gray dolomitic pebbly sandstone; shaly and silty in Hembrillo Canyon
		Unconformity				
	Canadian	El Paso group	306	580	760	Medium dark- to light-gray, laminated to massive dolomites; arenaceous and glauconitic in lower part; arenaceous and oolitic beds from 250 to 300 feet above base
		Bliss sandstone	46	46	105	Brown, grayish-green, to dusky red glauconitic calcareous sandstone; oolitic hematite near base
		Angular Unconformity				
Precambrian		Precambrian	----	----	----	Reddish-brown and gray granites, greenish mica schists, quartz-feldspar schists, quartzites, and amphibolites

	R.C.	H.C.	A.C.
Dona Ana	0	0	70
Arcente	0	0	33
Tierra Blanca	3½	25	62½
Nunn	28½	15	0
Alamogordo	21½	36	102½
Andrecito	8½	6	120
Caballero	0	0	60
Percha	75	67	0
Contadero	45	51	0
Sly Gap	31	70	75
Onate	32	23	10
Fusselman	0	61	94½
Cutter	57	182	168½
Aleman	86	138	131
Upham	115	77½	104
Cable Canyon	2½	2½	21
El Paso	306½	580	760½
Bliss	46	46	105½

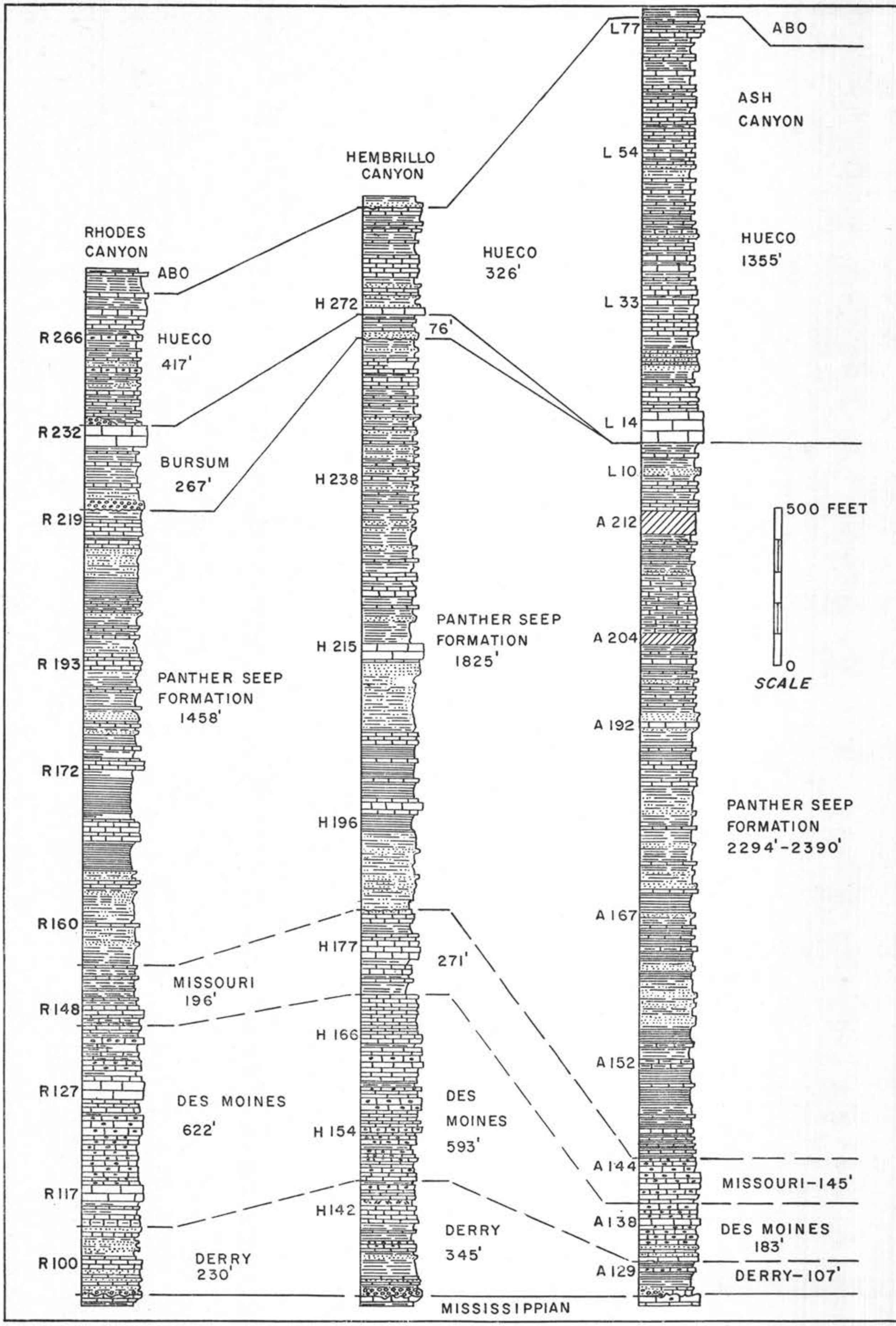
Thickness in feet

R.C. - Rhodes Canyon
H.C. - Hembrillo Canyon
A.C. - Ash Canyon
Mc — Caballero
Dc — Contadero
Do — Onate



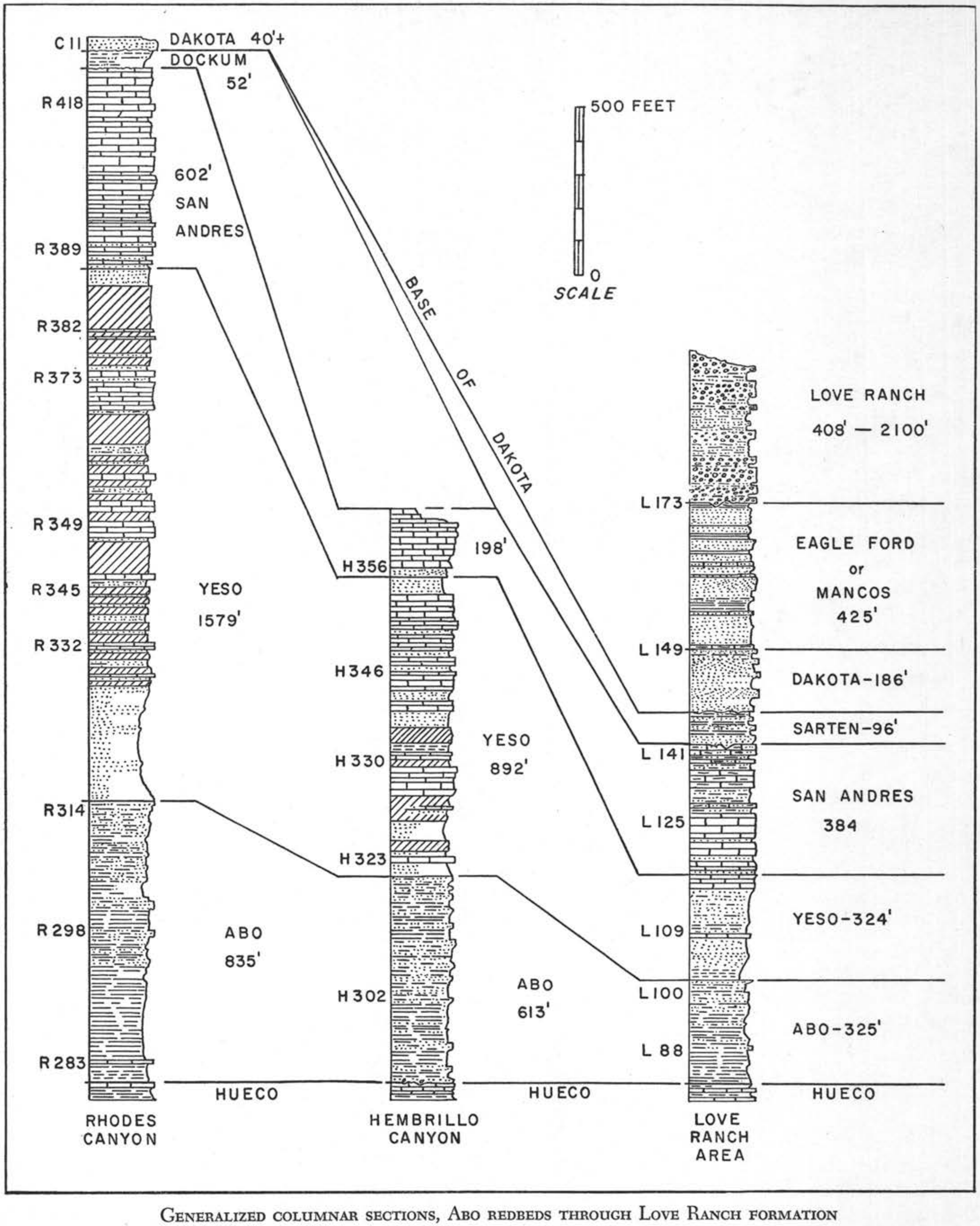
GENERALIZED COLUMNAR SECTIONS, PRECAMBRIAN THROUGH MISSISSIPPIAN

Figure 2



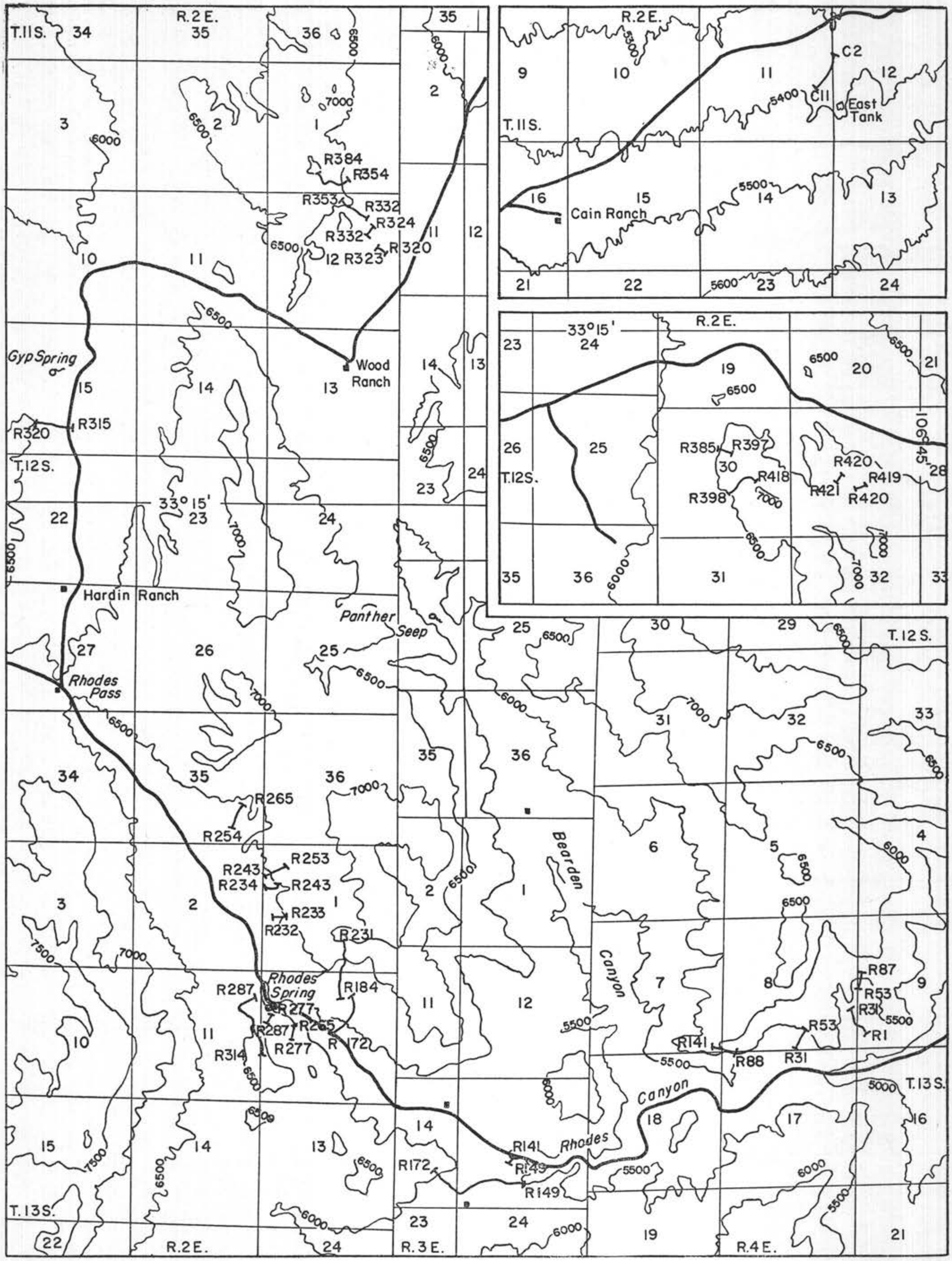
GENERALIZED COLUMNAR SECTIONS OF DERRY SERIES THROUGH HUECO FORMATION

Figure 3



Generalized columnar sections, Abo redbeds through Love Ranch formation

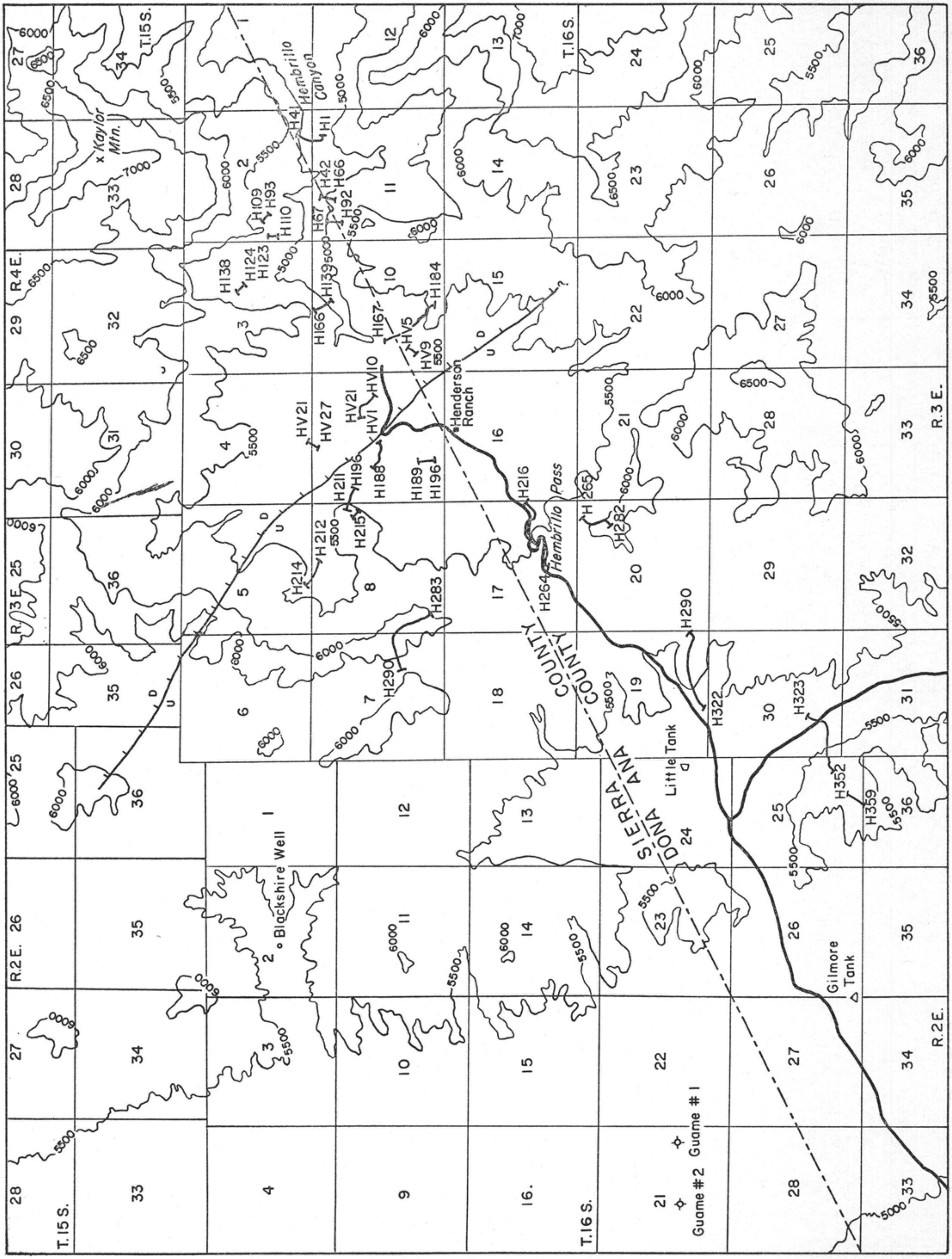
Figure 4



Location of measured section R in Rhodes Canyon and section C near Cain ranch

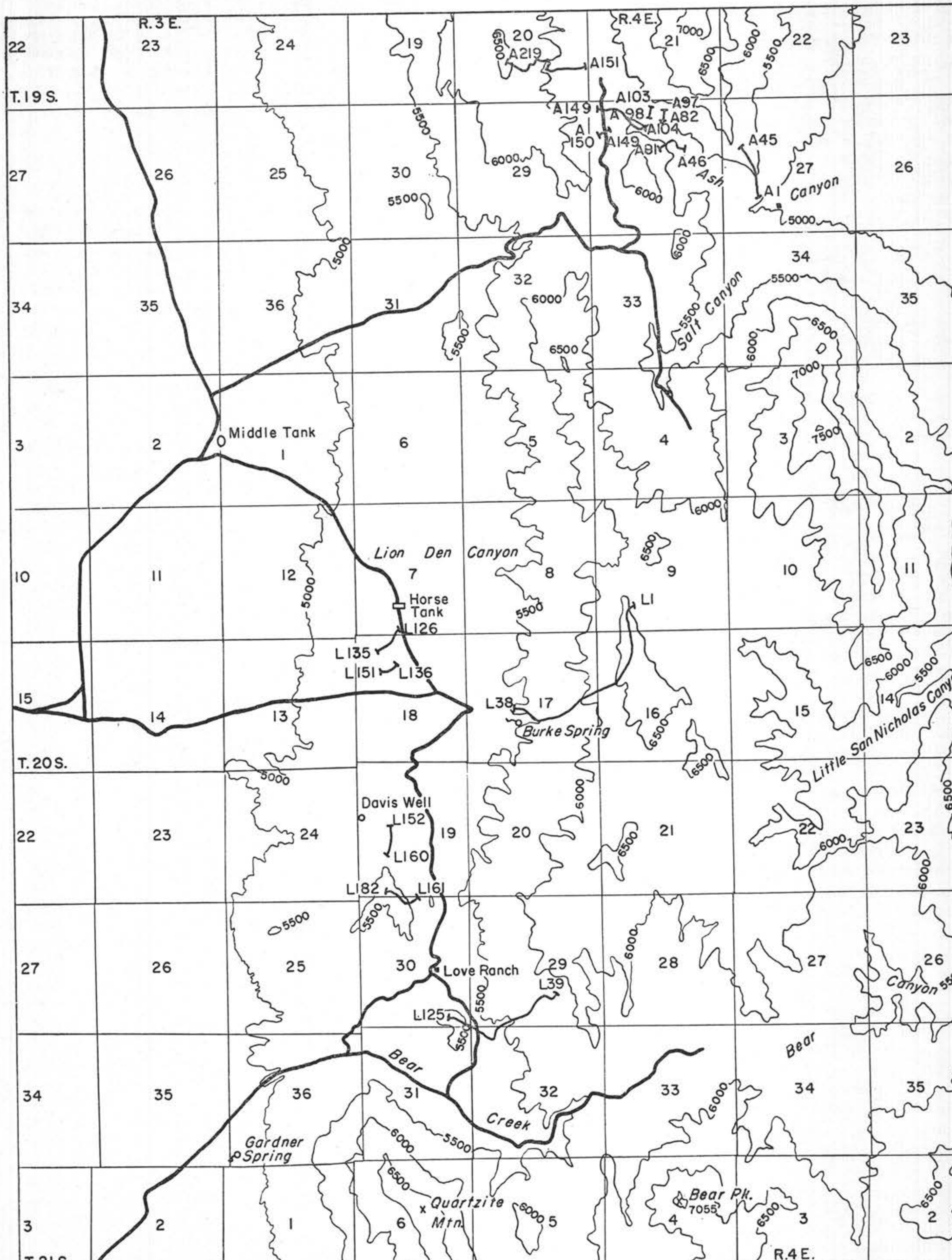
See Figure 1 for location of areas A, B, and C

Figure 5



Location of measured sections H and HV in Hembrillo Canyon

Figure 6



Location of measured section A in Ash Canyon and section L near Love ranch

Figure 7

Ab 75, in a hypidiomorphic-granular, medium-crystalline matrix composed of: orthoclase, microperthitic, 23 percent; quartz, 26 percent; greenish to brown biotite, 10 percent; and muscovite, 2 percent. The oligoclase forms about 39 percent of the rock, and contains tiny poikilitic crystals of quartz, as well as small clots of biotite, hornblende, and sphene. The oligoclase is altered in part to sericite, biotite in part to chlorite, and orthoclase in small part to kaolinite. Apatite laths and euhedral crystals, magnetite cubes, skeletal crystals of ilmenite, and sphene crystals are scattered throughout the rock, although most of the sphene is concentrated in and near biotite.

CAMBRO-ORDOVICIAN SEDIMENTARY ROCKS

The Bliss sandstone, El Paso group, and Montoya group are all considered on the basis of faunas to be of Ordovician age in the San Andres Mountains. At the base of the Bliss sandstone, however, are unfossiliferous beds lithologically similar to those bearing Upper Cambrian fossils in the Caballo and San Diego Mountains. As previously noted (p 5), a whitish quartzite bed cropping out in Hembrillo Canyon, and unconformable below basal hematitic Bliss sandstones, may be of Cambrian age.

BLISS SANDSTONE

The Bliss sandstone crops out as a conspicuous dark-brown ledgy cliff (pl 3-D) along the eastern front of the San Andres Mountains and contrasts with the light-brown to reddish concave slopes of the underlying Precambrian rocks and the overlying light-brown ledgy slope of El Paso strata. The type section is in the Franklin Mountains, where the formation was originally assumed to be of Cambrian age on the basis of the brachiopod *Lingulepis* (Richardson, 1909, p 3). Cloud and Barnes (1948, pp 68, 74), however, noted the large Gasconade fauna from the Bliss sandstone in the Van Horn region of southwest Texas and thus regarded the Bliss sandstone to be of early Ordovician age.

Examination of the sections of Bliss sandstone in New Mexico has showed two discrete faunal zones representing two periods of deposition, a lower zone of late middle Franconian age containing Cambrian fossils, and an upper zone of early Ordovician age. Basal Canadian beds are typically prominent coarse-grained crossbedded sandstones, slightly calcareous to hematitic, with lateral gradation between the calcareous and hematitic phases. The Cambrian beds of the Bliss sandstone, as compared with those of Ordovician age, are coarser-grained, contain a larger percentage of hematite, are less calcareous, and include yellowish-weathering shaly beds of siltstone and fine-grained sandstone, as well as beds of oolitic hematite ore.

The thick section of the Bliss sandstone at the type locality in the Franklin Mountains is barren for the basal 160 feet, but the upper 80 feet has yielded a meager fauna, chiefly of linguloid brachiopods, dominated by the so-called *Lingulepis,* which will be described as *Lingulella deltoidea* Flower, ms. Absence of a definite lithologic break in the Franklin Mountains section and absence of a Cambrian fauna in the lower beds are considered sufficient evidence by Flower for assigning the type Bliss sandstone to early Canadian age.

Some sections of the Bliss sandstone contain no fossils and lack two distinct lithologic units; it is, therefore, uncertain to which depositional faunal zone they should be attributed. The oolitic hematite beds in the lower part of the Bliss sandstone in the San Andres Mountains sections suggest a possible thinned tongue of Cambrian beds. The absence of Cambrian faunas and the general similarity of the sections to the Bliss sandstone in the Franklin Mountains are the basis for conceding an early Ordovician age for the entire sandstone unit in the San Andres Mountains.

Lithology

Most of the Bliss beds are of quartz sandstone, glauconitic in part, with thin interbeds and lenses of siliceous hematite, arenaceous shale, and arenaceous limestone. Basal beds are of oolitic hematite and pebbly siliceous hematitic sandstone. On a fresh surface the rocks are various shades of red, green, brown, or gray, depending on mineral content; weathered surfaces are similar but darker for most beds. Beds vary considerably in thickness but are mostly thin-bedded and crosslaminated with medium- to thick-bedded lenses.

At Ash Canyon the basal foot of the Bliss is oolitic hematite, but in the two sections to the north basal hematite is intercalated with quartz-hematite sandstone, quartz sandstone, and arenaceous shale. The hematite zone ranges from 5-10 feet in thickness from Hembrillo to Rhodes Canyons. Hematite occurs as solid oolites, in thin shells surrounding quartz grains, as thin laminae of siliceous and calcareous hematite, and as cement. The ratio of hematite to quartz varies greatly both vertically and laterally within the oolitic hematite zone. Thus, in section R, Rhodes Canyon, the basal 3 inches are arenaceous shale overlain by almost 5 feet of relatively pure oolitic hematite, but within 25 feet along the strike the shale and hematite grade into a quartz-hematite sandstone, with only a thin bed of oolitic hematite at the top of the sandstone. The sandstone contains scattered glauconite grains as well as pebbles and cobbles derived from underlying Precambrian rocks. In Hembrillo Canyon the basal 3 feet are siliceous glauconitic sandstone containing scattered hematite oolites overlain by 7 feet of oolitic hematite interbedded with thin crosslaminated conglomeratic lenses of sandstone.

Above the basal hematite zone in Rhodes Canyon is a sequence of highly glauconitic, poorly sorted to well-sorted quartz sandstone, with thin beds and laminae of siliceous hematite and lenses of arenaceous limestone. Quartz grains range in size from silt to very coarse-grained sand, and the sandstone contains scattered small pebbles. Most of the grains are angular, although some of the larger grains are sub-rounded to well rounded and frosted. Glauconite grains are chiefly globular and average 0.1-0.2 mm in diameter. There are minor amounts of micaceous and oolitic hematite, feldspar, magnetite, chert, smoky quartz, pyrite, quartzite, muscovite, chlorite, fossil fragments, calcite, and dolomite; the two carbonates are the most common cement, although glauconite, hematite, and/or silica are dominant cements in some beds.

The beds above the hematite zone in Hembrillo Canyon are similar to those of Rhodes Canyon except for lesser amounts of arenaceous limestone, a larger number of thin siliceous hematite beds, some conglomeratic lenses, and the predominance of silica as cementing material. At Ash Canyon, where the thickest measured section of Bliss sandstone occurs, light-colored, more quartzose, sandstones are predominant, and the friable shaly weathering glauconitic beds are subordinate. The quartz pebbles so common in the sandstones at Hembrillo Canyon are sparse at Ash Canyon and restricted to definite beds. Small limonite grains altered from hematite and glauconite occur scattered throughout the quartzose sandstone.

Thinsections show a higher percentage of calcite and dolomite than is apparent at the outcrop; some of the calcareous or dolomitic sandstones are more than 5o percent carbonates (e.g., beds in R *5,* 9; H 8). All the Bliss beds appear tightly cemented, the cement ranging from almost absent in the well-sorted sandstones to as much as 25 percent in poorly sorted beds. Above the basal hematite zone, hematite occurs chiefly as cement, and in most beds as films on calcite or dolomite; torn and worn hematite oolites continue, however, to the top beds of the Bliss sandstone. Magnetite is most common in lower beds as angular grains with jagged hematite rims. Feldspars are scattered throughout the formation but in only a few lenses make up more than **I** percent; only microcline and orthoclase were seen. In upper beds numerous rhombs have been formed by recrystallization of cement and clastic carbonate grains; the rhombs appear to be chiefly dolomite. The more quartzose sandstones of Hembrillo and Ash Canyons are relatively more poorly sorted and show much secondary growth of quartz in optical continuity with clastic quartz-grain cores. Glauconite in higher beds occurs predominantly as silt-sized grains and as cement (pl 4-F), in contrast with the sand-sized globular grains in lower beds; in some beds much of the glauconite is altered to limonite.

Contacts

The Bliss sandstone overlies Precambrian rocks with angular unconformity on an evenly beveled surface whose observed relief in most places does not exceed a few inches, but locally is as much as 12 feet. Underlying Precambrian metamorphic rocks in places dip (dip of foliation and of lithic units) almost 90 degrees to contact, although locally, as in Hembrillo Canyon, underlying quartzite beds are almost parallel to Bliss sandstones.

The contact of the Bliss sandstone with the overlying **El** Paso strata is gradational, and located at different places by different geologists. In Rhodes Canyon, for example, Darton (1928, p 184) listed only 6 feet as Bliss, apparently limiting the Bliss to noncalcareous sandstones. In contrast, Kelley and Silver (1952, p 228) list 8o feet of Bliss formation in Rhodes Canyon, apparently placing most of the arenaceous beds in the formation. The whole aspect of the base of the lower Canadian section is one of gradual decrease in quartz-hematite-glauconite sand and gradation into the predominantly calcic limestones and/or dolomites of the El Paso group. The implication is strong that physical conditions controlling deposition were relatively unchanged from the Bliss to the basal El Paso, the only essential change being the decrease of quartz sand and glauconite as constituents of the sediments. Gradation is clearly demonstrable in several sections in south central New Mexico where the Bliss sandstone is succeeded by thin beds of limestone not appreciably dolomitized. The sections in the Franklin and San Andres Mountains show much the same apparent gradation, except that in most parts of these sections the calcareous beds have been dolomitized, a change which has altered original lithologies and destroyed most of the fossils that were present.

At the type section of the Bliss sandstone in the Franklin Mountains, the upward gradation was shown to be more apparent than real by Cloud and Barnes (1948, p 368), who found evidence of breaks in deposition. Two thin sandstone beds containing foreign pebbles occur, the lower one on the top of the Bliss sandstone, the upper pebbly bed considerably higher. The two conglomeratic beds are the upper and lower limits of dolomites of Gasconade age in the El Paso group. The lower pebbly lens is similar to the many pebble beds that are common in that part of the section. It is distinctive, however, in containing among the numerous normal pebbles of quartz, sandy dolomite, and dolomitic sandstone a sparse scattering of relatively large pebbles of granite, porphyry, and quartzite, the largest being 6 x 2 x 2 inches, whereas most of the foreign pebbles are 0.5-1 inch in diameter.

Comparison of the Bliss sandstone and lower El Paso group sections in south central New Mexico with the Franklin Mountains section supports this conclusion of breaks in sedimentation at the base of the El Paso group and at the top of the Gasconade interval. The Gasconade zone of the type El Paso section near El Paso is anomalously thin when compared with the thicknesses of the zone in most of the New Mexico sections. The thinness of the Gasconade zone at El Paso is the more anomalous because the other younger zones of the El Paso group thicken from south central New Mexico southward to El Paso. Part of this thinning is clearly due to the absence of the *Kainella-Leiostegium* zone of the Utah sections (Ross, 1951, p 29; Hintze, 1952, p 9), which is present at the top of the Gasconade zone in the Big Hatchet and Caballo Mountains, Cooks Range, and Silver City region. The zone, significantly, is absent in most areas of eastern North America, where Middle Canadian beds overlie Gasconade beds in which the top of the *Paraplethopeltis* zone shows erosional features.

Evidence of a similar hiatus in deposition at the Bliss-El Paso contact is less conclusive. The faunas of the Gasconade zone of the El Paso group are anomalous, and remains are extremely fragmentary, but it is evident that the *Symphysurina* faunas, typical of basal Gasconade beds in the Mimbres Valley and Cooks Peak sections, are lacking in the Franklin and San Andres Mountains. The seemingly gradational Bliss-El Paso contact is consistent with the inclusion of the Bliss sandstone and lower part of the El Paso group as Gasconade and, in the broad sense, as Lower Canadian. The beds with foreign pebbles in the Franklin Mountains section, the anomalous thinness of the Gasconade zone of the overlying El Paso group, and the absence of zones present at this horizon in other areas, suggest actual interruptions in sedimentation both at the top of the Bliss and at the top of the Lower Canadian zone. Without physical evidence of these breaks, there is a deceptive gradation from the Bliss sandstone into El Paso limestones.

For mapping purposes, the distinct change from dark-weathering glauconitic and hematitic sandstones of the Bliss sandstone to the light-colored ledgy arenaceous carbonates of the lower El Paso group is located readily. It may not occur, however, at the same horizon in every outcrop, or may not be picked at the same bed by different geologists, because of the vertical and lateral gradation from sandstone through dolomitic sandstone to arenaceous dolomite. Happily, the possible differences of opinion are negligible in actual application, for the slopes formed by the transitional zone are steep, and the areal differences produced by drawing slightly different contacts are small and would remain so, even when mapped on a much larger scale than that generally used.

In Rhodes and Hembrillo Canyons the top of the uppermost relatively thick bed of glauconitic sandstone was chosen as the contact; at Ash Canyon there is a rather abrupt change from the calcareous sandstone of the Bliss to the arenaceous limestones and dolomites of the lower El Paso strata. In the Mud Springs Mountains Flower has noted that a decrease of quartz sand and glauconite to the level of only minor constituents marks the transition from the Ordovician part of the Bliss to the lower El Paso. In the Franklin Mountains (Cloud and Barnes, 1948, p 368) widely scattered dolomitic sandstone lenses containing sparse pebbles of metamorphic and igneous rocks occur at the base of the El Paso beds.

The section in Hembrillo Canyon illustrates the difficulties in choosing the Bliss-El Paso contact. The basal 46 feet (H 1-8) consists of typical hematitic glauconitic dark-brown-weathering sandstones as herein described. Above this there occurs 31 1/2 feet (H 9-13) of intercalated arenaceous, glauconitic, dolomitic limestones and limy glauconitic sandstone, yellowish to light-gray, the ratio of limestone to sandstone being about 3:1, although lateral and vertical gradation of sandy limestones and limy sandstones makes calculations approximate. Next comes 12% feet (H 14) of very arenaceous limestone, with lenses of limy sandstone, overlain by 10 feet (H 15-16) of arenaceous, glauconitic, hematitic limestone. In the lower part of this last interval is the top of a broken ledgy cliff and the Bliss sandstone top as chosen by Flower, in part on the basis of *Scolithus* in unit H 14. Above, below relatively nonarenaceous limestones and dolomites, is 11 1/2 feet (H 17) of arenaceous limestone, with some glauconite typical of the basal beds of the El Paso group. The basal 59 feet of the El Paso group in Rhodes Canyon and the basal 44 1/2 feet in Ash Canyon are arenaceous and sparsely glauconitic limestones and dolomites. If 46 feet is attributed to the Bliss sandstone in Hembrillo Canyon, the basal arenaceous beds of the El Paso group are 651/2 feet thick, thicker than in Rhodes and Ash Canyons, but it is not expected that sandy facies will follow slide rule proportions.

Thickness

Thicknesses of the Bliss sandstone depend on the basis used to pick the Bliss-El Paso contact and somewhat on who measures the formation. From the 8 feet measured at Mockingbird Gap, the sandstone thickens southward to 17 feet at Sheep Mountain, 46 feet in Rhodes Canyon, 46 or 90 feet in Hembrillo Canyon, 1051/2 feet in Ash Canyon, and 240 feet in the southern Franklin Mountains. North of Mockingbird Gap the Bliss sandstone pinches out in the Oscura Mountains. In the Mud Springs Mountains the Bliss sandstone is about 155 feet thick, with the lower 7o feet bearing late Franconian (middle Upper Cambrian) faunas. Kelley and Silver (1952, p 37) listed 109-138 feet of Bliss formation in the Caballo Mountains; Pray (1954, p 94) measured II feet of the Bliss sandstone in the southern Sacramento Mountains.

Age and Faunas

Faunas collected from the Bliss sandstone in the San Andres Mountains were extremely meager. The so-called *Lingulepsis,* reported from the type section in the Franklin Mountains, proves to be undescribed, and is *Lingulella deltoidea* Flower, ms. This form is common in the Ordovician part of the Bliss sandstone in many New Mexico sections, in the Caballo, San Diego, and Mud Springs Mountains, at Pierce Canyon in the Black Range, and at Tank Canyon in the Animas Hills, near Hillsboro. The same form was collected from units R 4 of Rhodes Canyon and A 8-9 of Ash Canyon. *Girvanella,* also confined to the Ordovician part of the sandstone, was found in Hembrillo Canyon and in unit R 3 of Rhodes Canyon; unit R 3 also yielded a small *Rhachopea,* a Lower Canadian genus. All the fossils collected in the San Andres Mountains are from the upper beds of the Bliss sandstone. The lower unfossiliferous strata contain more hematite and less calcite and/or dolomite, and are coarser grained; they do not appear, however, to be set off sharply from the overlying Ordovician beds.

Other localities in south central New Mexico have yielded more numerous faunas from the Bliss sandstone. The basal beds are attributed to the *Ptychaspis striata* zone of the Franconian (Howell et al., 1944, p 994), which contained *Ptychaspis striata, Chariocephalus* n. sp., and *Lingulella* sp. at San Diego (Tonuco) Mountain, and in addition *Idahoia* sp. and *Billingsella* n. sp. from Pierce Canyon, in the Black Range. The *Prosaukia-Briscoia* zone yielded the above-named genera and a possible *Billingsella.* Fragments apparently of these same forms occur in overlying prominent sandstones, which weather purplish and contain in addition *Westonea.* In most sections these Franconian beds are not more than 5o feet thick.

The Ordovician part of the Bliss sandstone has yielded *Dictyonema fiabelliforme* var. *anglicum, Symphysurina* (several species), *Apheoorthis melita, Finkelnburgia* sp., and *Bellefontia* sp. *Lingulella deltoidea* Flower, ms., is a very common and characteristic form throughout and is distinguished readily from the linguloids in the Cambrian part of the Bliss sandstone. Small *Girvanella* and cystoid plates are relatively common. Some additional linguloids are found, in particular a small, round ovate form common in a few inches of siltstone, which also yielded the *Dictyonema.* This zone is common to the Caballo, Mud Springs, and San Diego Mountains and Tank and Pierce Canyon sections.

The faunas show distinctly that the Bliss sandstone consists of two units, a lower one of late Franconian age, the *Prosaukia-Ptychaspis* zone, of which the *Briscoia* zone is probably a part, and an upper unit of early Ordovician age, characterized by *Symphysurina,* which similarly dominates the earliest Canadian fauna of Utah, and by *Apheoorthis melita. Apheoorthis* is now recognized as a genus particularly characteristic of the earliest Canadian of western North America.

EL PASO GROUP

Acceptance of group status for the El Paso beds is not predicated on discriminating the Sierrite and Bat Cave subdivisions (Kelley and Silver, 1952, p 42) but rather on the distinct succession of faunas and lithic units as outlined by Flower (1955, p 67). Subdivision of the El Paso group into a lower Sierrite limestone and an upper Bat Cave formation is complicated by the local scarcity or complete absence of the stromatolites that are characteristic of the basal beds of the Bat Cave formation. Stromatolitic beds are almost completely absent in the El Paso group where it was seen in the San Andres Mountains, and dolomitization is an inadequate reason to account for this absence. We have not attempted, therefore, to subdivide the El Paso into the Sierrite and Bat Cave units. Ideally the Sierrite-Bat Cave contact should be placed at the Lower-Middle Canadian boundary, but for practical purposes the lithic definition is insufficient, because although stromatolites may occur at the very base of the Middle Canadian, they are erratic and local in some sections, notably that of the Cooks Range, and may be completely wanting.

The El Paso group in New Mexico can be subdivided into three lithic units of probable formational rank which correspond closely to faunal zones. The lower unit is similar to the Sierrite limestone and contains beds of Gasconade, Lower Canadian age. The middle unit includes limestones and dolomites up to the top of the oolite beds containing faunas of Middle Canadian age. Beds above the oolite are a third upper unit, which has yielded an Upper Canadian fauna. The type section of the El Paso group in the southern Franklin Mountains, as well as sections in the Cooks Range and Florida Mountains, includes beds with a latest Upper Canadian fauna, beds higher and younger than most of the upper beds of the El Paso group in south central New Mexico; this youngest Canadian zone may be distinct enough lithologically to be a fourth formational unit. The El Paso group crops out as a steep ledgy slope throughout the San Andres Mountains. On present scales of mapping it is best treated as a single map unit; so this report does not propose elevation to formations of the lithic and faunal units described.

Lithology

Beds of the El Paso group crop out as a ledgy concave slope (pl 3-D) beneath the Montoya cliff, although in the southern part of the range upper massive beds of the El Paso form discontinuous cliffs. Colors on fresh surfaces range from light to dark gray, with dark gray most common. Weathered surfaces are light brown or light gray. Bedding thicknesses range from less than one inch to massive beds over 6 feet in thickness but average 6-12 inches. The rocks are chiefly limestones that have been vertically and laterally dolomitized and in places silicified; dolomitization is so complete in some of the San Andres Mountains sections that the lithology is atypical of the El Paso group.

In Ash Canyon, where the most complete section of the El Paso group in the San Andres Mountains has been left by pre-Montoya erosion, the following lithologic divisions were noted in the measured section, in ascending order:

I. Units A 11-13, 45 feet; basal laminated to medium-bedded brown to light-gray arenaceous dolomites and limestones, quartzose sandstones, and glauconitic sandstones; some glauconite and mica in all beds; approximates Gasconade zone.

II. Units A 14-21, 115 feet; interbedded limestones and dolomites, medium light- to medium dark-gray, aphanitic to medium-crystalline, laminated to thick-bedded; approximates first endoceroid zone.

III. Units A 22-23, 35 feet; dolomite, medium-gray, aphanitic to fine-crystalline, thin- to medium-bedded; near base a 6-foot interval contains abundant chert nodules; approximates first piloceroid zone.

IV. Units A 24-26, 50 feet; dolomite, oolitic, medium dark-gray, fine-crystalline, thin- to medium-bedded, massive at top; 10-foot arenaceous zone near middle.

V. Units A 27-32, 225 feet; dolomite, medium- to medium light-gray, fine-crystalline, massive-bedded; scattered dark-gray chert nodules in lower cliff-forming beds; lower 85 feet are of *Mcqueenoceras* zone.

VI. Units A 33-38, 145 feet; dolomite, medium- to medium dark-gray, aphanitic, thin- to medium-bedded; scattered nodules and lenses of dark-gray chert at base and near middle.

VII. Units A 39-45, 150 feet; dolomite, medium dark-gray, fine-crystalline, massive-bedded; top of second piloceroid zone is near middle of unit.

In Hembrillo Canyon division I is about 65 feet thick, division II thickens to 135 feet, and division III thickens to 70 feet. Division IV, the oolite horizon, is 50 feet thick but includes 25 feet of nonoolitic arenaceous dolomite in the lower part. Above is about 200 feet of dolomite similar to division V, but thin- to thick-bedded. Only the lower part of division VI, about 60 feet thick including basal cherty beds, is present.

In Rhodes Canyon lithologic divisions I-III are of about the same thickness as in the other two sections. Division IV, the oolite horizon, is poorly developed and thinner, whereas only the lower part of division V has been left by pre-Montoya erosion.

The basal arenaceous dolomites, limestones, and carbonate sandstones are partly recrystallized calcarenites, with much angular to subrounded quartz, scattered feldspar, chiefly microcline, muscovite flakes, calcite, and fossil fragments. Glauconite occurs as grains and cement but is most abundant in basal beds of the El Paso group. Hematite and limonite form dust rims and small aggregates concentrated near dolomite crystals and glauconite grains. Cement and many grains are of calcite and dolomite, with the percentage of dolomite increasing upward in the section.

The typical carbonate rocks of the El Paso group range from those that are a coarse-crystalline mosaic of anhedral to euhedral dolomite crystals to rocks composed of calcite fossil fragments in a cryptocrystalline calcite matrix in which scattered to abundant dolomite rhombs occur. Many of these dolomite rhombs have several growth lines indicated by iron oxide dust which produces a rhomb-within-rhomb structure. The coquinoid limestones contain many laminae and lenses of calcic calcarenite in which angular quartz is abundant. Iron oxides occur as dust rims on dolomite crystals, as tiny scattered grains, and in thin wavy laminae. Even in the totally recrystallized anhedral dolomite mosaics there are scattered to abundant quartz grains, angular to subrounded, silt-sized to fine-grained. Some of the quartz is strained, and some of the larger grains are of laminated quartzite. The dolomitized beds contain irregular patches of chalcedony and silicified fossils, which commonly are separated from the surrounding indistinct mosaic of dolomite crystals by prominent rims of hematite.

The oolitic zone is very arenaceous, containing scattered to abundant, angular to subrounded quartz grains, which are about half the size of oolites in the same laminae. Oolites average about 0.3 mm in diameter and range up to 1 mm, with a few as much as 2 mm, and down to about 0.1 mm. In oolite beds that have been completely dolomitized only faint dust rims within a subhedral dolomite mosaic outline the recrystallized oolites, but in other beds the oolites are seen as spherical or slightly ellipsoidal forms with concentric banding (pl 4-E). The core in most oolites is anhedral calcite, but in some the core is quartz silt or calcite fossil fragments. Some of the oolite beds contain a small amount of yellowish glauconite altered in part to limonite.

Dolomitization of the El Paso limestones in the San Andres Mountains is erratic and irregular; relatively pure calcite limestone grades vertically and horizontally into solid dolomite in the space of a few inches. There is an abrupt change from) fine-crystalline bluish-gray coquinoid limestone, with scattered tan dolomite rhombs, into (2) a transition zone, several inches thick, of numerous brownish dolomite rhombs and clusters of rhombs in calcite matrix changing in turn into (3) a brownish medium-crystalline mosaic of subhedral to anhedral dolomite crystals, with scattered interstices filled by cryptocrystalline calcite. Calcic beds are relatively dense and have little porosity; the dolomitized parts of the same beds are in most places porous and permeable.

Thickness

The El Paso group thickens southward, by the addition of successively younger beds, from 3o6 feet in Rhodes Canyon to 76o feet in Ash Canyon. As may be noted on the columnar sections (pl r), thicknesses from the base of the El Paso group to the top of the oolite zone, lithic division IV, are almost the same in all four sections, although some irregular northward thinning is indicated. Northward thinning of the entire group appears to be due to pre-Montoya erosion.

North of Rhodes Canyon the El Paso section is progressively thinner, with 285 feet at Sheep Mountain and only about 4o feet remaining at Mockingbird Gap. Kelley and Silver (1952, fig 3) noted 337-470 feet in the Caballo Mountains and o-188 feet in the Fra Cristobal Mountains. Pray (1954, p 94) measured 42o feet in the southern Sacramento Mountains. The type section of the group in the southern Franklin Mountains is 1,355 or 1,590 feet thick (Cloud and Barnes, 1948, p 361).

Upper Contact

The upper contact beneath the Cable Canyon sandstone of the Montoya group is a distinct unconformity, although lacking much local angularity. The change is abrupt from the dolomites and limestones of the El Paso group to the coarse-grained pebbly Cable Canyon sandstone or, in places, a basal sandy zone of the Upham dolomite. Karst topography was developed prior to deposition of the Cable Canyon sandstone horizon in some localities.

The erosion interval was certainly post-Canadian, as the upper beds of the El Paso group in the southern Franklin Mountains are very late, probably latest Canadian. The apparent presence at the base of the Montoya group in some localities in south central New Mexico of scattered remnants of sandstones which are correlative to the Harding-Winnipeg sandstones places the close of the erosion period as no later than early Black River time, and perhaps earlier, as current work suggests that these beds may possibly be as old as late Chazyan. The evident relationships of the El Paso group to the Garden City formation of northern Utah suggest that deposition of the El Paso group may have continued into Chazyan time, but that the sediments later were lost by pre-Montoya erosion, as appears to be true of the correlative Utah sequence.

Age and Correlations

The term Sierrite limestone may be retained conveniently for the Lower Canadian limestones of the El Paso group. Employment of the term Bat Cave formation to embrace **the** remainder of the group may prove too broad a generalization. The El Paso group, together with the related Ordovician part of the underlying Bliss sandstone, constitutes a series of sediments which were deposited throughout the entire Canadian interval. As a preliminary phase of the investigation of **the** El Paso group sediments, which exhibit a vexing lithological similarity, and which yield good fossils only after considerable physical persuasion, a completely empirical zonation was employed for the New Mexico sections; this has been found to hold amazingly well. The general succession is as follows, in ascending order:

1. Sierrite limestone, of thin-bedded calcilutites with undulate bedding planes; Lower Canadian, part of Gasconade interval. The fauna is meager: *Symphysurina, Lytospira gyrospira, Girvanella,* and some small brachiopods.
2. More massive limestones, with some calcarenites in the Cooks Range and local shale lenses in the Big Hatchet Mountains; the occurrence of a more advanced and more varied trilobite fauna marked by *Leiostegium* and *Kainella.*
3. First endoceroid zone, marked by lenses of limestone pebble-conglomerates at the base. Stromatolite reefs, massive calcilutites, pebbly beds, and some coquina calcarenites characterize this zone, particularly the basal beds. The first appearance of long, thin, straight endoceroid siphuncles is a conspicuous feature; the fauna, however, is large and is particularly characterized by *Diaphelasma* and a low-spired gastropod which has generally been misidentified as Raph*istoma trochiscus.* The zone is widespread in southwestern New Mexico and is found in the Dos Cabezas Mountains of southeastern Arizona. Small *Ophileta* and Ozarkispira give this fauna a Lower Canadian aspect which has proved completely deceptive, but which perhaps should be expected in lowest Middle Canadian beds. Sponges are extremely rare.
4. First piloceroid zone, of more massive, reefy stromatolitic beds, marked by the curved and rapidly expanding piloceroid cones, large endoceroids, coiled cephalopods, and sponges. In most places the sponges are silicified and weather from the rock, showing a reticulate structure, and have been mistaken for bryozoa. Bryozoa are not known from the El Paso group and rarely are found in strata as old as the Canadian.
5. Oolite zone, of thin-bedded, dark-gray oolitic limestone, with interbeds of dark-gray to blackish calcilutites, in some layers of which are small algal nodules. The large fauna is as yet undescribed; the most common forms are asaphid trilobites superficially resembling *Leiostegium,* a genus characteristic of considerably older strata, a low-spired and a high-spired gastropod, and small annulated orthoconic cephalopods. No obviously similar faunas have been reported from either the eastern North American sections or those of the Cordilleran region.

These five lower zones are generally recognizable throughout southern New Mexico and represent the Lower and Middle Canadian. The Upper Canadian remainder of the section is more variable; evidently interfingering facies play a more important role and produce many local variations. The following continuation of the section of the El Paso group is generalized, based primarily upon the sections in the Big Hatchet Mountains and Cooks Range:

6. Mcqueenoceras zone of massive algal reefs, relatively barren faunally, but yielding a large, characteristic *Orospira.* Locally small *Mcqueenoceras* are found. Sponges are common but poorly preserved.
7. Thin beds of calcilutite filled with hoards of tiny gastropods and small worm borings, a typically "bird's-eye" limestone reminiscent of the Lowville limestone of New York.
8. Second piloceroid zone, of more massive, coarser crystalline limestones, with some layers of dark-gray calcarenite

reminiscent of the oolite below, but never with large oolites; the dark-gray beds form relatively thin lenses between the gray limestones.

9. Thin-bedded limestone, with many "bird's-eye" beds similar to zone 7, but with a more varied and more advanced fauna, which has largely defied extraction adequate for identification.

o. Third piloceroid zone, with a repetition of massive-bedded limestones. Reefs of stromatolites and sponges occur, which are commonly found in the second piloceroid zone.

Cloud and Barnes (1948, pp 361-369) measured and described the type section of the El Paso group in the southern Franklin Mountains. Their divisions have proved of exceptional value; further detailed work by Flower has resulted in only the most minor revision of their section. The type section of the El Paso shows several significant features not found in the New Mexico sections. There are persistent units which are typically dolomite instead of limestone. In most of the 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. Sand occurs as a dominant, and indeed a conspicuous, element at several horizons, in particular at the base of the oolite zone, at the base of the Upper Canadian, and again at the base of the highest Upper Canadian, which is faunally and lithologically distinct from underlying beds.

A summary of the El Paso group near El Paso, using the units designated by Cloud and Barnes (1948, pp 361-369), is as follows, in ascending order:

Zone A, predominantly dolomite, with arenaceous beds:

25-27 Dolomites of Lower Canadian age.

23-24 Dolomites containing fauna of the first endoceroid zone.

21-22 Limestones, reefy below, alternating with dolomites above; a much enlarged unit representing the first piloceroid zone.

18-2o Units difficult to differentiate, but including: (I) dolomites probably belonging with the underlying beds of unit 21; (2) sandy dolomites at the base of the oolite zone; (3) the oolite beds, dolomitized but still showing oolitic texture and yielding a few silicified fragmentary forms recognizable as characteristic of the oolite horizon.

Zone B, predominantly limestone:

17 Massive dolomite, sandy at the base, weathering to a brown, conspicuous horizon. Above are cherty dolomites, originally a stromatolite reef, containing endoceroids, of which *Mcqueenoceras aculiferum* and M. *mediate* are the most common. Other genera occur, including *Clitendoceras* and *Lobosiphon.*

16 Limestones and dolomites, with a meager fauna of Jefferson City-Honeycut aspect.

11-15 Limestones; top chosen largely on basis of thickness, as equivalent to the maximum known thickness of the Honeycut of the Llano uplift. The basal 6o feet is made up of massive stromatolite beds replete with *Archaeoscyphia* and silicified endoceroids. A large fauna is evidently present, but representatives of other groups usually are not silicified and almost defy extraction. Above are thick beds of very hard limestone, some quite dark-gray, containing piloceroids, the lithic equivalent of the second piloceroid zone of south central New Mexico. These beds grade up into thinner bedded limestones intercalated with shale lenses, which are, in most places, covered with rubble. There follows a second succession of reefy beds, less massive, with a more advanced fauna, massive beds with the aspect of the second piloceroid zone, and thin-bedded, largely barren limestones with shaly limestone interbeds. Unit 12 is the third major reef limestone. The anticipated third repetition of this tripartite cyclic series of beds is obscured by dolomitization. Large sparse quartz grains occur near the top, and a prominent brown-weathering sandy zone marks the inception of the next interval.

8-10 Dolomites; basal beds sandy; upper beds with some blackish layers yielding a characteristic silicified fauna of gastropods, cephalopods, and a pelecypod. Amazingly, this is the only horizon in the section which has yielded common and abundant gastropod operculae known under the generic name of *Ceratopea.*

7 Dominantly very thin-bedded limestones, with a few beds and lenses massive-bedded. Calcarenite beds at about the middle yield silicified *Hesperonomia.* Lenses throughout the interval have yielded a large fauna of cephalopods, gastropods, sponges, brachiopods, and trilobites. *Pseudocybele* seems to be particularly characteristic of the upper layers, which are here characterized by abundant vermicular and nodular reddish-brown to orange-weathering chert.

Unit C, inequigranular shell-limestones, shale, and minor dolomite:

1-6 Thin-bedded limestones, which apparently grade up into orange to tan-weathering shaly limestones interspersed with calcarenites. A large association, dominated by brachiopods and trilobites, characterizes this horizon.

In terms of characteristic fossils Cloud and Barnes (1948, p 74) subdivided their measured section into the following zones: A, zone of *Diaphelasma;* B, zone of *Ceratopea* and *Archaeorthis,* divided into lower subzone (B1) of *Orospira* and *Xenelasma,* middle subzone (B2a) of *Polytoechia,* and upper subzone (B2b) of *Polytoechia* and *Hesperonomia;* C, zone of *Syntrophopis magna.*

Correlation of the type El Paso section with the New Mexico sections is adequate for the lower beds, but from the base of the Jefferson City equivalent (unit 6) upward precise correlation has not as yet been possible. The first tripartite cycle of reefy, massive, and thin-bedded limestones contains the fauna of the second piloceroid zone of south central New Mexico. The higher beds of the New Mexico sections lack good faunas, so that further correlation is not possible from the evidence now available. It is believed, however, that the highest beds extend at least as high as the third reefy zone (unit 12 of Cloud and Barnes), and there is a strong suggestion that upper cherty beds in the Florida Mountains and Cooks Range may be equivalent to units 7-10 (B2b). The brown-weathering sandy dolomites which mark so conspicuously the base of B2b in the southern Franklin Mountains are not present, however, in the New Mexico sections—similar to the absence in New Mexico of the sandy facies that marks the base of the Jefferson City equivalent at the type section.

In the San Andres Mountains the lowest zone of the El Paso group, the Gasconade portion, is 63 feet, 5o feet, and

48 feet in thickness in the three sections from Ash Canyon northward. Fossils identified from this zone *are: Lytospira gyrocera* (H 16), *Finkelnburgia* cf. *F. obesa* (H 18), and *Tetralobula texana* (H 18, R I).

Compared with other sections in south central New Mexico the Gasconade zone is relatively thin, and the pebbly beds observed in the southern Franklin Mountains suggest that the thinness is due to two appreciable diastemic breaks, one at the base, the other at the top of the zone. The underlying Bliss sandstone thins northward from the Franklin Mountains, as does the Gasconade zone of the El Paso group. The latter thinning, however, is more gradual; from 8o feet near El Paso to 48 feet in Rhodes Canyon, as compared with the Bliss sandstone's thinning from 240 feet to 46 feet at the same localities. The overlying *Kainella-Leiostegium* zone is apparently absent in the San Andres Mountains.

The first endoceroid zone, at the base of the Middle Canadian, is dolomitized in most of the San Andres Mountains sections, but it appears to be 102 feet, 45 feet, and 8i feet in thickness in the three measured sections from south to north, as compared with only 65 feet in the southern Franklin Mountains. The boundary between the first endoceroid zone and the overlying first piloceroid zone is not precise, as the upper part of the endoceroid zone may grade up into relatively barren strata, above which the fauna of the first piloceroid zone appears. The two zones together range without pattern from i31 to 145 feet thick in the San Andres Mountains sections but thicken to the south to 195 feet near El Paso. The sections which show an anomalously thin first endoceroid zone also indicate an anomalously thick first piloceroid zone.

Fauna collected from the first endoceroid zone includes the endoceroid siphuncles of *Platysiphon* and *Kirkoceras,* trilobites, gastropods (including *"Raphistoma trichiscus,"* which is neither a true *Raphistoma* nor actually of that species), *Ophileta, Ozarkispira,* the brachiopod *Diaphelasma pennsylvanicum* (which is commonly silicified), a small undescribed sponge, and some cystid plates.

The first piloceroid zone is about 29 feet, 100 feet, and 5o feet in thickness in the three sections from Ash Canyon northward, compared with a thickness of 105 feet in the southern Franklin Mountains, in which section there is 25 feet of barren beds between the first piloceroid zone and the underlying first endoceroid zone. Diagnostic *Bisonoceras* and *Piloceras andersoni* Flower, ms. were collected from the first piloceroid zone. The first endoceroid and piloceroid zones in the San Andres Mountains differ from corresponding zones in many other sections in New Mexico in respect to the almost complete absence of stromatolitic beds and the sparseness of sponges. There is 15-20 feet of thin-bedded barren dolomite in Hembrillo Canyon (H 25) between the first piloceroid zone and the oolitic beds, 45 feet of barren beds in the type section of the El Paso group, and perhaps as much as 43 feet barren in Rhodes Canyon. Middle Canadian beds below the oolite zone are 131 feet, 165 feet, and 174 feet in thickness from Ash Canyon northward, but thicken southward to 240 feet in the southern Franklin Mountains, and thin northward to 145 feet on Sheep Mountain.

The oolite zone is transitional downward into the first piloceroid zone, so that the base is somewhat empirical. The anomalous nature of the numerous and varied fauna, chiefly of small fossils, which is unlike that in beds above or below, and which seems to have little in common with anything in the Garden City formation of the Utah sections, makes dubious the assignment of this oolite zone to Middle or Upper Canadian. Middle Canadian assignment rests on the presence of a rather sharp upper contact with overlying beds, at which horizon there is a sandy zone more persistent than that found at the base of the oolite zone. Quartz sand has been found only sparingly at the base of the oolite, and only in the southern Franklin Mountains are the sandy beds conspicuous. The oolite beds appear to decrease gradually in thickness from south to north, but dolomitization of the beds obscures the zone's contacts and leads to variance in estimates of thickness.

Fauna of the oolite zone in the San Andres Mountains has been mostly destroyed by dolomitization, but the trilobites *Isoteloides ?* and *Hystericurus,* planispiral gastropods, and small straight cephalopods representing the Baltoceratidae and Protocycloceratidae were collected.

The Upper Canadian zones in the measured sections fail to show any great uniformity. Facies changes appear to account for a good part of the variation in lithology and faunas from one section to another. The beds above the oolite zone in Rhodes Canyon are relatively thin-bedded dolomites, in which original features have been obscured by dolomitization. There are suggestions of stromatolitic beds, some unidentifiable fragments of endoceroid siphuncles, the sponge *Calathium,* and, near the top of the El Paso group strata, fragmentary silicified brachiopods, probably *Archaeorthis.* Clearly the fauna of the second piloceroid zone is not attained.

The basal Upper Canadian zone in Hembrillo Canyon is similar in lithology and fauna to the correlative zone in the Franklin Mountains marked by *Mcqueenoceras.* Scattered lenses containing sparse quartz sand occur in places at the base of this zone, which is marked within the massive beds by vertical masses of stromatolites, not over 5 inches across and closely packed together. Accompanying the stromatolites are small silicified siphuncles with *Mcqueenoceras* as the dominant form; also *Lobosiphon* and *Clitendoceras.* Above the *Mcqueenoceras* zone in Hembrillo Canyon is 110 feet of thin-bedded barren dolomites grading up into medium-bedded ledges of the upper 125 feet of the El Paso group, which contain the fauna of the second piloceroid zone. These upper beds correlate with the massive reefy beds having the same fauna in the southern Franklin Mountains, the lower 15o feet of Cloud and Barnes' (1948, p 365) unit 15. The beds of the zone in the section near El Paso are considerably thicker, are of extremely massive stromatolitic limestones in the basal 6o feet, and are quite different lithologically, compared with the beds of the zone in Hembrillo Canyon. True stromatolitic beds in Hembrillo Canyon are confined to five or six widely separated layers 2-3 inches thick. Farther west in New Mexico, where this zone occurs, it normally lacks any stromatolitic materials and in most places consists of very massive beds.

The Upper Canadian in Ash Canyon consists of a lower 85 feet attributed to the *Mcqueenoceras* zone; then 285 feet of relatively barren dolomites, with the lower 190 feet massive-bedded like the beds of the *Mcqueenoceras* zone, but with very sparse chert; and the upper 95 feet of thinner bedded dolomites, with scattered cherty beds. Forming the upper 145 feet of the section are medium- to massive-bedded dolomites, with the top of the second piloceroid zone at about the middle of the sequence. The uppermost beds yielded *a Tarphyceras* similar to a form found in the second of the three reefy beds in the Upper Canadian of the southern Franklin Mountains.

Strata of Upper Canadian age in the El Paso group decrease in thickness northward from 975 feet near El Paso to 515 feet in Ash Canyon, 270 feet in Hembrillo Canyon, and 60 feet in Rhodes Canyon. Erosion at the top of the El Paso group is clearly responsible for this northward decrease in thickness. The thicknesses of the various Canadian zones in the El Paso group and Bliss sandstone can be compared as follows:

TABLE 3. COMPARISON OF CANADIAN ZONES IN EL PASO GROUP AND BLISS SANDSTONE

Zone	Southern Franklin Mountains Thickness (feet)	Southern Franklin Mountains C. & B. Units*	C. & B. Zones*	Ash Canyon Thickness (feet)	Hembrillo Canyon Thickness (feet)	Rhodes Canyon Thickness (feet)	Utah Zones
Uppermost fauna	335	1-7	C, B2b	0	0	0	J-K
Third piloceroid	90	8-10	B2b	0	0	0	I
Total late Upper Canadian	425			0	0	0	
Middle Upper Canadian	250	11-14	B2a	70	0	0	
Second piloceroid	190	14-15	B1, B2a	75	125	0	H
Thin-bedded, barren	40	16	B1	285	110	0?	
Mcqueenoceras	70	17	B1	85	35	60?	G2
Total Upper Canadian	975			515	270	60	
Oolite	60	18-19	A	51	50	25	G1
Barren	45	20	A	0	20	43?	
First piloceroid	105	21-22	A	29	100	50	F
Barren	25	22-23	A	0	0	0	
First endoceroid	65	23-24	A	102	45	81	E
Total Middle Canadian	300			182	215	199	
Total Middle Canadian below oolite zone	240			131	165	174	
Leiostegium-Kainella	absent			absent	absent	absent	D
Gasconade	80	25-27	A	63	50-94	48	B, C
Ordovician Bliss	240			106	90-46	46	A?, B
Total Lower Canadian	320			169	140	94	
Total El Paso Group	1355			760	535-580	307	
Total Canadian	1595			866	625	353	

* Cloud and Barnes, 1948, pp 361-369.

vine, and Black Rock of the Missouri section unrepresented. Although the Missouri section of Canadian beds has largely been recognized as a standard section with which other Canadian sections are compared, the faunas of the upper formations are still inadequately known; indeed, the published descriptions of the formations are of only varying adequacy. For this reason, definite Cotter and Powell zones have not as yet been recognized in the El Paso section. The upper beds, subzone B213, contain a fauna which is clearly correlated with that of the Smithville limestone of Missouri and the

Regional Relationships

The El Paso group as developed in southern New Mexico and southwestern Texas is clearly continuous with the Ellenburger group. It was also originally continuous with the Manitou limestone of Colorado and the Garden City formation of Utah. The upper part of the Abrigo limestone in the Dos Cabezas Mountains of southeastern Arizona is correlative with the first endoceroid zone of the El Paso group, and the Longfellow limestone of the Clifton-Morenci area of southeastern Arizona is correlative at least with that zone and perhaps with younger beds of the El Paso group. The El Paso group is a link between the midwestern and eastern Lower Ordovician sections, in which the faunal succession is based primarily upon molluscs, and the Utah sections, in which trilobites are the principal zone indicators.

Cloud and Barnes (1948, pp 72-75) have indicated correlations of the type section of the El Paso group with the Canadian section in the Llano uplift of Texas, and their work requires no emendation. Probably, however, the Llano uplift Lower Ordovician section extends not quite to the top of the Jefferson City beds, leaving the Cotter, Powell, Smith-

Fort Cassin formation of New York. The upper shaly beds, zone C, were among the first known to contain a late Canadian fauna of abundant trilobites and brachiopods, and it is not surprising that some geologists considered these beds to be Chazyan in age, equivalent to lower Simpson group strata. Ross (1951) and Hintze (1952), however, described similar trilobite assemblages from the upper beds of the Garden City formation of Utah and made known for the first time North American trilobite faunas of very late Canadian age.

Correlation and recognition of regional relationships with the Garden City formation of northern Utah are as yet very incomplete. The faunas collected by Ross (1951) and Hintze (1952) from the Garden City formation are largely of trilobites and a few brachiopods. In contrast, the limestones and dolomites of the El Paso group contain few trilobites, and those present are in most cases poorly preserved, as are the brachiopods. Zones A and B of Ross (1951, p 29), of which only zone B is definitely recognized by Hintze (his *Symphysurina zone; 1952,* p 6), are correlated with the Ordovician part of the Bliss sandstone and the lower two-thirds of the Gasconade zone of the El Paso group. *Symphysurina* occurs in both the Ordovician Bliss and lower El Paso beds, along with numerous *Apheoorthis melita* in the Ordovician Bliss zone.

The beds in the El Paso group at the horizon where zone C should be are largely barren, so that the zone is not as yet recognized. Hintze (1952, p 8) regards this as the zone of *Parapletbopeltis ?* . Flower concludes from unpublished evidence that *Parapletbopeltis* is not a pustulose trilobite and questions the assignment of the species from zone C of the Garden City formation to that genus. *Parapletbopeltis* characterizes the upper beds of the Gasconade equivalent, the Tanyard formation in the Llano uplift, and occurs in the same zone of eastern New York.

Zone D, the *Leiostegium-Kainella* zone, is an interval of deposition present in the Big Hatchet Mountains, Silver City area, and Cooks Range, but is absent in the Florida, Franklin, and San Andres Mountains, as well as in all sections to the east. The absence of this zone in the eastern sections is suggested as diastemic by the thinness of the Gasconade interval and the presence of pebbly beds in the southern Franklin Mountains section at the base of the overlying zone.

Correlation with zones E, F, and GI has not yet been possible. In the Garden City formation they are characterized largely by trilobites, which are almost completely wanting from beds in the El Paso group above the *Kainella* zone, insofar as identifiable material is concerned. This appears to be the Middle Canadian interval, which in New Mexico embraces the first endoceroid zone, first piloceroid zone, and oolite beds, correlative with the Gorman formation of the Ellenburger group in the Llano uplift. Almost no trilobites are known from the Gorman formation or its Eastern equivalents. In the past Gorman or Roubidoux equivalents have been recognized by one fossil, *Lecanospira,* which is an Eastern form known as far west as the Llano area, but not in the typical development of the El Paso group. The Middle Canadian age designation of the medial beds in the El Paso group rests upon obvious cephalopods, *Archaeoscyphia,* and the brachiopod *Diaphelasma pennsylvanicum.* Hystricurid trilobites, common to the Lower and Middle Canadian but not definitely known in the upper part, occur in the El Paso group as high as the oolite zone, and are found in zones E and F, but not higher, in the Garden City formation, confirming Ross' (1951, p 32) suggestion that those zones are of Middle Canadian age.

There is as yet little factual basis for correlation between the lower Upper Canadian of the El Paso group and the Garden City beds of Utah. New Mexico sections have yielded only a handful of trilobite fragments; the listed faunas from Garden City zones G2 and H, within which correlation may be expected, consist of specifically determined trilobites and only generic references, some somewhat tentative, for gastropods, cephalopods, and brachiopods.

A thin lens occurring about 10 feet above the oolite zone of the El Paso group in the Pierce Canyon section, Black Range, yielded trilobites, the commonest of which is *Leiostegium* cf. L. *manitouense** (similar to forms from the Manitou limestone of Colorado). This genus has not been recognized in beds as young as any of early Upper Canadian Age in the Utah sections, being reported only from late Lower Canadian, zone D. Cloud and Barnes (1948, pp 37o-371) list the genus from Gorman equivalents.

Correlation of the uppermost Canadian rests upon a better basis, for the upper El Paso group, zones B2b and C, contains trilobites, conspicuous among which is *a Pseudocybele* cf. P. *nasuta,* of zone J of the Garden City formation. When these uppermost Canadian faunas were first noted, they were in the first beds of that age of a shaly limestone facies with faunas of abundant trilobites, brachiopods, echinoderm fragments, small gastropods, and cephalopods. The initial general reaction was to note that the trilobites and brachiopods particularly were similar in aspect to those which had been known previously as Chazyan. Cloud and Barnes (1948, p 363) recognized these beds as late Canadian and noted that while the trilobites seemed to have lowest Middle Ordovician affinities, the high Lower Ordovician trilobites were poorly known, and the brachiopods strongly indicated a high Lower Ordovician age. Subsequently Ross (951) and Hintze (1952) described closely related forms from the Canadian zones of Utah, showing that the pliomerid stock can be recognized not only in the highest beds, but also in beds below, apparently at or close to the base of the Upper Canadian. Although there is still some difference of opinion as to the exact position of the Canadian-Chazyan boundary, late Canadian beds evidently yield a trilobite-brachiopod association which contains forerunners of Chazyan types not previously known in the Canadian. Ross (1951, p 32) would place the Canadian-Chazyan boundary relatively low and regards *Anomalorthis* as a Chazyan type. This genus, however, is known from the Providence Island beds of the Champlain Valley, although its presence in the Swan Creek formation of Utah and the Oil Creek limestone of Oklahoma indicates that it extends properly into the true Chazyan and may be one of several genera which pass this boundary. Correlation of these uppermost beds of the El Paso group with the Smithville-Black Rock and Fort Cassin-Providence Island to the east, and with the upper cherry member of the Garden City formation to the northwest, appears inevitable, but a significant conclusion and more precise correlation must await closer faunal studies. Unit B2b of the Franklin Mountains section contains *Hesperonomia,* known from zones I and J of Utah, and *Phyllograptus,* reported only from zone I (the cephalopod assemblage, however, also suggesting zone J, as does the apparent identity of the common *Pseudocybele* with *P. nasuta).* The overlying beds, unit C of the El Paso group, are shaly limestones with a fauna of brachiopods and trilobites, but the contact with unit B2b appears to be gradational, and some species appear to be common to the two units. Unit C has yielded pliomerid trilobites and cystids similar to *Blastoidocrinus,* which suggests a possible correlation with zone K rather than a part of zone J of the Garden City formation.

***Identified by Christina L. Balk, Bureau staff.**

MONTOYA GROUP

Darton (1928, p 12) subdivided the original Montoya formation of Richardson (1909, p 4) into two members: a lower member of arenaceous limestone and massive limestone, and an upper member of interbedded limestone and chert. Entwistle (1944, pp 16-19), at Boston Hill in the Silver City area, applied the names "Second Value" and "Par Value" to Darton's lower and upper members. He also designated as the Raven member of the Montoya the unit overlying the upper member of the Montoya and below dark-brown-weathering beds assigned to the Fusselman dolomite. This unit previously had been considered as part of the Fusselman, but Entwistle did not mention this prior classification. Pray and Bowsher (1952, p 1342) subdivided the Fusselman dolomite in the Sacramento Mountains and noted Ordovician fossils in the lower member. Kelley and Silver (1952, pp 56-58) revised the definition of Montoya to include the lower Fusselman, raised the Montoya to group status, and called the four subdivisions, from base upward, the Cable Canyon sandstone, Upham dolomite, Aleman formation, and Cutter formation. Pray (1953, p 198) named the lower Fusselman of the Sacramento Mountains the Valmont dolomite; this is in general equivalent to the Cutter formation, which has priority. Actually Entwistle's (1944 PP 16-19) units have priority, but have not been accepted outside the Silver City area.

The lower part of the Montoya group crops out in most places as a dark-weathering cliff composed of the Cable Canyon sandstone, Upham dolomite, and most of the Aleman dolomite. The upper part of the Montoya, the upper Aleman dolomite and the Cutter dolomite, forms a ledgy cliff or steep slope. In most outcrop areas, only the lower Montoya and the Cutter are mappable units, as the El Paso-Cable Canyon, Cable Canyon-Upham, and Upham-Aleman contacts on any map scale will be the same line. The units are distinct lithologic intervals, the justification for group status being that the Lower Montoya is of probable late Trenton and Eden age, and the upper Montoya of Richmond age, leaving a possible hiatus of all or part of Maysville time in the middle (Flower, 1953, p o8).

Cable Canyon Sandstone

Lithology. In Ash and Rhodes Canyons the Cable Canyon sandstone is the basal part of the Upham-Aleman cliff, whereas in Hembrillo Canyon the sandstone is a notch at the base of the cliff. The sandstone is siliceous in Ash Canyon but dolomitic in Rhodes and Hembrillo Canyons. On a fresh surface the sandstone is light to medium gray but weathers moderate to dark grayish brown. Beds range from the thick, hard crosslaminated ledges of Ash Canyon to the shaly bedded silty notch of Hembrillo Canyon. Grains are angular to well rounded and range up to 3o mm in diameter, the average size being 1-2 mm. The grains are dominantly clear quartz, with minor amounts of smoky, brown, blue-gray, and purple quartz, as well as scattered white feldspars and black or light-brown chert. Some of the quartz grains have dull pitted surfaces. In thinsection even the most quartzose beds are seen to contain scattered dolomite as cement and as euhedral crystals that in part replace quartz. The few feldspars are microcline; scattered rounded grains of El Paso limestones also occur. Basal sandy beds of the Upham dolomite are arenaceous dolomitized coquinoid calcarenites.

Thickness. The sandstone is variable in thickness in the Rhodes and Hembrillo Canyons areas, ranging from 2 to 8 feet. It thickens southward to 21 feet in Ash Canyon, although absent farther south in the Franklin Mountains.

Upper contact. In Ash and Hembrillo Canyons the upper contact can be drawn on a bedding plane between the dark-brown-weathering Cable Canyon sandstone below and the overlying medium-gray dolomitic sandstone in the basal part of the Upham dolomite. In places in Rhodes Canyon no visible bedding plane marks the top of the Cable Canyon sandstone, but an abrupt change in color and in percent of quartz grains occurs. Actually, although the basal beds of the Upham appear to be arenaceous dolomites, they contain more than 5o percent quartz grains and should be called dolomitic sandstones. The Cable Canyon appears to be only a basal arenaceous phase of the Upham, with gradation upward from sandstone to dolomitic sandstone to arenaceous dolomite to quartz-free dolomite. In some areas dolomitic sandstone or arenaceous dolomite locally appear higher in the Upham and above relatively pure dolomites. Where quartz grains of sand size make up an estimated 65 percent or more of the basal arenaceous unit, the latter crops out as dark-brown-weathering ledges, is called Cable Canyon sandstone, and appears to be strikingly different from the overlying medium-gray arenaceous beds called Upham dolomite.

Fauna and correlations. Fossils were found in the Cable Canyon sandstone only in Rhodes Canyon, where the unit yielded a poorly preserved *Endoceras* and a large *Maclurina* or *Maclurites.* In other areas in southwestern New Mexico the sandstone bears a fauna composed of *Maclurina, Endoceras, Hormotoma* cf. *H. winnipegensis, Receptaculites, Lambeoceras,* and *Armenoceras,* the specimens being identical to those from the overlying Upham dolomite, which is regarded as late Trenton and Eden in age.

In other sections outside of the San Andres Mountains Flower has noted two different units that have been included in the Cable Canyon sandstone. A lower unit of friable white to light-gray sandstone, not as yet observed to be more than 2 feet thick, occurs in several places as isolated lenses above the El Paso strata and below typical Cable Canyon sandstone or sandy Upham dolomite. This unit Flower believes to be a remnant of sand deposited during early Mohawkian time. Vanderpool, on the basis of insoluble residues, has suggested that the Cable Canyon may be equivalent to the Simpson group, which is in part of early Mohawkian age. The other unit is the typical brown-weathering Cable Canyon sandstone, which is here considered a basal sandy facies of the Upham dolomite.

The sandstone remnants of possible early Mohawkian age probably were once continuous with the Harding sandstone of Colorado, the fish-bearing sandstone beneath the Bighorn group, which is erratically present in Wyoming outcrops and in the Williston Basin subsurface, and with the Winnipeg sandstone of southern Manitoba. The typical Cable Canyon sandstone probably correlates with part of the Lander sandstone of Wyoming and is similar to the basal sandstone of the Lake Winnipeg region, which consists in part of the true Winnipeg sandstone and in part of a basal sandstone of the Red River group.

Regional relationships. The Cable Canyon sandstone appears from our data to thicken southward in the San Andres Mountains from 2 to 21 feet, but Darton (1928, p 184) reported 8 feet in Cottonwood Canyon (between Rhodes and Sulphur Canyons), none in Sulphur and Dead Man Canyons, and 15 feet in San Andres Canyon. The sandstone is not present in the Franklin Mountains, is a few inches to 12 feet thick in the Sacramento Mountains (Pray, 1954, p 96), and varies irregularly from 17 to 35 feet in the Caballo Mountains (Kelley and Silver, 1952, p 58). In the Big Hatchet Mountains about 6 feet of relatively sand-free dolomite occurs beneath the Cable Canyon arenaceous beds. The Cooks Peak outcrops are of a basal 4 feet of sandy dolomite beneath 29 feet of light-gray dolomitic sandstone, with an overlying 10 feet of sandy dolomite transitional into the massive Upham dolomite (Jicha, 1954, p 14). The basal beds of the Montoya group in the Florida Mountains are similar to the Cooks Peak outcrops.

Upham Dolomite

Lithology. The lower 5-20 feet of the Upham dolomite is medium-gray pebbly dolomitic sandstone and arenaceous dolomite. Most of the formation is a medium dark-gray, fine-to medium-, and in some beds coarse-crystalline, massive, crinoidal dolomite, which forms the lower vertical part of the Montoya cliff (pl 3-D). A distinctive feature is the abundance of recrystallized crinoid columnal fragments, in places composing beds having much intergranular porosity. Considerable amounts of dark-gray to light-gray stringers, scattered lenses, and concentrically banded nodules of chert occur locally, as in Rhodes Canyon, in the upper part of the Upham dolomite (unit R 36).

The Upham dolomite is massive, with bedding planes imperceptible or discontinuous. The color mottling typical of this lower part of the Montoya group at its type locality in the Franklin Mountains does not occur in the San Andres Mountains, nor in the Robledo or Caballo Mountains.

The basal sandy beds of the Upham dolomite are dolomitized arenaceous coquinoid calcarenites or dolomitized fossiliferous carbonate sandstones. Some beds, chiefly at the base, contain as much as 8o percent quartz grains, whereas other sandy beds consist of only 20 percent quartz, with about 75 percent dolomitized coquinoid grains. Quartz grains are rounded to angular; minor amounts consist of strained quartz, laminated quartzite, and chalcedonic chert, in addition to scattered microcline grains, numerous recrystallized fossil fragments, and angular to rounded pieces of El Paso limestones. Dust rims, scattered tiny grains, and thin wavy laminae of iron oxides occur within the subhedral to anhedral mosaic of dolomite cement which replaces parts of the silica and feldspar grains.

Most of the Upham dolomite is massive, medium dark gray, and crinoidal. In thinsection (pl 4-D) it is a subhedral to anhedral mosaic of cloudy dolomite, fine- to medium-crystalline, with scattered iron oxide grains, and films and ghosts of fossils, most of which are replaced by relatively coarse-crystalline dolomite (some, however, by a single large dolomite crystal). Relic texture is that of a recrystallized coquinoid crinoidal calcarenite. Calcite veinlets are open-space fillings of coarse crystals with comb structure. Quartz veinlets, however, are short lenses with gradational borders, and include double dolomite rhombs, with rhomb-within-rhomb structure marked by thick iron oxide rims. The quartz is anhedral and appears to have formed during dolomitization.

Upper contact. In Hembrillo and Ash Canyons the basal unit of the overlying Aleman dolomite is a thin (1-3 in.), irregular bed of dark-gray chert, the Aleman dolomite containing abundant chert in contrast to upper beds of the Upham dolomite, which contain only scattered nodules and lenses of chert. In Rhodes Canyon a zone of spheroidal chert occurs in the upper Upham dolomite and a chert zone in the lower Aleman dolomite, with noncherty beds separating the two chert horizons and the main cherty beds of the Aleman dolomite. The contact was picked at the base of the second-lowest cherty horizon, the underlying Upham dolomite being massive and crinoidal and containing chert only in the lowest cherty horizon, whereas the basal Aleman dolomite is thin- to thick-bedded, with distinct bedding planes, and contains laminae of silicified fossils and brown chert.

Thickness. The Upham dolomite varies irregularly in thickness from one section to the next in the San Andres Mountains. The relatively thick section at Ash Canyon, 104 feet, thins at Hembrillo Canyon to *77* feet, thickens again at Rhodes Canyon to 115 feet, and then thins to about 35 feet at the north end of the range. The lithologic subdivisions of the Montoya group as based on the visible presence or absence of quartz sand and chert appear to be facies generalizations not susceptible to precise correlation.

Age and fauna. Dolomitization has obscured most of the fossils in the Rhodes Canyon section of the Upham dolomite. *Receptaculites, Halysites* (probably *Catenipora rubra* Sinclair and Bolton), and poorly preserved *Maclurites* are sparsely scattered through units R 32-34. An imperfectly silicified fauna associated with large spherical chert nodules in R 36 yielded *Sowerbyella, Rhynchotrema,* and *Streptelasma.*

Units H 43-46 in Hembrillo Canyon contained *Halysites, Receptaculites,* small *Streptelasma,* and *Maclurites,* a fauna similar to that in the basal 8o feet of the Upham dolomite in the southern Franklin Mountains. Units H 47-48 yielded fragments of *Rhynchotrema* and *Sowerbyella.*

In Ash Canyon dolomitization is not quite so complete as in the two northern sections, and a larger fauna was found. Units A 47-48 contained numerous *Receptaculites, Maclurites,* small *Streptelasma* like those from Hembrillo Canyon, *Halysites, Peleophyllum,* and *Stromatocerium.* A loose *Actinoceras* from the upper beds is identical with an undescribed form collected from the upper Upham beds in the Mud Springs Mountains.

The faunas of the Upham dolomite in south central New Mexico, as yet unworked in detail, show clearly a facies control. In the Cooks Peak area, for example, the following lithic divisions exist, from base upward: (1) basal massive arenaceous dolomitic limestone, within which the Cable Canyon sandstone is a sandy lens; (2) crinoidal calcarenites; (3) hard aphanitic dolomitic limestones, with few calcarenite lenses; (4) dense limestones that grade up into calcarenites, in most places containing large spheroidal chert nodules; (5) conspicuous whitish crinoidal calcarenite, as yet seen only in the Cooks Peak area. The massive, hard, dense limestones contain a typical Red River association of cephalopods, gastropods, and corals, in which brachiopods are only a minor constituent. The fossiliferous lime sands contain a fauna dominantly of brachiopods and trilobites, along with abundant crinoid fragments. Where the two types of lithologies are intercalated, the two types of facies faunas are intermixed.

The Cable Canyon sandstone and Upham dolomite are best considered to be of the same faunal and depositional unit, a unit equivalent to Entwistle's ([1]944 p 16) Second Value member of the Montoya. The fauna is characterized by species of the Red River fauna, including the corals *Halysites, Foerstephyllum (Columnaria* of most paleontologists), *Streptelasma, Paleofavosites, Calapoecia,* and *Palaeophyllum,* the hydrocorals being represented by *Beatricea* and *Stromatocerium. Receptaculites* is common. Cephalopods include *Endoceras, Actinoceras, Armenoceras, Lambeoceras, Westonoceras, Cyrtogomphoceras, Charactoceras, Wilsonoceras,* Or*thonybyoceras,* and *Gorbyoceras.* Characteristic Red River gastropods include *Maclurina,* a large *Hormotoma* close to *H. winnipegensis, H.* cf. *H. gracilus, Subulites,* and *Liospira.* Brachiopods include some forms similar to Red River types, such as a large nasute *Rafinesquina,* but are chiefly an elongate thick-shelled species of *Rhynchotrema, Sowerbyella,* and *Clitambonites,* with many forms unknown in the Red River faunas. Trilobites are fragmentary asaphids, illaenids, and an *Encrinurus.* The trilobites suggest a Kimmswick fauna, as do the trilobites in the Burnam limestone of central Texas. The brachiopods, however, have their closest affinities in the

Rogers Gap fauna of Kentucky. The "Second Value" faunas suggest an equivalence with those of the Red River formation of southern Manitoba, as well as with those of the late Trenton Cobourg limestone and the Eden group of the eastern United States, intervals which other considerations suggest are actually overlapping and not two successive time intervals, as has been generally believed.

Regional relationships. Thickness depends on which beds are included in the Upham. As illustrated (pl 1), the dolomite varies irregularly in thickness in the San Andres Mountains, although thinning at the north end to about 35 feet. Darton's (1928, p 184) thicknesses in the range also vary erratically; thick in Sulphur Canyon, thin in Rhodes, Hembrillo, and Dead Man Canyons, and thicker in the southern canyons. There is a suggestion of a generalized southward thickening comparable with that in the Caballo and Sacramento Mountains. In the Robledo Mountains, south of the Caballo Mountains and west of Ash Canyon, however, the Upham dolomite is only about 45 feet thick. Clearly the zone of *Rhynchotrema* and *Sowerbyella* associated with sparse to numerous spheroidal chert nodules is present only where the Upham dolomite is relatively thick, as in Rhodes Canyon, and is an upper unit which appears either to have been removed in some areas by pre-Aleman erosion or was not deposited.

Aleman Dolomite

Lithology. The Aleman dolomite is mainly hard, medium dark- to dark-gray, aphanitic to fine-crystalline, thin- to massive-bedded dolomite, with abundant lenses and nodules of chert (pl 2-C). The nodules are mostly small, aphanitic, and dark gray to black. Lenses are less than z inches thick and as much as 20 feet long. Chert in the lower part of the Aleman varies in amount and type from the sparse, thin, brown chert and silicified fossil beds in Rhodes Canyon to the abundant dark-gray to black lenses and nodules found in Ash and Hembrillo Canyons.

Chert lenses impart a thin-bedded or laminated appearance to the Aleman dolomite. Where the chert lenses pinch out, the dolomite continues without a bedding separation to form medium-bedded to massive beds. Varying amounts of the lower Aleman dolomite combine with the Upham dolomite to form a prominent dark-weathering cliff. Upper beds in most places crop out as a steep ledgy slope, although at Hembrillo Canyon the upper Aleman dolomite forms a second, higher Montoya cliff separated by a steep slope from the lower cliff of Upham dolomite (pl 3-D).

The Aleman dolomite is rather uniform as seen in thin-sections, consisting of a subhedral to anhedral dolomite crystal mosaic, with numerous lath-shaped crystals, ghosts of fossils outlined by iron oxides and carbonaceous material, veinlets of somewhat coarse crystals compared to the average size of o.03 mm, and wavy thin laminae of iron oxides. Relic texture suggests dolomitized calcilutite. In places fossil fragments and irregular patches are silicified to chalcedony, which grades into bordering dolomite mosaic and is spotted with dolomite rhombs.

Thickness. The Aleman dolomite is thicker in the two southern sections, being 131 feet thick at Ash Canyon and 138 feet thick in Hembrillo Canyon. It thins to 86 feet at Rhodes Canyon and thickens to 116 feet on the south side of Sheep Mountain.

Upper contact. The change from the medium- to dark gray cherty dolomite of the Aleman dolomite to the lightgray-weathering, slightly cherty, thinner bedded Cutter dolomite is in many places gradational. Scattered chert continues up into the Cutter dolomite in Rhodes Canyon, whereas in the other two canyons relatively chert-free beds appear in the upper part of the Aleman dolomite. The contact was selected at the base of beds having at least several features typical of the Cutter dolomite.

Age and correlations. Faunas are well preserved in the cherty Aleman dolomite and are readily seen, collected, and studied. The general succession is as follows:

A. *Zygospira, Dalmanella, Cornulites* assemblage.
B. Beds with similar genera but characterized, and in most localities dominated, by large *Rafinesquina.*
C. *Hebertella, Rhynchotrema capax,* R. *cuneata, Platystrophia, Streptelasma, Dinorthis* assemblage.
D. Meager fauna of *Orthonybyoceras* and *Endoceras,* with numerous silicified bryozoa.

The fauna is probably of Richmond age and appears to extend down to the Arnheim, lowest Richmond, as an equivalent of the *Zygospira zone.* The varied faunas of the upper Aleman are clearly closely similar to those of the Waynesville beds, but the lower two zones can be interpreted as either Maysville or Arnheim.

Units R 38-39 constitute the *Zygospira* zone in Rhodes Canyon; *Zygospira, Dalmanella,* and *Cornulites* are abundant; spheroidal silicified sponges and *Bythopora* occur near the top amid thin-bedded cherts. Unit R 41 is the *Rafinesquina* zone and has yielded large, numerous *Rafinesquina* and rarer *Zygospira* and *Dalmanella.* Unit R 43 is the *Hebertella* zone, with a large fauna of *Hebertella, Rhynchotrema,* and *Platystrophia,* marked by silicified *Byssonychia* and *Lophospira.* The meager fauna in tan-weathering cherty beds of unit R 45 consists of small silicified bryozoa, an endoceroid, and an *Orthonybyoceras* obtained from this zone in Cottonwood Canyon.

Units H 49-52 in Hembrillo Canyon contain numerous *Zygospira* and *Bythopora,* but *Dalmanella* and *Cornulites* are rare. The zone is abnormally thick and probably persists into what is elsewhere the *Rafinesquina* zone, although no *Rafinesquina* were found. Higher beds appeared mostly to be barren, although float of the usual varied brachiopods and of a large silicified endoceroid were found. Brown-weathering dolomites of units H 54 and H 58 yielded poorly preserved silicified gastropods, chiefly *Hormotoma,* and silicified bryozoa.

In the Ash Canyon section the *Zygospira* fauna was not found in chert characteristic of the zone. Fragments of *Rafinesquina* were found above, and the upper 20 feet of the Aleman dolomite contains a prolific fauna of *Hebertella, Platystrophia, Rhynchotrema,* and *Streptelasma.*

Regional relationships. Thicknesses of the Aleman dolomite vary considerably with interpretation, the lower and upper contacts not being obvious in many localities. At the upper boundary especially there is an alternation of Aleman and Cutter lithologies. Regionally the Aleman dolomite tends to thicken southward. Pray (1954, p 96) reported 86-128 feet in the Sacramento Mountains; Kelley and Silver (1952, fig 3), 108-169 feet in the Caballo Mountains. They also noted a basal sandstone of the Aleman dolomite in the Sierra Cuchillo Darton (1928, p 194) noted that the Aleman dolomite equivalent is only 6 feet thick beneath the Devonian erosion surface in the southern Oscura Mountains; no part of the

Montoya group was left beneath this surface in Mockingbird Gap.

Cutter Dolomite

The term Cutter, as applied by Kelley and Silver (1952, p 62) to the lower part of Richardson's (1909, p 4) Fusselman, has priority over Pray's (1953, p 1898) term Valmont, but agewise should yield to Entwistle's (1944, p 18) term Raven. Cutter, however, has been used more often in south central New Mexico

Lithology. The Cutter consists of medium- to dark-gray, aphanitic, thin- to medium-bedded, calcareous dolomite that weathers light gray and forms angular ledges. In most places the Cutter dolomite crops out as a light-gray-weathering steep slope broken by numerous thin angular ledges that contrast with the darker weathering Aleman dolomite below and the dark-gray Fusselman dolomite cliff above. In Rhodes Canyon, where the Fusselman dolomite is absent, the Cutter dolomite crops out as a sloping ledgy bench beneath a steeper slope cut in the Devonian rocks.

Near the middle of the Cutter dolomite in Ash and Hembrillo Canyons is a bed of soft argillaceous dolomite, 3-12 feet thick, that is an excellent marker horizon. It has been removed by early Devonian erosion in Rhodes Canyon, but was noted by Darton (1928, p 186) in other canyons from Ash to Hembrillo Canyons. Pray (1953 p 1907) used the horizon to subdivide lower and upper members of the Valmont dolomite in the Sacramento Mountains. Chert occurs as scattered small light-brown round nodules and, in a few beds, as thin lenses of Aleman-like chert. Vugs lined with tiny quartz, calcite, and dolomite crystals are common.

Typical dolomites of the Cutter are seen in thinsection to be a decussate mosaic of tiny dolomite crystals, averaging less than 0.03 mm in diameter, with various amounts of admixed anhedral calcite, angular quartz silt, ghosts of fossils, fossil fragments, limestone grains, irregular wavy laminae of clay, and carbonaceous material. The rocks appear to be recrystallized and partly dolomitized coquinoid calcilutites, in part silty and argillaceous.

Thickness. Where not eroded by pre-Onate erosion, the Cutter dolomite is relatively uniform in thickness beneath the Fusselman dolomite, being 168 feet thick in Ash Canyon and 182 feet thick in Hembrillo Canyon. At Rhodes Canyon only the lower beds remain, and the thickness varies considerably from the 57 feet of the measured section R to extremes of 26-75 feet less than one-half mile away. Northward from Rhodes Canyon the Cutter dolomite thins, owing to preOnate erosion, and is absent north of Sly Gap.

Upper contact. In Ash and Hembrillo Canyons the Cutter dolomite is overlain unconformably by the Fusselman dolomite. As much as 6 inches of relief was noted at the contact with the upper thin bed of Cutter dolomite locally removed by pre-Fusselman erosion (pl 2-D). The contact with the overlying Onate formation in Rhodes Canyon is exposed at only a few places and appears deceptively conformable, but local variations in the thickness of the Cutter dolomite indicate considerable erosion prior to deposition of Devonian beds.

Age and correlations. The lowermost beds of the Cutter dolomite, with small round chert nodules, contain silicified *Hebertella* (a different species from those in the Aleman dolomite), and *Gorbyoceras.* The argillaceous dolomite horizon yielded *Hebertella* and a large pelecypod fauna. Upper beds in most places are barren, although the highest beds in Rhodes Canyon contain elements of a zone that is well developed in the Black Range and characterized by *Beatricea undulata, B. nodifera,* and small favositid corals. The fauna is of late Richmond age.

The *Beatricea* zone may be as young as the Elkhorn and as old as the Liberty formations of southern Indiana; equivalent faunas in the nearer Maquoketa formation of Iowa seem to be absent. The basal *Hebertella* zone may be as old as the Liberty formation.

Unit R 5o in Rhodes Canyon yielded sparse favositids and *Beatricea. Hebertella* and *Gorbyoceras* occur in the basal beds; *Hebertella, Modiolopsis,* and *Byssonychia* were collected from shalt' silty beds about 20 feet above the base. In Hembrillo Canyon *Hebertella,* gastropods, and pelecypods were collected from H 65, the argillaceous dolomite marker bed. No fossils were found in Cutter dolomite in the Ash Canyon area, where the unit is mostly covered and crops out only in narrow deeply cut gullies.

Some transition and interbedding of lithologies takes place at the contact of the Cutter dolomite and underlying Aleman dolomite, notably in Hembrillo Canyon, and no evidence was seen in the San Andres Mountains of any break in deposition between the two upper formations of the Montoya group. In contrast, a distinct unconformity occurs at the top between the Cutter and Fusselman dolomites. The Cutter-Valmont faunas are similar to those of the Aleman dolomite, but the Aleman and Upham dolomites are strikingly unlike faunally. Lithological distinction between these two lower facies, the Aleman and Upham dolomites, is complicated by dolomitization, which has obscured the original nature of the beds and destroyed many of the fossils, and by the variation in silicification and amount of chert from place to place.

Regional relationships. The Cutter dolomite thins northward because of post-Cutter erosion; it is absent north of Sly Gap and in the Fra Cristobal Mountains. Pray (1953, p 1907) noted a range of from 15o to 225 feet in thickness in the Sacramento Mountains and a relative thinning in the Franklin Mountains to 160 feet. Kelley and Silver (1952, p 62) reported 121-162 feet of Cutter dolomite in the Caballo Mountains. Entwistle's (1944, p 18) correlative Raven member is about 12o feet thick in the Silver City area.

SILURIAN ROCKS

FUSSELMAN DOLOMITE

The term Fusselman dolomite is applied here to the upper part of Richardson's (1909, p 4) original Fusselman limestone, as redefined by Pray and Bowsher (1952, p 1342) and Kelley and Silver (1952, pp 56-58). The lower part of the original Fusselman is now called Cutter or Valmont dolomite.

Lithology

The Fusselman is a relatively pure, medium- to medium dark-gray, aphanitic to medium-crystalline, massive-bedded dolomite that forms a prominent dark-brown-weathering cliff (pl 3-A). Chert occurs in the upper part of the dolomite in Hembrillo Canyon as scattered small black nodules and thin dark-brown-weathering silicified zones, with numerous crinoid columnals and coarse-crystalline dolomite. Vugs filled with quartz crystals are numerous in the lower part of the Hembrillo Canyon section. The quartz-filled vugs were noted in Ash Canyon not far above the base in units A 79-80.

The Fusselman dolomite in Ash Canyon contains abundant chert as small nodules, lenses, and silicified laminae.

The Fusselman dolomite, as observed in thinsection, is a relatively coarse mosaic of subhedral to anhedral dolomite crystals that average 0.25-0.1 mm in diameter (aphanitic to fine-crystalline). It is cut by quartz veinlets and grades into irregular patches of chalcedonic chert. Clusters of medium-to coarse-crystalline dolomite are scattered throughout the fine-crystalline mosaic, in most places separated by pore spaces. Euhedral dolomite rhombs of all sizes are scattered to abundant (pl 4-C).

Thickness

The Fusselman dolomite pinches out about 6 miles south of Rhodes Canyon, owing to post-Fusselman erosion. Beneath the erosion surface the dolomite thickens southward to 6 feet in Hembrillo Canyon and 94 feet in Ash Canyon. Dunham (1935, p 40) reported 180-210 feet in the Organ Mountains. The Fusselman dolomite is about 840 feet thick in the southern Franklin Mountains.

Upper Contact

The massive cliff of the Fusselman dolomite contrasts sharply with the overlying slope developed on the shaly Devonian beds. The contact is not exposed at most places, but where debris from Devonian beds has been removed, the top of the Fusselman dolomite is an undulating, knobby, ridged and channeled, silicified surface, with relief of at least several inches. This early Devonian erosional surface regionally bevels the Fusselman dolomite, Montoya group, El Paso group, and Bliss sandstone, south to north, in the San Andres and southern Oscura Mountains.

Age and Correlations

No fossils were found in the Fusselman dolomite in the sections studied. Darton (1928, p 186) collected *Pentamerus, Cyanthophyllum, Heliolites,* and *Hormotoma* from the upper part of the Fusselman dolomite in San Nicholas Canyon (between Ash and Bear Canyons), a fauna which Edwin Kirk (Darton, ibid) regarded as Niagaran age. Pray (1953, pp 19131914) reported an Alexandrian, Lower Silurian, fauna from the Fusselman dolomite in the Sacramento Mountains. The fossils were poorly preserved, Flower noting that the genera identified are not confined to the Lower Silurian. Should Alexandrian age determination be substantiated, the Fusselman dolomite will prove to be as intricate, although as innocent looking, as most of the other rock units of the New Mexico column, for there are at least two zones known in the south central region, one characterized by a large pentameroid, apparently *Pentamerus,* and the other by a smaller form, *Conchidium,* which, with the meager associated faunas, suggest ages ranging from low Clinton (lower Niagaran) to Racine (middle Niagaran).

Regional Relationships

The Fusselman dolomite in the Sacramento Mountains thins northward to a knife-edge from a maximum of about 100 feet (Pray, 1953, p 1911), similar to the northward pinching out of the dolomite in the San Andres Mountains. The 180 feet reported by Dunham (1935, p 40) in the southern Organ Mountains is regarded as thinned by faulting, as thicker sections occur on Bishop Cap, a few miles south of the Organ Mountains, and on Robledo Mountain, northwest of the Organ Mountains. The often-quoted statement of Dunham (1935 pp 46-47) that Devonian beds are absent in the southern Organ Mountains, and that Pennsylvanian strata there rest on Fusselman dolomite, is incorrect; the rocks are intricately faulted, and the Pennsylvanian-Fusselman contact is a strike dip-slip fault. This locality is along Target Canyon, then and now a very active part of the Fort Bliss artillery range.

Kelley and Silver (1952, p 67) reported only remnants of Fusselman dolomite spotted throughout the Caballo Mountains; in most places less than **20** feet, but up to 50 feet, in thickness. Southward and westward the Fusselman thickens, although most observers have included the Cutter dolomite in the Fusselman dolomite. In the Robledo Mountains the Fusselman dolomite is about 250 feet thick; in the Franklin Mountains, at the type locality, it is about 840 feet thick (subtracting 160 feet of Cutter dolomite). Kelley and Bogart (1952, p 1646) reported nearly 1,400 feet in the Florida Mountains.

DEVONIAN FORMATIONS

Although beds of Devonian age are the thinnest of all the Paleozoic systems represented in the San Andres Mountains, they present unusual lithologic and faunal complications, which are still being unravelled. Numerous new fossil collections currently (1956) being made indicate that reinterpretation of correlations and perhaps of nomenclature is needed. When these faunal studies are completed in the range and throughout southern New Mexico, it is planned through an additional report to show the new interpretations and the paleontologic data on which these interpretations are based. For the purpose of this report the designations made by earlier workers will be used, although in somewhat modified form.

Study of the Devonian rocks is rendered difficult by the fact that, being typically a shaly unit, they form a gentle slope, almost everywhere covered by debris from overlying formations, and exposures are limited largely to narrow gullies separated by covered intervals. In spite of the fact that Devonian beds are only 183 feet thick in Rhodes Canyon, **211** feet thick in Hembrillo Canyon, and 85 feet thick in Ash Canyon, they have been divided in the San Andres Mountains into four stratigraphic divisions or formations by Stevenson (1945) and Laudon and Bowsher (1949). In ascending order these are the Onate, Sly Gap, Contadero, and Percha formations. Beds containing a fauna similar to that of the Three Forks formation in Montana were observed between the Contadero and Percha formations in the northern part of the range. These formations were examined where present in Rhodes, Hembrillo, and Ash Canyons, and at the type locality of the Sly Gap formation, on Sheep Mountain.

GENERAL LITHOLOGY

The Devonian rocks are chiefly slope-forming shales **and** siltstone, with minor amounts of calcareous sandstone, arenaceous limestone, and lenticular to nodular argillaceous limestone. The Onate formation is exceptional in containing much hard dolomitic or calcareous siltstone. The Devonian beds are in places very fossiliferous.

CONTACTS

Contacts within the Devonian beds range from transitional to sharp, reflecting the rapid lateral variations in lithology and thickness. Many of the siltstones and sandstones have a disconformity at their base, but these are in most places scour-and-fill features which do not represent widespread erosion.

The basal Devonian unit, the Onate formation, rests unconformably on rocks ranging from the Fusselman dolomite, in Ash and Hembrillo Canyons, to the Cutter and Aleman dolomites, in Rhodes Canyon and on Sheep Mountain, and down to lower El Paso strata at Mockingbird Gap. Locally the rocks below the Onate beds were folded, broken by minor faults, and differentially eroded before deposition of the Onate formation.

The contact between the upper Devonian beds and the Caballero formation in Ash Canyon is marked by the lithologic change from blackish Devonian shale to medium-gray, tan- to greenish-weathering Mississippian shale containing numerous limestone nodules and lenses. In Rhodes and Hembrillo Canyons the contact between the upper Devonian beds (the Percha formation) and the lowest Mississippian (the Andrecito member of the Lake Valley formation) roughly coincides with an abrupt change of topographic expression, the Lake Valley beds forming a conspicuous cliff above the steep Devonian slope. Locally, as in Rhodes Canyon, the basal unit of the Andrecito member contains phosphatic nodules and fossils.

ONATE FORMATION

Lithology

The Onate formation, named by Stevenson (1945, p 222) for basal Devonian beds in San Andres Canyon, changes noticeably in lithology from Rhodes Canyon to Ash Canyon. At Rhodes Canyon the Onate is dominantly siltstone, with minor amounts of shale and nodular limestone. Siltstones in most places crop out as thin ledges, are light to dark gray, olive gray or yellowish brown on a fresh surface, and are dolomitic, with gradation into very silty dolomite lenses. Near the base of the Onate formation is a prominent, light-brown-weathering ledge of siltstone than can be traced laterally for considerable distances, providing an excellent marker horizon in the Rhodes Canyon area. Rocks below this bed are similar to those of the Onate formation in Hembrillo Canyon; strata above the marker bed are somewhat similar to overlying Sly Gap beds and contain an anomalous fauna not typical of either the Onate or Sly Gap formation.

Limestone was found only near the base, where the beds are poorly exposed, and near the top of the formation, where limy beds occur as small, medium-gray pyritiferous nodules and short lenses.

Most shale beds in the Onate formation in Rhodes Canyon contain considerable silt, although in unit R 55 there are thin beds of clay shale. The shale is light to dark olive gray on fresh exposures.

The Hembrillo Canyon section of the Onate formation is also predominantly siltstone, similar in appearance to the siltstones of Rhodes Canyon. There are a few thin lenses of black fissile shale in the lower 8 feet in Hembrillo Canyon and olive-gray shales in the upper part of the formation. A 1-foot bed of light-brown crosslaminated sandstone marks the top of the Onate formation.

The beds attributed to the Onate formation in Ash Canyon differ in lithology but comprise two units of pale yellowish orange dolomitic shale separated by a 1-foot bed of siliceous, light-brown-weathering, very fine-grained sandstone. The interval is here placed in the Onate formation because of its position beneath probable Sly Gap beds and above the Fusselman dolomite.

Insoluble residues of the Onate formation consist chiefly of quartz grains and silty shale. The quartz, which is subangular, occurs along with mica and some quartzite fragments as coarse silt to a very fine-grained sand. Shale is micaceous and silty. Onate beds in Rhodes Canyon contain 48 percent quartz silt and 25 percent shale; in Hembrillo Canyon the quartz silt is 38 percent, shale 22 percent; the rocks attributed to the Onate formation at Ash Canyon contain 18 percent quartz silt and 52 percent shale. These insoluble residues of the Onate formation contrast with those of the overlying Sly Gap formation, which are predominantly carbonaceous shale, with scattered quartz sand and silt, as well as numerous fossil molds.

The prominent, hard dark yellowish-orange dolomitic siltstones of the Onate formation in Rhodes Canyon, as seen in thinsection, range from dolomitic siltstones to silty dolomites. Crystals and grains average 0.05 mm in diameter, are rimmed by iron oxides, and form an equigranular mosaic. Dolomite crystals are euhedral to subhedral; quartz silt grains are angular to subangular. A few flakes of muscovite and slivers of banded quartzite also occur.

Thickness and Contacts

The Onate formation seemingly thins southward from 32 feet in Rhodes Canyon to 23 feet in Hembrillo Canyon and o feet in Ash Canyon. Stevenson (1945, p 226) shows a northward thinning from the type section in San Andres Canyon, whereas Laudon and Bowsher (1949, p 35) indicate a general north and south thinning from San Andres Canyon. Stevenson's (1945, p 223) type section of the Onate formation was not visited, but the upper 45 feet appear more closely related to, and should be placed in, the Sly Gap formation.

The upper beds included in the Onate formation in Rhodes Canyon appear in part transitional into the Sly Gap formation. On Sheep Mountain these transitional beds are 9 feet thick (pl 1), and the Onate formation averages only 16 feet thick, ranging from 14 to 19 feet in thickness. The 15 feet of Devonian shown below the Pennsylvanian at Mockingbird Gap (pl 1) is probably all referable to the Onate formation. Laudon and Bowsher's (1949, p 57) Mockingbird Gap section was measured in a small canyon, Johnson Park Canyon, (see topographic map of Capitol Peak quadrangle) which is 2 miles north of Hays Gap and 6 miles south of Mockingbird Gap (but only I mile west of the Mockingbird Gap mine). Here they measured 23 feet of Onate formation above the Aleman dolomite (not El Paso limestone), overlain by 11 feet of Sly Gap formation, which is beneath the Alamogordo member of the Lake Valley formation.

The thickness of the lower Onate beds varies considerably at Rhodes Canyon. Where the thinnest section (26 feet) of the Cutter dolomite was measured, there are 19 feet of Onate strata beneath the brown siltstone marker bed, R 53. Above the Cutter section given in this report (57 feet thick), a like interval of Onate strata is only 9 feet in thickness. Though no actual erosional surface was observed between the two formations, folding and faulting of the Cutter dolomite and variations in thickness show considerable relief on the top surface of the upper Montoya group beds.

Age and Faunas

The delineation of the Onate formation is complicated by lateral changes in lithology and by a meager and generally long-ranging faunal assemblage. At Sly Gap and Rhodes Canyon there is a questionable interval, faunally anomalous, which may be either Onate or Sly Gap. This interval is shown in the Rhodes Canyon measured section by units R 54-61 and has been included in the Onate formation in the columnar section (pl I). The meager fauna from the typical Onate formation is not adequate for accurate correlation, but the Onate has been identified with beds in Johnson Park Canyon (not Mockingbird Gap) reported to contain *Paraspirifer acuminatus.* This brachiopod is regarded as an Onondaga (early Middle Devonian) species but is actually more common in the overlying Hamilton (late Middle Devonian).

Agoniatites collected by G. Arthur Cooper from the lower Sly Gap (?) at the type locality suggests that the questionable interval of the Sly Gap formation may be Middle Devonian, as *Agoniatites* is unknown in Upper Devonian beds. This would indicate an Onate assignment for the *Agoniatites* beds. The rest of the fauna found at Sheep Mountain consists of long-ranging types: *Sulcoretepora, Leiorhynchus, Meristella, Aulopora,* and *Spirifer* aff. S. *pennatus.* These forms range from Hamilton into lower Upper Devonian.

Silicified *Meristella, Sulcoretepora anomalotruncata, Spirifer* aff. S. *pennatus,* and *Aulopora* were collected from R 53, and ubiquitous *Atrypa* from R 6o. The upper shales of the Onate formation in Hembrillo Canyon yielded *Sulcoretepora anomalotruncata* and the brachiopod *Meristella.* No fossils were found in the Onate formation in Ash Canyon.

The upper Onate at Rhodes Canyon and Sheep Mountain, the zone with aspects of both the typical Onate and Sly Gap, yielded *Rhipidomella* cf. R. *vanuxemi, Ambocoelia, Nervostrophia multinervosa, Warrenella, Cariniferella, Devonoproductus* cf. D. *vulgaris,* small *Chonetes, Cyrtina* cf. C. *inulta, Thomasaria, Pugnoides schucherti,* and *Atrypa.*

SLY GAP FORMATION

Lithology

At the type section and at Rhodes Canyon the Sly Gap formation consists of alternating fossiliferous beds of shale, siltstone, and limestone. Most of the shales and limestones contain silt-size grains of quartz. At Sheep Mountain, on the north side of Sly Gap, the shales are dominantly yellowish gray, with only a small amount of gray shale. At Rhodes Canyon the shales are again chiefly yellowish, but there is also a thin interval of black, olive-gray, and dark-gray calcareous shale at the base of the section. Siltstones in the Sly Gap formation at Rhodes Canyon are nodular to thin-bedded, calcareous, and interbedded with both shales and limestones. The siltstones are dark gray in the basal portion of the formation and mostly medium gray above, although there is some yellowish siltstone in the lower part of the yellowish shale sequence. Limestones are medium to dark gray, very silty, aphanitic, and nodular.

At Hembrillo Canyon dark-gray to black shales are thicker in the lower part of the Sly Gap formation, and yellowish shales are absent; the amount of siltstone and limestone increases appreciably. Siltstones are calcareous, and light to medium gray; limestones are silty and medium to dark gray.

At Ash Canyon, the Sly Gap formation is almost entirely dark-gray to black shale. No limestone was observed, and only a 5-foot bed of siltstone occurs near the top of the section. The 15 feet of black shale that overlies the siltstone may be correlative to the Percha formation, but no fossils were found to substantiate this interpretation.

Black shale increases in amount from north to south in the Sly Gap formation between Indian Wells and Dead Man Canyon in the Sacramento Mountains. This facies change from limy fossiliferous silty beds to black shales also occurs between Rhodes and Hembrillo Canyons in the San Andres Mountains, and is the basis for applying the name Sly Gap formation to the black shale interval in Ash Canyon.

Thickness

The sections measured, excluding from the Sly Gap formation the basal beds with an anomalous fauna that may be Middle Devonian in age and which are included in the Onate formation in this report, vary in thickness from north to south: 57 feet at the type section on Sheep Mountain, 31 feet at Rhodes Canyon, 70 feet at Hembrillo Canyon, and 75 feet at Ash Canyon. The type section of the Sly Gap formation was studied, and Stevenson's (1945, p 23o) zones were redefined and remeasured. The latter listed zones C to L all as Sly Gap formation. Zone C, however, is the Onate formation; zone D, of sparse *Macgeea,* is the transitional zone, with anomalous fauna herein placed in the Onate formation; zones E to H are Sly Gap formation; zones I and J are Contadero formation; and zones K and L are a faunal equivalent of the Three Forks shale of the middle Rocky Mountains, clearly a post-Contadero faunal interval. Stevenson's Sly Gap formation, as thus restricted, is 57 feet thick, if the basal *Macgeea* zone is excluded (pl 1).

Age and Fauna

The prolific Sly Gap fauna is regarded as early Upper Devonian, equivalent to the Independence shale of Iowa and roughly equivalent to the early Senecan series, Ithaca formation, and Chemung formation, of New York. Faunas representing earliest Upper Devonian are absent, indicating a hiatus between the Onate and Sly Gap formations.

At the type locality and at Rhodes Canyon the Sly Gap formation can be subdivided into the following faunal zones: (1) basal *Macgeea* zone; (2) abundant *Atrypa;* (3) relatively barren, but some crinoid fragments; (4) *Nervostrophia multinervosa* abundant, *Atrypa, Spirifer strigosus, Thomasaria altumbona, Calvinaria bransoni,* and *Devonoproductus vulgaris;* (5) meager fauna; (6) *Atrypa, Macgeea, Elytha, Thomasaria,* Spirifer, *Cyrtina, Calvinaria, Cariniferella, Schizophoria,* and *Manticoceras; (7)* resistant beds with numerous corals. *Atrypa* far outnumbers all other fossils. At Hembrillo Canyon and in the Sacramento Mountains the fauna is sparse but, except for the absence of the ubiquitous *Atrypa,* is the same as that of the other sections. The fauna collected from the type section of the Sly Gap formation is as follows, using Stevenson's (1945, p 23o) zone designations:

Zone D: *Macgeea* and an undescribed *Leiorhynchus* species. G. Arthur Cooper collected a fragment of *Agoniatites,* probably from this zone. This zone is placed in the Onate formation.

Zone E: *Macgeea* abundant in the lower part; *Atrypa,* in the upper.

Zone G: Chiefly from the lower part, numerous Atrypa, with common *Nervostrophia, Spirifer, Pugnoides, Macgeea,* and *Thomasaria,* and rare *Cyrtina.* From the lower beds only, distinctive large strophomenids not found elsewhere in the section. The upper beds of zone G contain gyroconic cephalopods (not previously reported) and *Manticoceras; Thomasaria, Schizophoria,* apparently the Percha form S. *australis, Macgeea,* and *Atrypa;* corals, including large flat colonies and the genera *Alveolites, Hexagonaria,* and *Phillipsastrea* (reported by Stevenson from zone J); and numerous gastropods, including *Bellerophon.*

The fauna list of the type Sly Gap formation as herein restricted includes (identifications tentative):

Aulacella infera
Nervostrophia thomasi
N. *multinervosa*
Cariniferella iowensis
Macgeea thomasi
Douvillinaria variabilis
Devonoproductus vulgaris
Hypothyridina emmonsi
Spirifer strigosus
Calvinaria bransoni
Cyrtina *inulta*
Elytha diversa
Atrypa devoniana
A. varicostata
Hystricina trulla
Pugnoides schucherti
Thomasaria altumbona
undet. strophomenids
Pachyphyllum sp.
Michelinoceras sp.
Bembexia (?) sp.
Paracyclas sp.
Leiorhynchus sp.
Rhipidomella sp.
Schizophoria amana
S. cf. S. *australis*
Phillipsastrea sp.
Alveolites sp.
Hexagonaria sp.
undet. stromatoporoids
Loxonema sp.
Bellerophon sp.
Aviculopecten sp.
Modiomorpha sp.
undet. bryozoa
Manticoceras n. sp.
undet. orthoconic cephalopod (new)
undet. gyroconic cephalopod (new)
Aulocaulis singularis

The Rhodes Canyon section yielded *Macgeea* and strophomenids from R 63-65, abundant *Macgeea* from R 66-70, abundant *Atrypa* from R 66, *Nervostrophia* from R 67, and corals from the top beds of the Sly Gap formation. The faunal list from Rhodes Canyon also contains the following forms of the type Sly Gap: *Nervostrophia thomasi, N. multi-nervosa, CarinifereHa iowensis, Macgeea thomasi, Devonoproductus vulgaris, Hypothyridina emmonsi, Spirifer strigosus, Calvinaria bransoni, Cyrtina inulta, Elytha diversa, Atrypa devoniana, A. varicostata, Hystricina trulla, Pugnoides schucherti, Thomasaria altumbona, Alveolites sp., Phillipsastrea* sp., undet. stromotoporoids, *Loxonema* sp., and *Bellerophon* sp. Other forms found in the Sly Gap formation in Rhodes Canyon: *Productella rugatula, Acutatheca* sp., *Schuchertella* sp., *Goniophyllum? sp., Fenestella* sp., *Pleurotomaria* sp., siphuncle of cyrtoconic cephalopod, *Limoptera* sp., and *Trematopora?* sp.

The Sly Gap formation in Hembrillo Canyon yielded a sparse fauna similar to that from the Sly Gap formation at Indian Wells in the Sacramento Mountains. The fauna appears rather anomalous, containing only a few of the Sly Gap species, and a few species which are in other places found in younger beds. The list includes the forms: *Nervostrophia thomasi, N. multinervosa, Cariniferella iowensis, Devonoproductus vulgaris,* Spirifer *strigosus, Calvinaria bransoni, Atrypa devoniana, Hystricina trulla,* and *Thomasaria altumbona,* from the type Sly Gap fauna, as well as *Cleiothyridina* cf. C. *reticulata, Cranaena* sp., and *Streptorhynchus* sp.

Evidence suggests that the Sly Gap formation grades southward and westward into an unfossiliferous black shale, which has been called the Ready Pay member of the Percha shale. The upper part of the Sly Gap black shales near Ash Canyon may be Percha, but is undistinguishable from lower similar shales. In the Sacramento Mountains from north to south, from Indian Wells to Dead Man Canyon, there is a marked increase in the amount of black shale in the Sly Gap formation. In the Black Range, near Cooks Peak, the Ready Pay member has yielded a Sly Gap species of *Pugnoides* (unknown in the upper Percha) and a conodont fauna similar to that of the Sly Gap formation. If the Ready Pay member is a southward and westward black shale facies of the Sly Gap formation, it should be separated by a distinct break from the Box member of the Percha, for although the Contadero formation facies seems to be absent south and west of the San Andres Mountains, the Three Forks faunal zone of the Sheep Mountain section clearly pinches out southward between the Contadero formation and beds that apparently are Percha shale.

CONTADERO FORMATION

The section of the Contadero formation measured in Rhodes Canyon is at the same locality as the type section of Stevenson (1945, pp 239-241). The type Contadero formation is revised here to exclude upper beds containing a Percha fauna, and to include at the base barren silty shales that locally exhibit a sharp contact with the underlying Sly Gap formation.

Lithology

At Rhodes Canyon the Contadero formation is dominantly dark-gray to pale-olive, fissile silty shale, interbedded with medium-gray to dark brownish-gray siltstone. The upper 3 1/2 feet of the formation consists of dark-gray aphanitic silty nodular limestone. Basal very thin even-bedded sheety shales weather tan to purplish. The Hembrillo Canyon section of the Contadero formation is similar, consisting of interbedded light- to dark-gray silty fissile shale and dark-gray to brownish-gray micaceous siltstones. Near the top and base of the formation are thin light-brown sandstone beds. There is no limestone in the Hembrillo Canyon section of the Contadero formation. The Contadero apparently is absent in Ash Canyon.

Thickness

At Rhodes Canyon 45 feet of the Contadero formation was measured. A slightly thicker section of 51 feet was found in Hembrillo Canyon. The formation thins to the north and south, pinching out north of Sly Gap and south of Dead Man Canyon. Laudon and Bowsher (1949, p 5o) reported 33 feet of Contadero formation in Dead Man Canyon; and 23 feet of Stevenson's (1945, p 23o) type Sly Gap section (zones I and J) are considered Contadero equivalent.

Age and Fauna

The Contadero formation is probably uppermost lower Upper Devonian in age. On Sheep Mountain the fauna includes *Atrypa hystrix,* a small *Schizophoria,* abundant *Ambocoelia, Elytha diversa, Productella* cf. P. *belanskii,* and large cup corals.

The fauna from Rhodes Canyon was obtained chiefly from the upper part of R 76 and included abundant *Paraphorhyn-*

cus perchaensis, Atrypa, Spirifer, and *Ambocoelia,* along with *Michelinoceras, Modiolopsis, Actinopteria, Hystricina, N ervostrophia multinervosa, Thomasaria, Pugnoides schucherti, Cyrtospirifer,* and *Pseudodouvillina euglyphea.*

At Hembrillo Canyon, in unit H 92, a fauna consisting of abundant *Cariniferella iowensis,* small *Spirifer, Paraphorhynchus perchaensis, Pugnoides schucherti,* and *Ambocoelia* was found. A similar fauna was collected from H 93, along with *Aviculopectan?.*

The basal fauna suggests a recurrence of Sly Gap faunas; the change from the Sly Gap up into the Contadero formation appears to be a lithologic change without faunal break. The total fauna resembles that of the Cedar Valley formation of Iowa.

PERCHA FORMATION

Beds of Percha aspect overlie a thin "Three Forks" zone in Rhodes Canyon and are probably the beds present above the Contadero formation in Hembrillo Canyon. The unfossiliferous black to olive-gray shales called Sly Gap in Ash Canyon could be a northward facies of the Percha shale of the Franklin Mountains.

Lithology

In Rhodes Canyon the Percha formation is pale to dark olive-gray calcareous silty micaceous shale, with a few lenses and nodules of medium-gray or olive-gray calcareous micaceous siltstone. The Hembrillo Canyon section of the Percha formation differs considerably from the Rhodes Canyon section, lithologically more closely resembling the Mississippian Caballero formation. The basal unit at Hembrillo Canyon (H 99) is a 4-foot bed of black fissile shale. This is overlain by 3 feet of lenticular dark-gray fossiliferous arenaceous limestone (H 100), crosslaminated in places, which grades laterally into limy sandstone with coquinoidal lenses. Insoluble residues of this calcarenite (H oo) contain tiny euhedral quartz crystals found elsewhere in the San Andres Mountains only in Mississippian and Pennsylvanian limestones. In a gully near the measured section the calcarenite abuts against an 18-inch grayish-black argillaceous fine-crystalline nodular to medium-bedded limestone. In the measured section the horizon of the black limestone is occupied by black fissile shale (H 99). The blackish limestone was traced one-half mile, in which its maximum thickness is 81/2 feet. At one exposure the limestone had been partly cut out, and the channel, about 16 feet wide and 6 feet deep, is occupied by the calcarenite of H 100.

The arenaceous calcarenite (H 100) is succeeded by a 34-foot sequence (H 101-104) of light- to dark-gray silty fissile dolomitic shale, with some dark-gray silty limestone near the base and a few thin beds and nodules of siltstone in the upper part. The overlying 20 feet (H 105-107) consists of light olive-gray silty calcareous shale, with two thin beds of dark-gray limestone near the base and abundant nodules and thin beds of medium-gray siltstone throughout. The upper 6 feet (H 108-109) is medium-gray silty shale, with abundant dark-gray nodular silty limestone beds.

Thickness

Beds referred to the Percha formation are 75 feet thick in Rhodes Canyon, including a basal 18 inches of possible Three Forks equivalent. At Hembrillo Canyon 67 feet of the Percha formation was measured. The Percha formation thins north of Rhodes Canyon and is absent at Sly Gap. Beds of Percha aspect thicken southward in the Sacramento Mountains and are reported by Laudon and Bowsher (1949, p 37) to be 57 feet thick in the Franklin Mountains.

"Three Forks" Beds

Zones K and L of Stevenson's (1945, p 23o) type Sly Gap formation are regarded by G. Arthur Cooper (personal communication) as equivalent to the Three Forks shale of Montana, which is middle Cassadagan or middle Upper Devonian. The zone is 12 to possibly 19 feet thick and consists of blocky silty fine-grained sandstone and less resistant shaly calcareous siltstones. The fauna contains *Cyrtospirifer,* black phosphatic gastropods *(Loxonema* most numerous), orthoconic cephalopods (apparently pseudorthoceroids), *Hormotoma,* and a *Leiorhynchus,* not previously reported, that is similar to a Chemung species.

At the Rhodes Canyon section 6 inches to 2 feet (R 78) of very fine- to coarse-grained siliceous sandstone and silty shale represents the Three Forks faunal zone. Characteristic *Spirifer,* black phosphatic gastropods, and *Atrypa* were seen. The "Three Forks" beds thin southward, pinching out between the Contadero and Percha formations in the Rhodes Canyon area.

Age and Fauna of the Percha

The fossiliferous Box member (upper) of the Percha formation has been regarded as upper Devonian (Conewango), although Stainbrook (1947, p 302) considered it as possibly lower Mississippian in age.

In Rhodes Canyon unit R 79 (lower) contains a fauna of *Camarotoechia sobrina, Cyrtospirifer animasensis, Tylothyris novamexicana, Brachythyris* cf. *B. bisbeensis, Schizophoria australis, Heterolosia* cf. *H. nupera, Pustula praecedens,* Or*biculoidea sp., Dielasma, Pleurotomaria sp., Aviculopecten* sp., *Ambocoelia* sp., and *Actinopteria* sp.

Unit R 79 (upper) yielded a very different fauna: *Shumardella glabraventra, Cyrtospirifer animasensis,* C. *kindlei, Leioproductus plicatus, Cleiothyridina reticulata,* C. sp., *Aviculopecten* sp., *Loxonoma* sp., and *Leiorhynchus?* sp. This latter fauna, although larger, is essentially that which Stainbrook (1947, p 298) reported from the Rhodes Canyon area.

The higher beds are sparsely fossiliferous, but crushed *Ambocoelia, Cyrtospirifer kindlei,* C. *animasensis, Planoproductus hillsboroensis, Camarotoechia sobrina,* and *Heterolosia nupera* were found in the lower part of R 80.

In Hembrillo Canyon unit H 10o yielded a large complex fauna, not as yet completely studied, having mixed affinities with the Percha formation and with various Mississippian faunas. Brachiopods include *Syringothyris* sp., *Dielasma* cf. *D. chouteauensis, Camarotoechia* sp., and *Spirifer* sp.; in addition pelecypods and gastropods, of which *Platyceras* is the most common.

Unit H 101 contains *Rhipidomella* cf. R. *oweni* and *Syringothyris* cf. S. *texta.* In the upper part of the Percha formation (H 105-107) is a large fauna composed almost completely of brachiopods of mixed Percha and Mississippian elements. The Mississippian types are not particularly close to Kinderhookian species or to anything in the Lake Valley formation. Nothing collected from the Caballero formation is closely comparable, but one form is apparently conspecific with *Dielasma chouteauensis* found in the Kinderhookian Caloso formation in the Ladron Mountains (Armstrong, 1955, p 32).

MISSISSIPPIAN FORMATIONS

The Mississippian rocks in the San Andres Mountains have been studied in some detail by Laudon and Bowsher (1949)• The Caballero formation occurs only in the southern part of the range; the Lake Valley formation crops out along the entire length of the range; and the Las Cruces and Rancheria formations are present only in the southernmost part of the range. Collections were made of the faunas, but the type faunas of the formations, and indeed of the type Mississippian, are inadequately studied. It was considered futile accordingly to attempt to identify and classify the San Andres Mountains Mississippian fossils before critically studying the faunas from areas where fossils are more numerous. Lithologic units of the Mississippian are distinctive enough to allow subdivision into members and formations without detailed faunal studies.

CABALLERO FORMATION

Definite Caballero beds were found only in Ash Canyon. As noted in the discussion of Devonian beds, rocks herein attributed to the Percha formation in Hembrillo Canyon may be in part, or entirely, a facies of the Caballero formation.

The lower 52 feet (A 94) of the Caballero formation is composed of medium- to light-gray silty calcareous fissile shale containing abundant nodules and thin lenses of dark-gray silty aphanitic limestone. Immediately overlying the shale sequence is a 1-foot ledge (A 95) of light-brown-weathering calcareous siltstone; then 2 feet (A 96) of calcareous silty pale-olive shale, and 5 feet (A 97) of interbedded nodular lenticular arenaceous medium-gray limestone and silty calcareous grayish-olive shale.

The Caballero formation weathers light gray, contrasting with the darker weathering beds of the overlying Andrecito member of the Lake Valley formation and the underlying darker beds of the Sly Gap formation. The Caballero formation forms an irregular steep slope (pl 2-B) with the Devonian beds and the Andrecito member.

The 6o feet of beds measured in Ash Canyon appears to be the maximum thickness of the Caballero formation in the San Andres Mountains. Laudon and Bowsher (1949, p 35) reported that the formation thins abruptly to 13 feet in Bear Canyon and is absent in the Franklin Mountains. Northward from Ash Canyon the Caballero formation ranges irregularly in thickness from 25 to 44 feet and probably pinches out between Dead Man and Hembrillo Canyons. Similarly, in the Sacramento Mountains, the formation ranges from 15 to 6o feet in thickness, pinches out southward, and is absent to the south in the Hueco Mountains.

The contact between the Caballero formation and the Andrecito member of the Lake Valley formation at Ash Canyon is located at the top of a nodular arenaceous limestone unit that separates the olive-to-tan-weathering beds of the Caballero formation from the dark-gray silty limestones of the basal Lake Valley member.

The Caballero formation is of Kinderhookian, Lower Mississippian age. Fossils reported or collected from the San Andres Mountains sections include *Rhipidomella missouriensis*, *Spirifer louisianensis*, *Chonetes glenparkensis*, *Avonia boonensis*, *Productella concentrica*, *Dictyoclostus arcuatus*, *Brachythyris peculiaris*, *Recticularia cooperensis*, *Leptaena*, *Plectospira*, *Cleiothyridina*, and *Cyathaxonia*. Trilobite fragments are common in all beds of the formation.

LAKE VALLEY FORMATION

The Lake Valley formation is the most widespread Mississippian unit in southern New Mexico. In the San Andres Mountains it unconformably overlies the Caballero formation in Ash Canyon and the Percha formation in Hembrillo and Rhodes Canyons. All six members of the Lake Valley formation occur in the San Andres Mountains. The four lower members, Andrecito, Alamogordo, Nunn, and Tierra Blanca, are represented in or near all three measured sections; the two upper members, Arcente and Dona Ana, are present south of San Andres Canyon.

Northward from Ash Canyon the Lake Valley formation thins fairly consistently from 388 feet to 8z feet in Hembrillo Canyon, 62 feet in Rhodes Canyon, 20 feet in Johnson Park Canyon (Laudon and Bowsher, 1949, p 57), and absent in Mockingbird Gap (pl). At Lostman Canyon and Ritch Rim (ridge north of Lostman Canyon) local thickening within this northward trend was reported by Laudon and Bowsher (1949, p 35). Southward the formation thins abruptly to only 7o feet in Bear Canyon, and is absent in the Franklin Mountains. This abrupt southward thinning may be a reflection of southward gradation from the crinoidal limestone facies of the Lake Valley formation into the black argillaceous limestone facies of the Rancheria and Las Cruces formations, as suggested by Jones (1953, p 19). The Lake Valley formation is of Osage age; Laudon and Bowsher (1949, pp 16-19) considered the Rancheria and Las Cruces formations to be of early Meramec age on the basis of *Leiorhynchus carboniferum*. Weller et al. (1948, pp 115-16) noted this brachiopod horizon and suggested that the genus is characteristic of a certain type of dark shale environment rather than of any particular restricted time, conceding, however, that L. *carboniferum* is not known for certain in pre-Meramecian rocks.

The middle and upper members of the Lake Valley formation are interbedded coquinoid crinoidal biostromal to biohermal limestone facies and shaly fossiliferous marl facies that intertongue laterally, with thicknesses varying considerably within short distances. In section A, measured in Ash Canyon, thicknesses of members from the base of Alamogordo to the base of Pennsylvanian strata are: Alamogordo, 102 feet; Tierra Blanca, 6z feet; Arcente, 33 feet; and Dona Ana, 7o feet. A section measured in a tributary that enters Ash Canyon from the north gave thicknesses of the corresponding members as 96, 31, 87, and 7o feet respectively. The total thickness of the sequence and the thicknesses of the upper and lower members are fairly constant, but the thickness of the Tierra Blanca and Arcente members is almost reversed.

Andrecito Member

The type locality of the Andrecito member is along the south wall of Andrecito Canyon in the San Andres Mountains. At the type section the member is 35 feet thick and consists of lower medium-gray thin-bedded arenaceous fossiliferous limestone and an upper dark-gray thin-bedded slightly cherty limestone. Fenestelloid bryozoans are abundant. The Andrecito unconformably overlies the slope-forming Caballero formation from Bear Canyon almost to Hembrillo Canyon; northward it unconformably overlies the Percha formation. In most places the member is differentiated easily from the overlying cliff-forming Alamogordo member.

In Ash Canyon the lower 8o feet of the Andrecito member (A 98-99) consists of highly argillaceous silty dark-gray thin-bedded limestones, with partings and lenses of hard dark-gray silty calcareous shale. The upper 4o feet (A 100-104) is an alternating sequence of relatively pure, highly crinoidal limestones and of thin beds of medium- to dark-gray silty limestone, with lenses of light-gray shale.

At Hembrillo Canyon the basal lenticular bed (H 110) is light-brown calcareous very fine-grained sandstone overlain by 1 foot of thin-bedded nodular arenaceous limestone and 2 feet of dark-gray crinoidal limestone. In Rhodes Canyon the Andrecito consists of a lower 4 feet of crosslaminated arenaceous crinoidal dark-gray limestone overlain by thin-bedded arenaceous limestone with a few lenses of light-gray shale. Locally at Rhodes Canyon the basal unit contains abundant phosphatic fossils and pellets.

As seen under the petrographic microscope, the typical limestones of the Andrecito member range from cryptocrystalline calcilutites, with anhedral calcite crystals and grains averaging 0.005 mm, to very fine-grained fossiliferous calcarenites. Angular to subangular quartz silt is sparse to abundant, as are muscovite flakes and clay. The numerous fossil fragments are small, angular, and in part recrystallized. A few tiny euhedral quartz crystals are scattered throughout the limestones.

Upper beds of the Andrecito member are poorly exposed in Ash Canyon, but there is an apparent angular unconformity between the Andrecito and the Alamogordo members. The upper 2-foot bed of the Andrecito member in Hembrillo Canyon is separated from the Alamogordo member by a distinctive wavy contact with small local relief. At Rhodes Canyon the contact is located at the top of a thin-bedded arenaceous limestone unit (R 81). Above this contact the Alamogordo limestones are chiefly calcic, contain only minor amounts of quartz silt, and are thicker bedded. At Hembrillo and Ash Canyons the Andrecito member forms a slope beneath the cliff of the Alamogordo member (pl 2-B). At Rhodes Canyon the Andrecito is the basal part of the lower cliff of the Mississippian strata.

The fauna is sparse in most places. Recorded and collected from the member in the San Andres Mountains are numerous fenestelloids, *Dictyoclostus fernglenensis, Athyris lamellosa, Taonurus caudagalli, Cleiothyridina obmaxima, Spirifer vernonensis,* and S. rowleyi.

The thickest known section of the Andrecito member in the San Andres Mountains is in Ash Canyon, where 120 feet was measured. The member thins abruptly southward to 34 feet in Bear Canyon. Northward from Ash Canyon the sequence ranges from 3o to 5o feet in thickness between San Andres and Dead Man Canyons. Laudon and Bowsher (1949, p 54) reported 82 feet of the Andrecito member on Ritch Rim, 4 miles south of Hembrillo Canyon. At Hembrillo Canyon only 6 feet of Andrecito is present. The member remains thin farther north in the range, with 81/2 feet at Rhodes Canyon and 3 feet at Sheep Mountain.

Southward the Andrecito member thins to 34 feet in Bear Canyon and is absent in the Franklin Mountains. In the Sacramento Mountains the member is 25-35 feet thick in the northern part of that range and pinches out or grades laterally into basal Alamogordo limestones southward.

Alamogordo Member

The Alamogordo member, as originally defined (Laudon and Bowsher, 1941, p 2125), included the present Andrecito, Alamogordo, Nunn, and Tierra Blanca members, but was restricted (Laudon and Bowsher, 1949, pp 11-13) to the second-lowest member of the Lake Valley, as redefined. It is the most distinctive member of the Lake Valley formation and in most places forms a prominent cliff (pl 2-B) of massive cherty dark-gray limestones. The Alamogordo forms the base and central structure of the numerous Lake Valley bioherms.

In the Rhodes and Hembrillo Canyon sections the Alamogordo member is a massive dark-gray aphanitic limestone containing abundant large concentrically banded chert nodules and lenses. Recrystallized crinoid columnals and stem fragments are common in most beds. Microscopic euhedral quartz crystals are distinctive insoluble residues, although minor quartz silt occurs near the top of the member in the Hembrillo Canyon section. At Ash Canyon the limestones are similar to those of the northern sections, except that quartz silt is abundant in some beds, and the abundant chert occurs as small black nodules and lenses that lack the distinctive concentric light-and-dark banding.

The typical Alamogordo limestones, as viewed in thin-section, are cryptocrystalline calcilutites, with calcite crystals and grains averaging about o.003 mm; fossils and fossil fragments are in part recrystallized, with outlines shown by faint dust rims. Veinlets of relatively coarse-crystalline calcite are common. The tiny euhedral quartz crystals are replaced in part by calcite; the crystals are long slender rods, hexagonal prisms with hexagonal bipyramid terminations, averaging 0.0! mm in diameter and 0.04 mm in length.

The Alamogordo member is 96-102 feet thick near Ash Canyon. To the south the member thins abruptly to 26 feet in Bear Canyon (Laudon and Bowsher, 1949, p 42) and is absent at Bishop Cap, at the south end of the Organ Mountains. Northward Laudon and Bowsher (1949, p 35) reported that the member thins and thickens erratically, being 67 feet thick in San Andres Canyon, 36 feet in Dead Man Canyon, 64 feet in Lostman Canyon (between Dead Man and Hembrillo Canyons), and 36 feet thick in Hembrillo Canyon. North from Hembrillo Canyon the Alamogordo member is uniformly 20-25 feet thick where not removed in early Pennsylvanian river channels, and is the only Mississippian unit left at Johnson Park Canyon, south of Mockingbird Gap.

Where the Nunn member is present, as in Rhodes and Hembrillo Canyons, the upper contact is an abrupt change from the massive cliff-forming dark-gray limestone of the Alamogordo to the lighter weathering shaly slopes of the Nunn strata. In Ash Canyon, where beds of Nunn lithology are absent, there is an abrupt lithologic change from massive dark-gray Alamogordo limestone containing black chert to light thin-bedded to nodular Tierra Blanca limestone containing light-gray chert.

Fossils are sparse and difficult to obtain from the hard cherty limestone of the Alamogordo member. Those noted by Laudon and Bowsher (1949, p 57) and/or collected are:

Spirifer rowleyi, Dictyoclostus fernglenensis, and *Athyris lamellosa.*

Nunn Member

The Nunn member consists of interbedded hard light-gray calcareous shale; friable fossiliferous highly crinoidal limestone; and medium- to dark-gray argillaceous and silty thin-bedded nodular limestone. The beds weather light gray. Insoluble residues consist of abundant very fine-grained sand and silt-size quartz, along with locally abundant microscopic euhedral quartz crystals.

The Nunn member thins southward from 28 1/2 feet in Rhodes Canyon to 15 feet in Hembrillo Canyon, but thickens to a maximum of 66 feet farther south in San Andres Canyon. On Sheep Mountain 25 feet of the Nunn member was measured. Early Pennsylvanian erosion has removed the member at Mockingbird Gap. No beds of typical Nunn lithology were seen in the section measured in Ash Canyon, but Laudon and Bowsher (1949, p 44) reported 4 feet in nearby outcrops.

The contact with the overlying Tierra Blanca member is at the abrupt change from the slope-forming beds of the Nunn member to the cliff-forming light-gray crinoidal limestone of the Tierra Blanca member. In places, however, beds of typical Nunn lithology occur up in the Tierra Blanca member; conversely, Tierra Blanca-like beds occur in the Nunn member. Thickness varies within short distances, especially where bioherms occur.

The Nunn member is abundantly fossiliferous in most places, but the fauna is relatively undescribed. Fossils reported or collected from the member in the San Andres Mountains are: *Steganocrinus pentagonus, Platycrinites P. pocilliformis,* P. cf. P. *burlingtonensis, Cactocrinus, Rhodocrinites barrisi, Actinocrinites* cf. *A. rubra, Amphoracrinus divergens, Physetocrinus copei,* Spirifer *rowleyi, Cleiothyridina obmaxima,* and *Dictyoclostus fernglenensis.*

Tierra Blanca Member

The lower part of the Tierra Blanca member combines with the Alamogordo member at Ash Canyon to form a massive cliff (pl 2-B), whereas the upper part combines with the Arcente member to form a slope beneath a higher Mississippian cliff. In Rhodes and Hembrillo Canyons the Tierra Blanca member forms the upper Mississippian ledgy cliff.

Light-gray crinoidal limestones containing abundant very light-gray chert nodules and lenses comprise the Tierra Blanca member in Rhodes and Hembrillo Canyons. In Ash Canyon the lower 27 1/2 feet (A 110) and the upper **20** feet (A 113) are coquina beds consisting of crinoid stem fragments. The middle 15 feet (A 111-112 12) is light- to medium-gray aphanitic limestone. Small light-gray chert nodules and lenses are common except in the upper 20 feet. Microscopic euhedral quartz crystals and granular vuggy chert form the bulk of the insoluble residues, which range up to as much as 25 percent. In thinsection the crinoidal coquinoid limestones were observed to contain irregular patches of chert, which are chalcedony aggregates that replaced parts of the fossiliferous limestone, more or less preserving lamination and fossil structures and textures. No distinct boundaries between the replacement chert and the adjoining calcite coquina were noted; selective replacement of fossils, calcite clastic grains, or calcite cement by chalcedony is not apparent.

In Ash Canyon the Tierra Blanca member is overlain by the dark-gray siltstones and silty limestones of the Arcente member. Where observed in the central and northern parts of the San Andres Mountains, the upper contact of the member with Pennsylvanian beds is a deeply cut erosional surface overlain by, and with channels filled in by, basal Pennsylvanian chert-pebble-conglomerates. Where the Tierra Blanca member has not been removed by early Pennsylvanian erosion, the contact in places is difficult to pick within a sequence grading from highly cherry Tierra Blanca beds into relatively structureless conglomerates of reworked Tierra Blanca chert and crinoid fragments.

The Tierra Blanca member is a typical biostromal and biohermal limestone and grades laterally and vertically into the overlying and underlying shaly members. Its thickness is, therefore, variable. In Bear Canyon none is reported; in Ash and Salt Canyons, 47-62 1/2 feet; in San Andres and Andrecito Canyons, 75-10o feet; in Dead Man Canyon, 17 feet; but in Lostman Canyon and on Ritch Rim, 60-85 feet. From the 25 feet measured in Hembrillo Canyon the member thins irregularly northward beneath the Pennsylvanian beds, ranging up to 15 feet thick, with 3 1/2 feet at Rhodes Canyon and 8 feet on Sheep Mountain, and being entirely removed north of Sheep Mountain.

Fossils reported or collected from the Tierra Blanca member in the San Andres Mountains include *Spirifer rowleyi, Cleiothyridina obmaxima, Athyris lamellosa,* and *Dictyoclostus fernglenensis.* Numerous other forms are present but have not been studied. The limestone is hard; many of the fossils are broken and are only fragments within the crinoid coquina.

Arcente Member

The Arcente member is a Lake Valley formation facies similar to the Nunn member but is not particularly fossiliferous. The member is reported by Laudon and Bowsher (1949, p 39) as a thin discontinuous unit, 12-15 feet thick, from Bear Canyon north to Andrecito Canyon, but is absent to the north. In section A, measured in Ash Canyon, the member is 33 feet thick; in a side canyon beds of Arcente lithology are 87 feet thick. In places nearby the member is absent, owing to removal during early Pennsylvanian erosion.

In Ash Canyon the lower part of the Arcente member forms a ledgy slope with the upper part of the Tierra Blanca member; above, the upper Arcente and Dona Ana members crop out as the upper Lake Valley cliff.

The Arcente member in Ash Canyon is lithologically identical with the type Arcente and with exposures in the rest of the southern part of the range. The lower 25 feet (A 114-116) is dark-gray calcareous thin-bedded siltstones, with a few lenses of dark-gray aphanitic limestone near the base. The upper 8 feet (A 117-118) is a sequence of medium dark-to medium light-gray thin-bedded silty limestones containing scattered nodules of medium-gray chert and numerous crinoid columnals. These dark silty limestones and calcareous siltstones contrast markedly with the overlying light-gray crinoidal coquina of the Dona Ana member, but the contact is gradational.

Dona Ana Member

The Dona Ana member of the Lake Valley formation has a maximum thickness of 175 feet in San Andres Canyon, in the Sacramento Mountains. Exposures of the member are restricted to outcrops in the Sacramento Mountains east of Alamogordo and to the southern part of the San Andres Mountains. The Dona Ana is a facies similar to that of the Tierra Blanca member.

The 68 feet of the Dona Ana member measured in Ash Canyon consists of medium light- to light-gray crinoidal coquinoid limestone, which is thin- to massive-bedded. The small percentage of insoluble residue contains microscopic euhedral quartz crystals and some silt-size detrital quartz. Large nodules of light-gray chert occur scattered throughout the beds near the measured section; in other areas chert is more abundant.

The contact between the Dona Ana member and overlying strata is exposed in only a few places as the Dona Ana crops out as vertical cliff, on the top of which the less resistant Rancheria or Pennsylvanian beds form covered slopes. In many places, where overlain by basal Pennsylvanian beds, the upper surface of the Dona Ana member is channeled, silicified, and iron stained.

LAS CRUCES FORMATION

The Las Cruces formation consists of hard aphanitic grayish-black even-bedded limestones. It is about 6o feet thick at its type locality in Vinton Canyon, in the Franklin Mountains, thins northward to about 6 feet in Bear Canyon, and is absent in Ash Canyon and in the rest of the San Andres Mountains. Laudon and Bowsher (1949, P 17) considered it to be of early Meramec age.

RANGHERIA FORMATION

The Rancheria formation, of early Meramec age, is a sequence of cherty grayish-black argillaceous limestones. The type locality is in Vinton Canyon, in the Franklin Mountains, where the formation is 255 feet thick. The Rancheria formation is about 215 feet thick throughout the Hueco Mountains, to the southeast. The Rancheria overlaps northward onto the eroded Lake Valley formation in the southern Sacramento and San Andres Mountains. In the Sacramento Mountains the formation thins from 275 to 11z feet and to absent in about 6 miles; in the southern San Andres Mountains the formation thins from 195 feet in Bear Canyon to remnants near Ash Canyon.

PENNSYLVANIAN SEDIMENTARY ROCKS

Two approaches have been made to the delineation of units in the sedimentary rocks of Pennsylvanian age in New Mexico. Both have advantages and disadvantages in correlating between areas where it is not possible to follow selected beds or units from one locality to the next. One approach, which has been used in the north central part of the state, is to recognize three divisions based chiefly on gross lithology and topographic expression: a lower clastic facies called the upper member of the Sandia formation, a medial limestone facies named the lower gray limestone member of the Madera formation, and an upper limestone and clastic phase called the upper arkosic limestone member of the Madera formation. These three divisions are part of the Magdalena group, which in many places also includes a basal division, the lower limestone member of the Sandia formation, of Mississippian age, and an uppermost redbed and limestone division, the Bursum or Red Tanks formation, of Early Permian age.

The other approach, followed in this report, is to establish divisions based on lithology and zonation of the fusulinids into the series and parts of series as generally recognized in Pennsylvanian strata throughout North America. This method is particularly applicable to a relatively detailed study of measured sections and samples from oil tests. The relationships of faunas and lithologies allow interpretations of sedimentation, evolution, and geologic history that can be compared with those of contiguous areas (Thompson and Kottlowski, 1955, PP 71-76). Mapping of thick generalized divisions has an importance in widespread areal studies whose purpose is to delineate regional structural trends and to locate areas deserving a more detailed examination. Such generalized divisions, however, give little more than a summation of the entire Pennsylvanian, or of large parts thereof, and may obscure important time-rock relationships that are needed to interpret the geologic history and to locate mineral deposits, such as the petroleum products.

The monotony of Pennsylvanian rocks, the lateral and horizontal lithologic variation of individual beds, and the gradational evolution of the megafossils make difficult the establishment of easily recognizable mapping units. The Pennsylvanian sections in the San Andres Mountains have been divided into faunal equivalents of the Derry, Des Moines, Missouri, and Virgil series. Mapping of these divisions in the Rhodes Canyon area has established that they have lateral lithologic continuity and that they are valid mappable units. Exact equivalency with the type rock units of the midcontinent area is, of course, not suggested.

Pennsylvanian strata range from 2,506 to 3,034 feet in thickness, as measured in the three canyons, with the thickest section near Hembrillo Canyon. The lower three series (Derryan, Desmoinesian, and Missourian) are 1,000-1,200 feet in thickness as far south as Hembrillo Canyon, but thin southward to only 435 feet at Ash Canyon. The upper series (Virgilian) thickens southward from about 800 feet near Mockingbird Gap to 2,400 feet at Ash Canyon. The Virgilian rocks in the central and southern part of the San Andres Mountains are lithologically dissimilar to Virgilian strata to the north, west, and east.

Pennsylvanian rocks in the San Andres Mountains are very fossiliferous, although many of the fossils are securely embedded in hard limestones and therefore difficult or impossible to collect. None of the forms other than fusulinids have been studied in any great detail. Accordingly, although we have numerous collections, the Pennsylvanian megafossils have not been identified except where needed for stratigraphic control.

The Pennsylvanian strata overlie Mississippian beds with pronounced erosional unconformity in most places in the range; at some localities almost the entire Mississippian section was cut out, and channels filled by Pennsylvanian chert-pebble-conglomerates (pl 3-B).

DERRY SERIES

Strata bearing Derryan fusulinids occur throughout the San Andres Mountains, resting with erosional unconformity on various Mississippian beds. They are generally correlative with the Atoka series of the U. S. Geological Survey and with the Bend series of the Trans-Pecos area.

Lithology

Derryan beds vary laterally and vertically in lithology and thickness (pl 1). From Mockingbird Gap south to San Andres

Canyon the basal beds are chert-pebble-conglomerates and conglomeratic sandstones, whose chief constituents are reworked Mississippian cherts. Laudon and Bowsher (1949, p 2 I) suggested that the large concentration of chert indicates a source to the west, since such conglomerates are only of local extent in the Sacramento Mountains. South of San Andres Canyon the basal Pennsylvanian varies from conglomeratic arenaceous calcarenite to argillaceous limestone, the lower beds being more calcareous and less arenaceous, suggesting a dominance of marine conditions as compared to the northern continental or near-shore deposits.

At Mockingbird Gap the basal Derryan beds (MG 1-8) are 50-15o feet of calcareous sandstones with lenses of conglomerate and calcarenite. The upper 110 feet (MG 9-21) is cherty dark-gray limestones, with interbeds of siliceous siltstones, limestone pebble-conglomerates, calcarenites, and blackish shales.

In Rhodes Canyon the basal conglomerates (R 88-9o) include lenses of dark-gray carbonaceous shale and grade up into calcareous and quartzitic sandstones (R 91-98), with lesser amounts of grayish-black siliceous siltstones, carbonaceous shales, and arenaceous limestones. Medial beds (R 99-104) are chiefly calcarenites, silty limestones, and crinoidal limestones. Upper beds (R 105-111) are medium-gray calcareous sandstones, dark-gray calcareous siltstones, and carbonaceous shales; several horizons of aphanitic limestones contain calcarenite lenses. The Derryan interval crops out as a ledgy slope beneath Desmoinesian cliffs. Mapping of the Rhodes Canyon area has shown that where the Derryan beds are thin, the lower sandy beds were not deposited.

At Hembrillo Canyon (pl 3-A) the basal chert conglomerate (H 124) grades up into calcareous sandstone and arenaceous limestone (H 125-126a). Above is about 8o feet (H 126b-132) of argillaceous silty limestone, calcareous shale, carbonaceous shale, and thin conglomeratic sandstone; then about 4o feet (H 133-134) of silty limestones forming broken cliffs. These are overlain by about 6o feet (H 135-138) of calcareous shales and silty limestones. The upper 14o feet (H 139-147) is silty limestones intruded by olive-gray chloritic hornblende andesite sills. The Derryan beds in Hembrillo Canyon contain much less sandstone and more silty limestone and shale than those in the Rhodes Canyon area.

At Ash Canyon the lower 4o feet (A 121-125) of the Derryan beds consists of medium-gray argillaceous limestones and medium light-gray arenaceous calcarenites, in part silicified. In places the basal beds are sandy shales, coarse-grained arenaceous calcarenites, and limy sandstones with lenses of chert-limestone flat pebble-conglomerates. Above is about 35 feet (A 126-127) of calcareous shales overlain by 12 feet (A 128-129) of hard cherty fossiliferous limestones. The series is capped by about zo feet (A 13o) of grayish-black carbonaceous shales. Arenaceous limestones of the Des Moines series are angularly unconformable over the blackish shales; obviously, from lithology, thinness, and faunal hiatus, upper Derryan rocks were removed or not deposited before basal Desmoinesian sediments were laid down.

If considered as individual units, the three sections of Derryan rocks are lithologically different. Clastic ratios (conglomerate, sandstone, shale, siltstone : chert, limestone, calcarenite, calcilutite) range from 2.2 for Rhodes Canyon, to 1.85 for Ash Canyon, to 0.75 for Hembrillo Canyon. Sand-shale ratios (sandstone, conglomerate : shale, siltstone) range from 1.46 in Rhodes Canyon, to o.33 in Hembrillo Canyon, to 0.10 in Ash Canyon. The resulting lithologic groups (Krumbein and Sloss, 1951, p 406), with ratios of sand: shale: limestone, are as follows: Rhodes Canyon, 931/2: 641/2: 72, a sand-lime group; Hembrillo Canyon, 37: 112: 195 1/2, a lime-shale group, and Ash Canyon, 6 1/2: 63: 371/2, a shale-lime group. Upper Derryan rocks, absent at Ash Canyon, are chiefly limestones to the south at Bishop Cap. Southward in the range the Derryan rocks become predominantly limestone and marine shale, in contrast with the dominance of sandstone at Rhodes Canyon.

Conglomerates, except for lenses of limestone pebble-conglomerates, are near or at the base, intertonguing with pebbly sandstones. Pebbles, cobbles, and boulders are chiefly white to light-gray chert, similar to the chert of the Tierra Blanca member of the Lake Valley formation, but near Hembrillo Canyon, where channeling is common, the black-banded chert of the Alamogordo member is locally abundant. At Rhodes Canyon minor amounts of quartzite, sandstone, dolomite, limestone, granite, and schist also occur as pebbles and cobbles; at Ash Canyon limestone pebbles are locally numerous. Cementing material varies from calcareous sandstone and calcarenite to siliceous ferruginous silt. Fragments are angular to subrounded without regard to hardness or size.

The lower sandstones at Rhodes Canyon below marine limestones consist chiefly of clear, smoky, blue-gray, or milky angular quartz, with minor amounts of chert, calcite, muscovite, and white, colorless, and pink feldspars, cemented by calcareous to siliceous ferruginous silt. The upper sandstones are of two types: (1) hard, limy, siliceous ledges, in which the grains are of angular quartz (pl 4-B), with minor fossil fragments, calcite oolites, and a few white feldspars, cemented by calcite, cryptocrystalline quartz, and greenish clayey quartz silt; these limy sandstones grading laterally into arenaceous calcarenites; (2) silty, calcareous, fine-grained sandstone, with scattered muscovite and minor fossil fragments.

The Derryan sandstones in Hembrillo Canyon are poorly sorted, pebbly, and calcareous, consisting chiefly of quartz grains, with some grains of limestone and fossil fragments. At Ash Canyon the sandstones are silty and limy and are intercalated with calcarenites.

At Rhodes Canyon siliceous blackish carbonaceous siltstones occur as hard ledges and contain angular fine-grained quartz, muscovite, calcite, and altered feldspar grains as minor constituents. Lenses of this type of siltstone occur in the silty limestones in all three areas.

Shales in Rhodes Canyon are dark gray to black and carbonaceous; clayey, limy, and light gray; or silty and calcareous. At Hembrillo Canyon there are two additional types: (1) dark-gray to black and calcareous shales; (2) light-gray to greenish-gray limy shales, with nodules and lenses of argillaceous limestone. At Ash Canyon the calcareous shales vary from siliceous and greenish to limy, with numerous lenses of fossiliferous limestones.

Calcarenites in Rhodes and Hembrillo Canyons are similar, composed chiefly of fossil fragments, with variable amounts of quartz, minor chert, ferruginous silt galls, and black phosphatic gastropods, cemented by calcareous ferruginous silt; limestone pebble-conglomerate lenses are intercalated. Calcarenites in Ash Canyon are arenaceous to siliceous, with much silica as angular silt-size grains and as cement, although cryptocrystalline calcite cement dominates. Quartz grains are corroded in contact with calcite cement.

Derryan limestones in Rhodes Canyon are of five types:

(I) those that are dark gray, silty, and aphanitic, with scattered angular silt-size quartz, scattered fossil fragments (chiefly brachiopods and gastropods), and lenses of coquinoid calcarenite; this type grades into black calcareous siltstones or olive-gray siliceous siltstones; (2) arenaceous light-gray fine-crystalline limestones, with scattered quartz grains and fragments of brachiopods, crinoid columnals, algae, and bryozoa; (3) gray medium-crystalline limestones, with numerous fossil fragments and lenses of coquinoid calcarenite; (4) light-gray and light-brown to dusky-brown coquinoid limestone like type 3, with flakes, nodules, and stringers of chert; (5) gray aphanitic to medium-crystalline limestone, with scattered fossils and fossil fragments. Derryan limestones in Hembrillo Canyon are mainly dark-gray silty to argillaceous carbonaceous laminated calcilutites, in part with scattered fossils. Nodules and lenses of black chert occur in some beds. The upper limestones are coated by brownish ferruginous siliceous calcite films superficially resembling chert. Limestones in Ash Canyon, bearing only older Derryan fusulinids, are argillaceous and silty to sandy, with numerous fossil fragments, and contain lenses of coquinoid calcarenite. The lower limestones contain siltstone lenses, scattered muscovite flakes, black chert flakes, and phosphatic nodules. Lenses of light-to medium-gray chert are numerous in the upper limestones.

Thickness

Rocks of Derryan age range in thickness from 107 feet in Ash Canyon to 345 feet in Hembrillo Canyon. The thickest section may contain pre-Derryan Pennsylvanian rocks; the lowest diagnostic fusulinids occur rather high in the section. The thin section in Ash Canyon lacks beds with *Fusulinella,* as does the Rhodes Canyon section. In the former place these beds either were not deposited or were removed by pre-Desmoinesian erosion; in Rhodes Canyon the upper Derryan beds are mostly elastic and, therefore, bear no faunas. In contrast, upper Derryan beds at Mockingbird Gap are marine limestones and contain numerous *Fusulinella.*

In the Sacramento Mountains beds of Derryan and Morrowan (?) age are about 35o feet thick and are lithologically similar to those in the San Andres Mountains. From Mockingbird Gap northward to the northern Oscura Mountains Derryan rocks thin to 15o feet and, except for basal elastics, are mostly dark-gray nodular cherty limestones. In the Robledo Mountains, 25 miles southwest of Ash Canyon, Derryan rocks are only about 20 feet thick. In the Mud Springs Mountains, however, Derryan beds consist of about 200 feet of cherty limestones, with interbedded shales and conglomeratic sandstones. Southward, in the Deny Hills, the series has thinned to 130 feet. South of the Organ Mountains batholith at Bishop Cap, and in the Franklin Mountains, the Derryan and Morrowan (?) rocks are about 800 feet thick and are massive cherty limestones.

Fauna

Derryan and pre-Derryan (?) rocks are in the following fusulinid zones, in ascending order: *Millerella, Profusulinella,* and *Fusulinella. Millerella* ranges throughout the Pennsylvanian rocks and down into the Chester, Upper Mississippian. In the Lower Pennsylvanian, Morrowan series, *Millerella* is abundant almost to the exclusion of other fusulinids. In sparsely fossiliferous rocks, however, *Millerella* is not proof of Morrowan age, as few, if any, of the species have any great value for correlation. The lower beds in Ash and Rhodes Canyons containing only *Millerella* are probably Derryan. The zone of *Profusulinella* is chiefly of lower Derryan age; P. *copiosa* in most places is near the base of marine Derryan beds. *Fusulinella* ranges from upper Derryan into lower Desmoinesian, but in Desmoinesian rocks it is accompanied by *Fusulina.* Abundant *Fusulinella* were found only in the upper part of the Derryan at Hembrillo Canyon and Mockingbird Gap.

DES MOINES SERIES

Beds of Desmoinesian age occur throughout the San Andres Mountains. They rest relatively conformably on Derryan strata in many areas but in Rhodes and Ash Canyons are unconformable or disconformable on various Derryan beds. The Desmoinesian as here used is approximately correlative with the Strawn of the Trans-Pecos area.

Lithology

Desmoinesian rocks are chiefly massive- to medium-bedded cherty or coquinoid limestones, with arenaceous calcarenites near the base and argillaceous limestones near the top. The lithology is typical of rocks of this age, which form the prominent ledgy Pennsylvanian cliffs and contain abundant fusulinids throughout southern New Mexico (pl 3-A).

In Rhodes Canyon the basal 15 feet (R 112) is arenaceous to pebbly calcarenites. Above is a 22-foot (R 13) cherty fossiliferous limestone cliff. Next above (R 114-116) are partly covered shales and rubbly limestones, about 4o feet thick, with a medial massive limestone ledge. Then comes a 43-foot cliff (R 117) of fossiliferous massive sparsely cherty limestone, capped by 10 feet of siliceous aphanitic limestone. This is overlain by a thick sequence (R 118-123) of cherty limestones, forming cliffs and ledges, about 220 feet thick. The upper 270 feet (R 124-143) is interbedded coquinoid limestones, cherty limestones, and nodular shaly limestone, intruded by several thin sills of hornblende andesite. The upper contact with Missourian beds is gradational to sharp; in places cliff-forming limestones 25 feet thick are thinned in a southward direction, down to the ledge of R 143 below a ragged contact (pl 1).

In Hembrillo Canyon lower Desmoinesian beds, 10 feet thick (H 148 basal), are slightly cherty silty limestones like the uppermost Derryan. Above is about 285 feet (H 148-159) of interbedded hard cherty limestone and friable fossiliferous coquinoid limestone, which crop out as cliffs and ledges. The upper 30o feet (H 160-17o) is alternating thin- to medium-bedded argillaceous limestone ledges, friable coquinoid limestone slopes, and cliffs of massive biostromal coquinoid limestones. Only a few of these upper beds are cherty. Contact with the overlying Missourian strata is in most places a sharp break from cherty fossiliferous limestone to the intercalated shales and argillaceous limestones of the Missourian.

The Ash Canyon Desmoinesian beds are markedly thinned; from fusulinid evidence it seems likely that strata of upper Desmoinesian age are absent. The Desmoinesian beds overlie Derryan strata with a relatively pronounced unconformity. The basal 22 feet (A 131-132) is massive arenaceous calcarenites and limy sandstones, crosslaminated in part, containing prominent scattered grains of chert, mica, white feldspar, and hornblende (?). Next above is about 22 feet (A 133-136) of thin- to medium-bedded argillaceous to coquinoid limestones, with shale lenses, and a medial massive bed of calcareous sandstone or arenaceous calcarenite. The upper 140 feet (A 137-140) is cliff-forming cherty limestone and massive coquinoid limestone, with thin lenses of nodular argillaceous limestone and shale. This sequence is similar to that of the lower part of the Desmoinesian rocks in the other two sections. The contact with overlying Missourian beds seems to be conformable in most places, although locally there is a few inches of relief.

In Mockingbird Gap, at the north end of the San Andres Mountains, the lower 275 feet (MG 22-36) of the Desmoinesian beds is cherty to coquinoid cliff-forming limestones, with medial (MG 31) thin greenish sandstones, and thin beds of arenaceous calcarenite near the top (MG 34). The upper 265 feet (MG 37-56) is massive-bedded limestones, aphanitic to coquinoidal, alternating with nodular marly limestone. Basal beds (MG 37, 39) are arenaceous micaceous calcarenite; near the top (MG 50) are a quartz pebble-conglomerate and reddish micaceous sandstone.

No sandstones are present in Desmoinesian sections in Rhodes and Hembrillo Canyons but occur in the basal part of the Ash Canyon section (A 132, 135), where they are intercalated with arenaceous calcarenites, are very coarse grained and crosslaminated, have angular to subrounded grains, and consist of quartz, fossil fragments, calcite, and minor chert, cemented by crystalline calcite. Two sandstone units occur in the Mockingbird Gap section; the lower sandstone (MG 31) has basal lenses of quartz granule-sand, is greenish-brown, and is coarse to medium grained. The upper elastic bed (MG 50) is of basal crossbedded granule to pebble quartz conglomerate that grades up into coarse-grained brownish-red highly micaceous sandstone.

Shale occurs mostly as partings and thin lenses between limestone beds or intercalated with nodular argillaceous limestone. Shale beds over a foot thick occur only below and above the cliff-forming cherty limestones typical of medial Desmoinesian beds. The shale is light gray, although one bed (basal H 152) in Hembrillo Canyon is dark gray, calcareous to limy, fissile to clayey, with sparse to numerous limestone nodules and lenses.

Most of the Desmoinesian limestones, and indeed most of those in the Pennsylvanian, could be called calcarenites or calcilutites if a broad definition of these terms is followed. Even the cryptocrystalline limestones seem to be composed chiefly of fossil-fragment debris cemented by crystalline to cloudy cryptocrystalline calcite and minor ferruginous clay and silt. Many of the limestones are aphanitic (grains under 0.2 mm) but, although appearing structureless under hand lenses or binocular microscope, are composed of very fine-grained to silt-size fossil debris. Whether coarse grained or not, the fragments in most Desmoinesian limestones are unsorted and unoriented, resembling the trash-heap accumulations left by prehistoric man.

Calcarenite has been used for those fossil-fragment limestones that, at least in part, are sorted, whose fragments average larger than silt-size, and that would be called sandstones if the clastic grains were predominantly quartz. None were seen in the Desmoinesian at Hembrillo Canyon except as lenses in the coquinoidal biostromal limestones. In the Ash Canyon section calcarenites occur at or near the base of the Desmoinesian, where they are intercalated and laterally grade into limy quartz sandstones. They are crosslaminated, very coarse grained, with grains angular to subrounded, and show various proportions of calcite, fossil fragments, quartz, and minor chert, cemented by calcite; lenses of limestone, chert, and quartz pebbles are common. The basal beds (R 112) of the Desmoinesian in Rhodes Canyon are calcarenites, with only minor (2 percent) sand-size quartz grains. These calcarenites are medium to coarse grained, with scattered limestone pebbles up to 1 o mm long; grains are angular to subrounded and consist chiefly of fossil fragments and structureless calcite, cemented by calcite and minor hematitic silt. In the upper part of the Desmoinesian are conglomeratic lenses (R 129) composed of angular to subrounded, tabular granules and pebbles of limestone in a clay matrix. Above is a conglomeratic calcarenite (R 132), coarse to very coarse grained; grains are angular to rounded, consisting chiefly of fossil fragments and calcite, with about 4 percent chert and clay galls. Granules and pebbles are subangular and are limestone, fossil fragments, chert, and clay galls.

Desmoinesian limestones, whether classified chiefly by faunas or by gross lithology as the lower gray limestone member of the Madera limestone, are usually considered as monotonously uniform massive- to thin-bedded cherty medium-gray limestones. Relatively close examination of the Desmoinesian limestones in the San Andres Mountains indicated 8 generalized types and 28 variants, excluding calcarenites!

Composing 3o percent of the combined Desmoinesian sections, and 44, 44, and 13 percent respectively of the Desmoinesian sections in Ash, Rhodes, and Hembrillo Canyons, are light- to medium-gray, fine- to coarse-crystalline, cherty coquinoid limestones (e.g., R 123, H 148, A 137) that crop out as thick ledges or cliffs. Variants of this limestone type contain laminae and minor cement of ferruginous silt (R 113); are friable lenticular ledges with shale interbeds (R 6); contain scattered subangular quartz grains (R 118); are chiefly fine to medium crystalline, with scattered coarse-crystalline coquinoid lenses (H 148); and vary from medium light gray to medium dark gray in color (A 137, 139). This limestone type is chiefly lower and middle Desmoinesian.

Second in abundance is light- to medium-gray, fine- to coarse-crystalline, noncherty coquinoid limestone, comprising 21 percent of the total Desmoinesian limestones and the most common type in Hembrillo Canyon, where it forms 30 percent of the section, compared with 14 percent in Rhodes Canyon and 12 percent in Ash Canyon. This type is about equally divided between friable beds that crop out as rounded ledges and slopes (R 125, 138; H 15o, 168; A 134) and hard resistant beds forming ledges or cliffs (upper R 127, H 163). Variants of the well-cemented type contain scattered sub-rounded quartz grains (basal H 169) or, as in the basal Desmoinesian bed in Ash Canyon (A 131), are arenaceous and laminated and contain scattered to abundant grains of rounded to subangular quartz, mica, white feldspar, chert, hornblende (?), and limestone, the textures suggesting a recrystallized calcarenite.

Thinsections of this coquinoid limestone type (pl 4-A) show a breccia of fossil fragments, neither sorted nor laminated, with some angular crystalline calcite grains probably derived from large fossils. These elastic grains range in size from o.3 to 12 mm and average 1 mm. The rock contains up to 15 percent cement of anhedral crystalline calcite. The calcite crystals average 0.06 mm in diameter and tend to aggregate in comb structure between dust-rimmed elastic grains. Fragments consist of crinoid columnals, echinoid plates, brachiopods, corals, algae, bryozoa, and fusulinids. Gastropods are common to sparse; pelecypods, rare. Fine-grained and argillaceous lenses contain chiefly small gastropods and ostracods, with some pelecypods.

The third most abundant type (R 117, H '55) is light- to medium-gray, aphanitic to fine-crystalline cherty limestone, with scattered to abundant fossils. Confined to middle and lower Desmoinesian beds, this type comprises 18 percent of the total section, 24 percent of that in Rhodes Canyon, and 17 1/2 percent of that in Hembrillo Canyon; it is absent in Ash Canyon. This limestone type crops out as massive ledges and cliffs except for medial beds in the Hembrillo Canyon **(H** 155, 16o) Desmoinesian section, which are argillaceous, include shale partings and lenses, and crop out as ledges and rubbly slopes. Another variant (basal H 151) contains minor amounts of silt-size quartz.

In thinsections this aphanitic to fine-crystalline limestone is an unsorted, unorientated mesh of fossil fragments, averaging 0.05-0.3 mm in size. Their shape is predominantly tabular, platelike, or rodlike, and they occur in a matrix of brownish cloudy cryptocrystalline calcite apparently of silt-size fossil fragments and calcite crystals under o.01 mm in size. As in all the cherty beds, aggregates of chalcedony are scattered throughout, replacing fragments and cement, and containing scattered euhedral dolomite rhombs. This general silicification, of which the chert masses are only the expression of larger, more totally silicified areas, appears to be chiefly responsible for the hard resistant nature of most of the cherty beds, and for the pitted and pointed weathered surface characteristic of even the relatively noncherty, but massive, Desmoinesian limestone.

The other five types of Desmoinesian limestones comprise only about a third of the total and tend to be abundant in only one of the three sections. Fourth in rank, comprising 9 percent of the combined sections and 20 1/2 percent of the Hembrillo Canyon section (absent in Rhodes and Ash Canyons), is a light- to medium-gray, aphanitic to fine-crystalline, relatively chert-free limestone. It has coquinoid lenses, **is** friable, and crops out as thin lenticular ledges and slopes. Lower beds (e.g., medial H 149) contain laminae of ferruginous silt and a few scattered chert flakes; upper beds (upper **H** 169, 103 feet), comprising most of the upper Hembrillo Canyon Desmoinesian section, contain lenses of silty laminated fine-grained calcarenite, with scattered quartz grains.

Fifth in rank, comprising 8 percent of the total section **and 14** percent of the Hembrillo and Ash Canyon sections, **is** dark-gray aphanitic to fine-crystalline cherty fossiliferous limestone cropping out as ledgy cliffs (upper R **141, H** 159). Variants are silty, very cherty limestones **(H** 158), relatively unfossiliferous beds (H 17o), and hard limestones cropping out as thin brittle ledges (A 140).

Sixth in rank, comprising 6 percent of the combined sections and 11 1/2 percent of the Rhodes Canyon section (R 142), is a thin-bedded to nodular, dark-gray argillaceous aphanitic to fine-crystalline noncherty limestone, typical of upper Desmoinesian beds, with sparse fossils and some shale lenses. Variants are fetid, slightly argillaceous limestones with scattered fossils, which crop out as thick ledges (R 139), and basal beds of the Desmoinesian in Hembrillo Canyon (basal **H** 148), which are silty, carbonaceous limestones similar **to** upper Derryan limestones.

Seventh in rank and comprising 5 percent of total Desmoinesian limestones, is a light- to medium-gray, aphanitic to fine-crystalline noncherty unfossiliferous limestone cropping out as thick ledges (basal R 117) or as nodular argillaceous limestones forming slopes (R 14o, **H** 164, upper A 139). A variant of the thick-ledged type contains scattered quartz grains and chert flakes (A 138).

Eighth in rank, comprising only 3 percent of the total section but making up 13 percent of the Ash Canyon Desmoinesian section, is light- to medium-gray, fine- to coarse-crystalline noncherty fossiliferous limestone, which crops out as massive ledges (upper H 151, basal R 120, A 138).

The lithology of the Desmoinesian limestones can be summarized as follows:

Lower Desmoinesian limestones are typically cherty, light to medium gray, and fine to coarse crystalline; they crop **out** as cliffs or massive ledges. In Rhodes Canyon only the uppermost limestones are dark gray and associated with dark-gray chert; at Hembrillo Canyon darker colored limestones and dark-gray chert occur throughout the section, interbedded with lighter gray limestones. Except for the lower Hembrillo Canyon beds, the argillaceous and silty limestones are more often light to medium gray than dark gray. Limestones that are dark gray are aphanitic to fine crystalline, but aphanitic to fine-crystalline limestones that are light to medium gray are more numerous. Compared with the Desmoinesian limestones, Derryan limestones contain more quartz silt and more clay; Missourian limestones are more argillaceous and are interbedded with numerous shales.

Like the Desmoinesian both the Derryan and Missourian

TABLE 4. LITHOLOGIC CHARACTERIZATION OF THE DESMOINESIAN LIMESTONES (in feet)

	Total	Rhodes Canyon		Hembrillo Canyon		Ash Canyon
		Lower	Upper	Lower	Upper	
	(1,311 ft)	(R 112-123)	(R 124-143)	(H 148-159)	(H 160-170)	(A 131-140)
Cherty	736	315	69	186	71	94
Noncherty	575	10	171	113	209	70
Light- to medium-gray	1,116	325	170	227	259	135
Dark-gray	195	0	70	73	21½	30
Aphanitic to fine-crystalline	589	138	100	137	162	51
Fine- to coarse-crystalline	722	187	140	163	118	113
Cliffs and thick ledges	792	272	130	177	95	118
Thin ledges and slopes	519	53	110	123	185	47
Silty	224	22	0	99	103	0
Arenaceous	170	27	0	0	118	24½
Argillaceous	181	26	58	38	59	0
Dark-gray, argillaceous or silty	86	0	13½	73	0	0

contain cherty beds, although the percentage of chert is much lower. The cherts were examined, therefore, in some detail to see if they could be used as horizon markers. Color appears to be the only major characteristic that does not change greatly within individual beds. Most of the Pennsylvanian cherts are smooth and chalcedonic, although on weathering surfaces they may be vuggy, drusy, or chalky (LeRoy and Crain, 1949, p 115).

The detrital chert at the base of Derryan beds is chiefly that derived from Mississippian cherts; except when mixed with other elastic fragments, it is predominantly whitish or is blackish banded and mottled gray. Chert is not abundant in Derryan limestones except in several Ash Canyon beds (A 128, 129) where it occurs as lenses and large nodules. In most Derryan limestones chert, where present, is in scattered laminae, irregular flakes, small nodules 1/2-2 inches long, or thin (1/2-1 inch) discontinuous lenses. The chert is light to medium gray except for sparse grayish-black chert near the middle of the Derryan in Hembrillo Canyon (H 134). Many of the upper Derryan beds, as well as some Desmoinesian limestones, have surface coatings of vuggy chalky light-brown to brownish-gray, partly silicified casehardened calcite, which occurs as irregular patches on the outcrops and may be mistaken for chert. The lower Derryan sandy calcarenites in Ash Canyon (A 123) are in part totally silicified and could be called cherts.

Cherts in the Desmoinesian limestones in Rhodes Canyon are medium to light gray except for medium dark-gray chert lenses in a 5-foot unit (upper R 128) in the upper part of the section. In Hembrillo Canyon the Desmoinesian cherts vary from medium light gray to black without regard to position, although the lowest grayish-black chert (upper H 149) is about 65 feet above the base, and medial cherts (H 156158) are predominantly dark gray and vuggy. Chert in the Lower Desmoinesian of Ash Canyon is dominantly medium dark gray to grayish black. The chert occurs as knobby nodules, flakes, laminae, discontinuous lenses, stringers crosscutting bedding planes, and irregular masses defying description as to shape.

As seen in thinsection, the chert is chiefly chalcedony, with minor opal; it occurs throughout the limestones with no sharp boundaries delineating the megascopic borders of chert nodules and masses; the chert nodules are merely areas where silicification is almost total. The chalcedony occurs as aggregates, with grains that average o.03 mm, and which obscure original limestone textures, or it occurs as spherulitic filling of cavities, such as in fusulinids, bryozoans, crinoid columnals, or algae. Euhedral dolomite rhombs are scattered throughout the aggregated chalcedony.

Cherts in Missourian limestones follow no set patterns among sections. Missourian limestones in Rhodes Canyon contain only sparse, scattered small chert nodules, which range from light to dark gray. The medial limestone cliffs (H 177-178) in Hembrillo Canyon contain sparse to abundant medium dark-gray chert. Similar cliff-forming limestones (A 144) in Ash Canyon contain 15-25 percent light-gray to bluish-gray chert, but the other cherty limestones in the Missourian in this canyon have dark-gray to black chert. The Virgilian limestones contain almost no chert.

As sandstone is absent in the Desmoinesian beds of Rhodes and Hembrillo Canyons, the sand-shale ratios have no significance. Clastic ratios range from 0.02 for Hembrillo Canyon, through 0.05 for Rhodes Canyon, to 0.09 for the Desmoinesian strata in Ash Canyon. The overall elastic ratio is 0.04, compared with a ratio of 1.24 for the Derryan strata.

Thickness

In Rhodes and Hembrillo Canyons Desmoinesian beds are about 600 feet thick but thin abruptly to 183 feet in Ash Canyon, where upper Desmoinesian beds appear to have been removed by erosion or not to have been deposited. Southward Desmoinesian rocks are more than 600 feet thick at Bishop Cap and in the Franklin Mountains, although the top is eroded; in the Hueco Mountains they are 63o feet thick. To the east, in the Sacramento Mountains, almost 1,000 feet of Desmoinesian strata occur, with significant amounts of elastics in the upper part. Northward, Desmoinesian rocks thin to 540 feet at Mockingbird Gap and then to the 32o feet reported (Thompson, 1942, p 41) in the Oscura Mountains. To the west 700 feet of cherty limestones intercalated with thin beds of arkosic sandstones and red shales occur in the Caballo and Mud Springs Mountains, whereas to the southwest, in the Robledo Mountains, Desmoinesian strata are thinned to 215 feet.

It is apparent from this variation in lithology and thickness that Pennsylvanian sedimentary rocks in south central New Mexico are not a simple three-facies combination of lower elastic transgressive sediments, medial uniform marine sediments, and upper regressive sediments. Sedimentation and erosion were more complex, and their interrelationships will not be solved until relatively detailed mapping studies based on lithology and faunas have been made.

Fauna

Desmoinesian rocks are in the zone of *Fusulina,* which, in addition to rapidly evolved species of *Fusulina,* contains *Eoschubertella, Wedekindellina, Pseudostaffella,* and others. Fusulinids identified by Thompson (see pl 1 and measured sections R, H, and A) include many undescribed species, sufficiently similar, however, to known faunas to indicate a complete range of Desmoinesian forms except in Ash Canyon, where beds of upper Desmoinesian age are absent. Masses of *Chaetetes* are common throughout the Desmoinesian strata.

MISSOURI SERIES

Missourian strata occur throughout the San Andres Mountains, although they are the thinnest of the four series represented. They are probably equivalent to the Canyon series of the Trans-Pecos area.

Li thology

Rocks of Missourian age are interbedded argillaceous limestones and calcareous shales, with medial massive cherty limestones, although at Mockingbird Gap numerous beds of greenish micaceous sandstones are present. In Rhodes Canyon the basal 37 feet (RR 144-147) is calcareous shale, with some limestone ledges; above is 35 feet (R 148-149) of massive cliff-forming limestone. The upper 125 feet (R 150-156) is interbedded medium dark-gray argillaceous limestones and calcareous shales, with beds of oolitic limestone near the middle. Contact with overlying Virgilian beds appears conformable, but several feet of relief was observed in a few places.

At the Hembrillo Canyon section the lower 1o feet (H 171) is intercalated argillaceous limestone and calcareous shales, above which is 30 feet (H 172-173) of calcareous dark-gray shale, with silty calcarenite lenses near the top. Above is 54 feet (H 174-175) of argillaceous limestone with shale lenses, followed by a 3-foot limestone ledge and 16 feet (H 176) of calcareous shale. Above the shale is 85 feet (H [1]77178) of cherty medium-gray massive limestone, which crops out as a prominent ledgy cliff; this is overlain by 34 feet (H 179) of olive-gray shale. The upper 41 feet (H 180-184) is interbedded argillaceous limestone and shale, with lenses of calcarenite and oolite. Along the strike the upper shale thickens (HV 1), and the upper argillaceous limestone and shale break into an upper (HV 4) and lower (HV 2) sequence separated by 35 feet (HV 3) of partly carbonaceous dark-gray shale.

Near Ash Canyon the Missourian beds differ from those of the other two localities in being chiefly massive cherty limestones similar to the underlying Desmoinesian strata. The lower 8 feet is argillaceous nodular limestone (basal A 141) teeming with fusulinids; above is 24 feet (upper H 141 and lower H 142) of massive medium dark-gray limestone, cherty at the top. Next is 12 feet (upper H 142) of nodular argillaceous limestone with shale laminae. This is followed by a 54-foot (H 143-144) cliff of medium-gray limestone, highly cherty in the upper two-thirds. The upper 47 feet (H 145-147) is thin- to medium-bedded, cherty to coquinoid limestones. The top surface is undulating, silicified, and iron stained beneath the grayish-black to dark-gray shales and argillaceous Virgilian limestones.

At Mockingbird Gap basal Missourian beds are partly covered quartz conglomerates and greenish micaceous sandstones (MG 57-62) about 63 feet thick, with several crinoidal limestone ledges. Above is 72 feet (MG 63-72) of limestones, cherty to massive, with medial thin sandstone (MG 68). Then comes 84 feet (MG 73-76) of thick micaceous greenish sandstones, with a medial fusulinid limestone, above which is about 50 feet (MG 77-82) of interbedded coquinoid limestone and greenish micaceous sandstone. Next above is 30 feet (MG 83-85) of massive cliff-forming limestones overlain by 37 feet (MG 86-88) of massive to nodular algal limestones, with lenses of "edgewise" limestone pebble-conglomerate. The upper 20 feet is interbedded greenish micaceous sandstone and algal limestones.

Southward from Mockingbird Gap the percentage of limestone in the Missourian beds increases, although the actual thicknesses of the limestones vary only 20 percent between sections. Decrease in the amount of sandstone (131 ft to absent) accounts for most of the decrease in thickness from Mockingbird Gap to Rhodes Canyon, although the amount of shale increases slightly. Clastic ratios from north to south are: northern Oscura Mountains (type sections of Missourian groups, Veredas and Hansonburg; cf. Thompson, 1942, p 58), 0.19; Mockingbird Gap, 1.07; Rhodes Canyon, 0.36; Hembrillo Canyon, 0.57; and Ash Canyon, 0.02. Sand-shale ratios, north to south, are 1.38, 2.87, 0, 0, and 0 respectively, reflecting the interbeds of sandstones in the Oscura Mountains and the lack of quartz sand in the three southern sections. The large amount of sandstone near Mockingbird Gap and the total absence of even sand-sized quartz grains in the Missourian strata in Rhodes Canyon indicate vastly different sedimentation in areas only 28 miles apart.

Shales occurring from Rhodes Canyon southward are calcareous to limy, with some fossiliferous beds, coquinoid lenses, and numerous limestone nodules and lenses. They are light to medium gray or olive except for dark-gray shales (H 72) low in the Hembrillo Canyon section and carbonaceous medium dark-gray shales near the top (HV 3).

Of the Missourian limestones, almost half of those in Rhodes and Hembrillo Canyons are argillaceous, compared with only 17 percent of the Ash Canyon limestones. Most of the argillaceous limestones are medium dark gray to grayish black, aphanitic to fine crystalline, and thin- to nodular-bedded, and contain scattered to abundant fossils. Coquinoid lenses are chiefly of crinoid columnals, ostracods, small high-spired gastropods, small thin brachiopods, such as *Chonetina*, and bryozoans. Crinoid stems up to a foot long were noted (H 175), indicating almost in situ deposition. Some of the upper fossiliferous argillaceous limestones are laminated calcilutites grading laterally into silty very fine-grained micro-oolitic calcarenites.

Beds of micro-oolite, not found in Derryan or Desmoinesian strata but also occurring in the Virgilian sequence, are marker beds in the upper part of the Missourian of Rhodes and Hembrillo Canyons. Under hand lens these aphanitic limestones appear minutely speckled. In thinsection, the oolites are structureless and partly recrystallized; many are in optical continuity with the surrounding cement. They average 0.1 mm in diameter and vary from tabular to spherical in shape. The cement is cloudy cryptocrystalline calcite, with vague anhedral crystals averaging 0.03 mm in diameter. Algal and microcoquinoid lenses are common. The beds are thin and lenticular; desiccation cracks occur on some bedding surfaces.

Increase in the amount of sorted sand-size elastic material marks the vertical and lateral gradation from oolitic calcilutite and oolitic limestone into calcarenites, which occur only as minor lenses in the Missourian sections in Rhodes and Ash Canyons, but which occur as discrete horizons near the base and near the top of the Hembrillo Canyon section. The lower calcarenites are silty and argillaceous, with lenses composed almost entirely of crinoid debris; the upper calcarenites are oolitic, fine to very fine grained, finely laminated, and mottled light brown. In thinsection the calcarenites are a laminated mesh of fossil fragments, which tend to be tabular and deposited parallel to the bedding. Typically the calcarenites contain alternating medium-grained and very fine-grained laminae and lenses, the very fine-grained to silt-size fragmental lenses being predominantly of cloudy argillaceous calcite cement made up of crystals averaging 0.02 mm.

Chert occurs only as small, widely scattered nodules in several lower beds of the Rhodes Canyon section, but the medial cliff-forming limestones in Hembrillo Canyon, and more than half of the Missourian limestones in Ash Canyon, are cherty. The medial cliff-forming limestones in Hembrillo and Ash Canyons (H 177, 178; A 144) are medium light gray, with some medium dark-gray, fine- to medium-crystalline beds, dark-gray chert nodules comprising up to 25 percent of the beds. In thinsection the relatively chert-free beds consist of scattered to abundant recrystallized fossil fragments, unbedded, unsorted, and unorientated, in a matrix of cloudy cryptocrystalline calcite. Many of the fragments are enveloped by the cryptocrystalline matrix and are seen only as faint dust-rimmed ghosts; others are replaced by anhedral crystalline calcite averaging 0.13 mm in diameter, with outer edge of tiny crystals and inner core of relatively coarse crystals.

In addition to the medial cliff-forming cherty limestones of Ash Canyon, lower (basal A 142) medium dark-gray limestone ledges contain up to 4o percent grayish-black chert as nodules and flakes. Upper (A 145, 146) medium-gray fine-crystalline medium-bedded to thin, nodular-bedded and silty limestones contain 5-25 percent light- to dark-gray chert.

Gradational into the cherty cliff-forming limestones are noncherty medium light-gray fine-crystalline limestones, with lenses of coarse-crystalline coquina that crop out as thick ledges or cliffs (R 148, basal H 176, A 143). Massive lower (upper A 141) and uppermost (A 147) Missourian limestones in Ash Canyon are medium dark gray and contain scattered chert nodules. Thin-bedded medium-gray to dark-gray, aphanitic to fine-crystalline limestones, which are not argillaceous, constitute only a minor part (4 percent) of the Missourian limestones.

Thickness

Beds of Missourian age thicken from 195 feet in Rhodes Canyon to 271 feet in Hembrillo Canyon, and then thin southward to 145 feet in Ash Canyon. Southward, at Bishop Cap and in the Franklin Mountains, Missourian beds are not known to be exposed; to the southeast, in the Hueco Mountains, they are only about 120 feet thick and consist of interbedded calcareous shales and cherty phosphatic limestones, with lenses of limestone pebble-conglomerates. In the Sacramento Mountains, Missourian strata are 500-90o feet thick and are thin-bedded argillaceous limestones and calcareous shales. Northward from Rhodes Canyon they thicken to 345 feet at Mockingbird Gap and then thin in the northern Oscura Mountains to about 240 feet of thin- to thick-bedded limestones, with lenses of red to green shales and arkosic to micaceous sandstones. Westward, in the Mud Springs Mountains, Missourian beds are cherty algal limestones below and intercalated limestones and shales above; about 270 feet thick. To the southwest, in the Robledo Mountains, Missourian rocks are about 215 feet thick and consist of interbedded nodular limestones and calcareous shales, with several thick massive limestones near the top.

Fauna

Missourian beds are in the lower part of the zone of *Triticites.* The lowest horizons are characterized by a recurrence of *Wedekindellina* in the form of W. *ultimata,* which occurs in a widespread zone throughout the central and western United States in such formations as the Coane limestone of New Mexico (Thompson, 1942, p 6o) and Bethany Falls limestone of the midcontinent area. Missourian rocks in the three measured sections did not yield many fusulinids, but typical Missourian *Chonetina* and *Echinoconchus* also were noted.

VIRGIL SERIES

Sedimentary rocks of Virgilian age in the San Andres Mountains are lithologically distinct from typical beds of similar age in the rest of New Mexico. In the San Andres Mountains they are deltaic- to brackish-water clastics and precipitates, consisting of silty brownish shales, dark carbonaceous shales, dark-gray argillaceous limestones, laminated calcilutites, silty calcarenites, silty calcareous sandstones, and thick lenses of massive biostromal limestones. Two thick gypsum beds are close to the top near Ash Canyon; numerous biohermal reefs (pl 3-C) are near Rhodes and Hembrillo Canyons.

These materials were deposited in a narrow north-south Virgilian basin extending from Rhodes Pass south to the New Mexico-Texas line near Newman, where Thompson, (1942, p 18) noted in drill cuttings thick Virgilian beds with two gypsum horizons. The upper gypsum crops out in the western foothills of the Franklin Mountains, southwest of Anthony Pass. Unfortunately, Virgilian beds have been removed almost entirely by early Wolfcampian erosion in the Hueco Mountains area, so that the original extent of the basin to the southeast is not known. East, north, and west of the basinal deposits Virgilian rocks are thinner and contain significant amounts of interbedded redbeds, arkosic sandstones, and gray calcareous siltstones.

The Virgilian rocks here considered are the approximate equivalent of the Cisco series of the Trans-Pecos area. Fusulinids are sparsely distributed in these thick Virgilian deposits. Lack of faunal control in upper beds at Hembrillo and Ash Canyons allows the possibility that those beds may be lowermost Wolfcampian; however, they are similar to upper beds at Rhodes Canyon that contain Virgilian fusulinids.

Panther Seep Formation

The Virgilian deposits are dissimilar lithologically to the Keller and Fresnal groups and the Del Cuerto, Moya, and Bruton formations of Thompson (1942, pp 67-82), although approximate equivalents can be seen in the northernmost section at Mockingbird Gap. They are also dissimilar to the Holder formation of Pray (1954, p 93) in the Sacramento Mountains and to the Bar B formation of Kelley and Silver (1952, p 93) in the Caballo Mountains. Owing to the distinctiveness of the lithology and the possibility that upper portions may be Wolfcampian, the unit is here given a formational name, the Panther Seep formation, and has been mapped as such in Black Top Mountain quadrangle, which includes the Rhodes Canyon area.

Panther Seep is in Bearden Canyon, 4.1 miles from the mouth of the canyon, where the latter joins Rhodes Canyon. (See U. S. Geological Survey topographic map of Black Top Mountain quadrangle and fig 5.) The formation is well exposed along Bearden and Rhodes Canyons. The type section is listed herein as units R 157-219 (see description and pl 1) of section R, measured in or near Rhodes Canyon. Units R 157-172 were measured (fig 5) in the SE1/4 sec. 14, T. 13 S., R. 3 E., on the northwest side of Bosque Canyon, above Potter ranch headquarters, and also 0.7 mile from the mouth of Bosque Canyon where the latter joins Rhodes Canyon. Units R 172-219 were measured (fig 5) on the northeast side of Rhodes Canyon, beginning just below the road in the center of sec. 12, T. 13 S., R. 2 E., 0.5 mile below Rhodes Spring. Although certain lithologies typical of the formation south of Rhodes Canyon, such as bioherms and gypsum beds, are not in the type section, the Rhodes Canyon section is a fair representative of the lithologies and faunas and, more important, is easily accessible, if permission is secured from the military authorities.

The Panther Seep formation can be mapped from Mockingbird Gap to the southern end of the San Andres Mountains, and the upper part of the formation is exposed in the northern Franklin Mountains. The term is applied to the basinal deposits as detailed below, which are chiefly, if not entirely, of Virgilian age in the San Andres Mountains and in adjoining areas where the unit retains its lithological entity. It is correlative to most of the Holder formation of the Sacramento Mountains, to the upper part of the Bar B formation of the Caballo Mountains, and to the Keller and Fresnal groups as measured by Thompson (1942) in the Oscura, Mud Springs, and Robledo Mountains.

The Panther Seep formation, as mapped near Rhodes Canyon, has been subdivided into two members, which are approximately equivalent to the Keller and Fresnal groups respectively, and which have been traced to Hembrillo Canyon. Tentative equivalents of the members are recognized in Ash Canyon.

Lithology

In the Rhodes Canyon area the lower 13o feet of the Panther Seep formation (R 158-159) is olive-gray silty shale and calcareous siltstone, with sandstone laminae and lenses on which lies a prominent brown-weathering coquinoid 5-foot limestone (R 160) followed by 102 feet (R 161) of olive-gray shale and sandy siltstone. These are overlain by about 83 feet (R 162-167) of interbedded calcareous sandstones, sandy shales, calcareous shales, and silty limestones. A medial 13-foot sandstone (R 166) crops out as a prominent light-brown ledge. Above is about 86 feet (R 168) of grayish-black carbonaceous shale, capped by 7o feet (R 169, 17o) of massive biostromal limestones, which crop out as the lower of two cliffs traced along the outcrop from Rhodes to Hembrillo Canyons. The lower cliff thins south of Sulphur Canyon but is probably the massive limestone of H 196 (pl 1). Above the lower cliff is 163 feet (R 171) of grayish-black carbonaceous shale, with lenses of argillaceous calcilutite. The upper cliff (R 172-175) in Rhodes Canyon, where section R was measured, consists of a lower 35-foot limestone cliff, a medial 21 1/2 feet of calcareous shale, and an upper ledgy limestone cliff, 20 feet thick. This double cliff, traced southward, appears to be the massive cliff of H 215 in Hembrillo Canyon and is the top bed of the lower member of the Panther Seep formation.

The upper member, above the "upper" cliff, consists of 30 feet (R 176) of calcareous shale followed by 10 feet (R 177) of olive-gray calcareous sandstone and 3o feet (R 178-181) of interbedded argillaceous limestone and shales. These in turn are overlain by 33 feet (R 182) of calcareous sandstone and 8 feet (R 183) of limestone and shale, capped by the prominent fossiliferous brown-weathering limestone, 8 feet thick, of R 184. Above is 50 feet (R 185-186) of intercalated silty shale and calcilutite, 20 feet (R 187) of coquinoid limestone, 5o feet (R 188-190) of shale with lenses of glauconitic sandstone, 58 feet (R 191-194) of medium light-gray limestone overlain by 22 feet (R 195-196) of olive-gray calcareous sandstone, shale, and arenaceous calcarenite. These beds are overlain by 48 feet (R 196-198) of calcareous to carbonaceous shale, with lenses of argillaceous limestone, 15 feet (R 199200) of limestone and calcarenite, and 36 feet (R 201) of gray silty shale with plant fragments, capped by 11 feet (R 202) of calcareous sandstone and calcarenite. Above is 7o feet **(R** 203-basal 208) of interbedded argillaceous limestone, calcareous shale, greenish-gray sandstone, calcarenite, and silt-stone. Next is 25 feet (R 208) of grayish-black shale overlain by 7o feet (R 209) of interbedded shale and sandstone, which is capped by 3o feet (R 210-212) of calcareous glauconitic sandstone and arenaceous limestone. Above is 28 feet (R 213215) of interbedded calcareous shale and argillaceous carbonaceous limestone, capped by a 10-foot limestone ledge (lower R 6). The upper 89 feet (R 216-219) is a lower light-gray nodular limestone and upper interbedded limestone and shale.

Panther Seep beds are overlain with pronounced erosional unconformity by the basal Bursum limestone pebble-conglomerates.

The Panther Seep formation in Hembrillo Canyon (pl 1) is about 370 feet thicker than it is in Rhodes Canyon and consists of the same wide variety and intimate intercalation of lithologies (see description of measured sections H and HV). The increase in thickness is due almost entirely to an increase in the amounts of shale beds. For example, in Rhodes Canyon, between the two prominent cliff-forming biostromal limestones of R 169-170 and R 172-175, is 163 feet of grayish-black shale. In Hembrillo Canyon, between the correlative cliff units of H 196 and H 215, is 485 feet of grayish-black shale, olive-gray sandy shales, calcareous sandstones, and calcilutites.

The basal silty sandy greenish-gray Panther Seep shales (H 185, 186; HV 6) in Hembrillo Canyon contrast with the underlying calcarenite, gray calcareous shales, argillaceous limestones, and calcilutites of the Missourian beds. Notable intervals in the Panther Seep in Hembrillo Canyon include the massive greenish-gray calcareous sandstone of **HV** 6; the olive-gray slightly glauconitic sandstones of HV 9, 15 and H 187, 189, which contain scattered plagioclase grains; and the micro-oolitic to conglomeratic limestones of HV 25 and H 206, in which are calcarenite and calcilutite lenses. H 196-197 is the limestone traced north to R 169-170. Within three-fourths of a mile (eastward) this prominent limestone thins into HV 19, but within a mile to the north and south is the horizon of biohermal reefs (pl 3-C). The sequence from H 199 to H 208 is chiefly of carbonaceous shale and calcilutite, with lenses of micro-oolite. H 213 is a dusky-yellow to moderate-brown calcareous sandstone below the massive vertical biostromal cliff of H 215, which, traced north to Rhodes Canyon, is R 172-175 and the top of the lower member. In the upper member H 219-222 includes numerous calcarenite lenses. H 229 is a prominent grayish-red to grayish-green feldspathic calcareous sandstone. H 253-254 is interbedded arkosic sandstone and silty shale, with lenses of limestone pebble-conglomerates; the lower beds are notable for the angular grains of reddish feldspar. From **H** 255 to **H** 268, the uppermost unit of the Panther Seep formation, the rocks are chiefly interbedded calcareous shale and argillaceous calcilutites, overlain with local unconformity by basal Bursum (?) conglomeratic sandstones.

In Hembrillo Canyon a repeated section of upper Missourian and lower Virgilian rocks was measured when cursory examination suggested only slight displacement along a fault zone; detailed mapping has shown stratigraphic displacement of 400-600 feet and illustrated the abrupt lateral variation in the Panther Seep deposits (measured sections H and **HV,** pl 1). Unit HV 6, a 13 1/2 -foot olive limy micaceous sandstone, grades into H 187, a 7-foot olive conglomeratic sandstone with scattered grains of white feldspar and glauconite. **H** 188, greenish calcareous sandy shale 73 feet thick, appears to be the lateral equivalent of HV 7-8, dark-greenish silty sandy shale only 251/2 feet thick, with lenses of brownish micaceous sandstone. The sandstone of HV 9, 23 1/2 feet thick, gray, calcareous, and micaceous, with scattered glauconite and white feldspars, is partly equivalent to **H** 189, 7 feet thick, a similar sandstone but olive and limy. To an observer following the outcrop of this sandstone, the lower beds of HV 9 appear to grade laterally into the sandy shale of H 188 in a southwest direction.

Near the outcrop where section H was measured, a fanglomerate lens of boulder-conglomerate pinches out and grades into sandstone lenses in H 191; the rounded to subangular pebbles and boulders are chiefly of limestone with some sandstone, in a matrix of coarse-grained calcareous sandstone. Units H 191-193, 78 feet thick, consist of greenish sandy shale, dark-greenish silty calcareous sandstone, medial lenses of argillaceous calcilutite, and upper sandy carbonaceous blackish-green shale. These beds grade laterally into or intertongue with units HV 106 feet thick, of blackish-green sandy shales; brownish, olive, and gray calcareous sandstones; and lenses of argillaceous limestone, with conglomeratic, glauconitic, and feldspathic sandstone (basal HV I 5) near the top. Unit HV 16, silty limestones with silty calcarenite lenses, appears to be laterally correlative with upper H 193, a carbonaceous silty calcilutite. Units HV 1718, olive and gray calcareous shale, with lower sandy laminae and upper lenses of carbonaceous laminated calcilutite, grade laterally into H 194-195, basal carbonaceous blackish shale with calcilutite lenses and upper calcareous shale with silty calcarenite and coquinoid limestone lenses. Units H 196-197, a basal 15-foot siliceous silty cliff-forming limestone and an upper 12 1/2 feet of argillaceous dark-gray limestone with shale interbeds capped by microcoquinoid oolitic limestone, grade eastward into HV 19, a 0-foot-thick limestone, of which the lower part is argillaceous and silty and the upper part dark-gray and microcoquinoid. Unit H 198, a calcareous and silty to carbonaceous shale, is equivalent to HV **20,** a similar shale with basal fossiliferous lenses. Units H 199-200, interbedded calcareous silty shale and dark-gray argillaceous limestones, with lower coquinoid calcilutite, grade into HV **21,** argillaceous medium-bedded limestone. Unit H 201, 29 feet of carbonaceous blackish shale, appears laterally correlative with **HV 22,** **46** feet of calcareous greenish shale. Upper H **202,** fine-crystalline fossiliferous limestone, grades eastward into HV 23, aphanitic fossiliferous limestone with microcoquina and calcilutite lenses. Units H 201-205 are carbonaceous blackish shales, lenses of dark-gray argillaceous laminated oolitic calcilutite, fossiliferous limestone, and calcareous shale, which grade laterally into units HV 24-27, beds of similar composition but with less carbonaceous shale and calcilutite, and with lenses of limestone pebble-conglomerate.

The Panther Seep beds near Ash Canyon are about 55o feet thicker than those in Hembrillo Canyon. The Ash Canyon beds include more sandstone, more argillaceous calcilutite and dark limestone, and less shale, as well as two thick gypsum beds. The two massive cliff-forming biostromal limestones traced from Rhodes to Hembrillo Canyons are not recognizable in Ash Canyon; the section is dominated by interbedded dark-gray argillaceous calcilutites and gray calcareous shales. Most of the sandstones are feldspathic to arkosic, and calcareous, containing as minor constituents varying amounts of milky quartz, white potassium feldspar (orthoclase and albite), and white plagioclase (more calcic than albite).

The basal massive biostromal limestone of the Hueco formation overlies the Panther Seep formation near Ash Canyon and L0ve ranch with apparent marked unconformity. At section A, 288 feet of Panther Seep strata occurs ab0ve the upper gypsum bed (A 212) and below the Hueco; at section L, 4 miles to the south, 191 feet of Panther Seep rocks lies between the gypsum (L) and Hueco formation. Most of the additional 97 feet is sandstones and sandy shales; quite possibly some of these clastic beds could be basal Hueco or Bursum strata.

The basal Panther Seep beds (A 148) in Ash Canyon are interbedded dark-gray calcareous shales and argillaceous limestones, 125 feet thick, capped by argillaceous limestone with oolitic calcarenite lenses. These contrast with the basal Virgilian sandy shales in Rhodes and Hembrillo Canyons and are somewhat similar to uppermost Missourian beds in Hembrillo Canyon. Next above (A 149) is 107 feet of calcareous shale with argillaceous limestone lenses, capped by a prominent ledge-forming limestone (A 150) 8 feet thick, which is coquinoidal, oolitic, and calcarenitic. Above 47 feet (A 151) of blackish carbonaceous shale is 133 feet (A 152-153) of interbedded dark-gray shale, calcareous to carbonaceous, of which the upper part is sandy and silty carbonaceous calcilutite. Cyclic units follow (A 154-162), 272 feet thick, consisting of basal calcareous olive arkosic crosslaminated sandstones, in part channeled into underlying beds and grading up into greenish sandy shale and then into silty carbonaceous calcilutites interbedded with dark calcareous to carbonaceous shales. Above a silty conglomeratic calcarenite (A 163) is 54 feet (A 164) of interbedded silty calcilutite and calcareous shale, capped by 28 feet (A 166) of dark-gray carbonaceous shale and calcilutite, which grades up into silty shale (basal A 167). Overlying the shale is 91 feet (A 167-171) of arkosic calcareous micaceous sandstones as ledges amid intercalated calcareous shale and argillaceous limestone. Following this is 64 feet (A 172-173) of interbedded arkosic sandstone and sandy silty shale, overlain by 37 feet (A 174) of interbedded dark-gray shale and silty calcilutite. This cyclic deposition is repeated again by 45 feet (A 175) of sandy shale and arkosic sandstone, overlain by 17 feet (A 176) of interbedded calcareous shale and laminated limy siltstone, in turn overlain by 83 feet (A 177) of interbedded sandy shale and calcareous arkosic sandstone. Thin (7 feet) carbonaceous shales and limestones (A 178-179) follow, overlain by 55 feet (A 179- 18) of interbedded sandy shales and arkosic sandstones. Uppermost beds (A 182-186) of the lower member (?) are interbedded calcilutite, shale, sandstone, and ledgy calcarenite, about 77 feet thick.

The upper member of the Panther Seep formation, up to the lower gypsum bed (A 204, 25 feet thick), consists mostly of (A 182-203, about 500 feet) interbedded calcareous shales and silty calcilutites, with several beds of limy feldspathic sandstone (A 191, **194, 201).** Beds (A **205-21 I,** 312 feet) between the lower and upper (A **212,** 65-79 feet) gypsum beds are also chiefly interbedded calcilutites and calcareous shales, with a few lenses of limy sandstone and calcarenite. The upper 288 feet (A 212-218) near Ash Canyon or 191 feet (L **2-13)** near Love ranch is chiefly lower argillaceous calcilutites, medial limy conglomeratic sandstones, and upper carbonaceous to silty shales and siltstones, with lenticular sandstones.

The Panther Seep beds are the only part of the Pennsylvanian that actually should be called cyclic deposits. As seen from the columnar sections and lithologic descriptions, the "cycles" are irregular and vary laterally to a considerable degree. Rather than being dependent only on eustatic change in sea levcl, they are in part consequences of sudden floods of sand or mud from source areas, shifts of sediments moved by offshore currents or by channel shifts of meandering streams, and filling of partly closed marine basins.

Most of the sediments appear to have been deposited in shallow marine waters, although some of the conglomeratic sandstones are stream deposits. Plant fossils, chiefly fragments of stems, are common in the sandy shales and in the calcareous ferruginous concretions in the sandy shales. The blackish carbonaceous shales and fetid carbonaceous calcilutites were deposited in anaerobic waters that were probably shallow compared to the deep anaerobic Permian Delaware Basin (Newell et al., 1953, p 19), in which the sediments consist of similar calcilutites but interbedded with fine-grained buff quartzose sandstones. The interlamination of gypsum and carbonaceous calcilutite also suggests relatively shallow depth. Gypsum, requiring hypersaline conditions for deposition, is somewhat anomalously associated with carbonaceous calcareous shales and relatively nondolomitic limestones, which contrast with the typical relatives of anhydrite-gypsum, dolomites and redbeds.

Clastic ratios of the lower member of the Panther Seep formation are fairly constant, being 3.8, 4.4, and 4.6 for Rhodes, Hembrillo, and Ash Canyons respectively. Relative increase of impure limestone in the upper member is shown by the Rhodes Canyon clastic ratio, 2.3, and that of Ash Canyon, o.8, contrasted with that of Hembrillo Canyon, 4.4. Clastic ratios for the formation, 2.8 for Rhodes Canyon, 4.4 for Hembrillo Canyon, and 1.8 for Ash Canyon, reflect the prominence of shale in Hembrillo Canyon and of argillaceous limestones and calcilutites in Ash Canyon. Sand-shale ratios for the three sections, being 0.19, 0.16, and o.21, north to south, show the dominance of clay and silt in the clastic fraction. In the lower member in Rhodes Canyon sand-size clastics are uncommon, with a resulting sand-shale ratio of o.08, compared to 0.23 for Hembrillo and Ash Canyon. The relative abundance of sand in the upper member in Rhodes Canyon yields a sand-shale ratio of 0.33, contrasted with 0.11 for Hembrillo Canyon and o.16 for Ash Canyon.

Lithologic variants in the Panther Seep formation are summarized in Table 5, which lists the major lithologic types.

TABLE 5. LITHOLOGIC VARIANTS OF THE PANTHER SEEP FORMATION (in feet)

Rock type	Rhodes Canyon			Hembrillo Canyon			Ash Canyon		
shale, gray		2	2				90½		90½
shale, blackish		29½	29½				70		70
shale, gray-olive, calcareous	5½	58	63½	28½	474½	503	170½	87	257½
shale, blackish, calcareous		6½	6½	15½	31	46½	109½	93	202½
shale, reddish, calcareous					24	24			
shale, reddish, silty, micaceous		5	5						
shale, gray-olive, calcareous, silty	207*	198†	405‡	43*	36†	79‡	25*	98†	123‡
shale, dark-gray, calcareous, silty	3	21	24						
shale, gray-olive, calcareous, sandy	16½	8	24½	48	138½	186½	30½	16	46½
shale, blackish, calcareous, carbonaceous	248½	9½	258	15	3	18		40	40
shale, blackish, carbonaceous				97½		97½	89½	29	118½
shale, blackish, carbonaceous, sandy				32		32			
shale, olive, silty		61½	61½				51	12½	63½
shale, greenish, sandy				282		282	160½		160½
shale, dark-gray, sandy				2		2	42		42
siltstone, olive, brown, yellow, calcareous	14	8½	22½		12½	12½	3½	6	9½
siltstone, gray-olive, limy, sandy	1½		1½					6	6
sandstone, gray-olive-brown, calcareous	34½	35	69½	36	5	41	17	4	21
sandstone, gray-olive, limy, micaceous to silty	3	35	38	29	10	39	16	19½	35½
sandstone, olive-brown, calcareous, silty		12½	12½	25	8½	33½	6	6½	12½
sandstone, gray-green, calcareous				28	16½	44½	15	4	19
sandstone, olive-yellow, silty, micaceous, calcareous				8½	15	23½			
sandstone, reddish, calcareous, silty, micaceous					15	15			
sandstone, olive-gray, arkosic, calcareous					7½	7½	112½	29	141½
sandstone, dark-gray, arkosic, calcareous, micaceous							25½		25½
subgraywacke, greenish, calcareous, silty, micaceous		51	51		1	1	3½		3½
calcarenite, dark-gray, arenaceous, feldspathic		2½	2½				4	2	6
calcarenite, gray, silty, partly argillaceous, micaceous		10	10	2	10	12	15½		15½
calcarenite, dark-gray, silty, coquinoid, oolitic		8	8		26½	26½	4		4
calcilutite, dark-gray, argillaceous		7	7	12½	33½	46	2		2
calcilutite, dark-gray, carbonaceous, silty, argillaceous		6½	6½	2		2	37½		37½
calcilutite, gray, silty, argillaceous				1½	10½	12	50½	131½	182
calcilutite, dark-gray, silty, oolitic				11	5½	16½			
calcilutite, dark-gray, argillaceous							15½	81½	97
gypsum, gray, granular, medium-crystalline								104	104
limestone, gray, ledges-cliffs, coquinoid	73½	103	176½	88½	17	105½	9½		9½
limestone, dark-gray, ledges-cliffs	29½	44½	74	4½	18	22½			
limestone, gray, nodular to thin-bedded	9	19	28	1	9	10			
limestone, dark-gray, argillaceous, thin-bedded	3	1½	4½	17	3	20	26	57	83
limestone, gray, argillaceous, nodular to thin-bedded		17½	17½		28½	28½	8	4½	12½
limestone, dark-gray, argillaceous, silty							45		45
limestone, gray to dark-gray, silty	12	2½	14½	16	18½	34½	2		2
limestone, dark-gray, carbonaceous, silty to argillaceous		8½	8½				7½	196	203½
limestone, gray to dark-gray, arenaceous	13	4½	17½					1	1

* Lower member; † upper member; ‡ total formation.

The dominant shale type in all three sections is gray to olive, calcareous to calcareous and silty. Blackish calcareous carbonaceous shales are prominent in Rhodes and Ash Canyons, greenish sandy shales in Hembrillo Canyon. Although silt makes up significant parts of all lithologies, siltstones are scarce. Sandstones are variable, although mostly calcareous; calcite occurs as cement and as elastic grains. The sandstones in Rhodes and Hembrillo Canyons are predominantly silty and micaceous, although the Panther Seep sandstones near Ash Canyon are chiefly feldspathic to arkosic. Clastic feldspars are principally light-gray plagioclase and orthoclase; pinkish microcline and pinkish orthoclase are uncommon. Some of the micaceous sandstone contains appreciable amounts of brown biotite, in part chloritized. Scattered rounded grains of glauconite occur in most of the sandstones. Conglomeratic lenses are typical intraformational conglomerates that contain angular to subrounded pebbles and cobbles of limestone, sandstone, and silty shales, apparently derived by cannibalism of beds within the Panther Seep sequence.

The arkosic sandstones range up to arkoses that contain only 1 0 percent quartz. In thinsection (pl 5-E) these arkoses, such as lenses in unit H 253b, consist chiefly of angular grains of feldspar, chlorite, aphanitic limestone, fossil fragments, and magnetite, with lesser amounts of quartz. Grains consisting of micrographic intergrowths of clear quartz and highly altered feldspars are prominent in thinsections because of their texture. Cement is crystalline anhedral calcite, which replaced edges and parts of clastic grains. Feldspars, with sodic plagioclase appearing to be most common, are altered to clays and sericite. Scattered grains of apatite and zircon occur.

Precambrian granite and monzonite in the Florida Mountains consist chiefly of white feldspar, quartz, chlorite, and magnetite, with apatite and zircon as accessory minerals (Darton, 1917, p 3). This type of rock could be the source of the Panther Seep arkosic sandstones.

The less feldspathic sandstones contain sparse to abundant mica, chiefly muscovite, but also brown biotite and numerous grains of limestone and fossil fragments, as well as chert, quartzite, and ferruginous clay galls. With increase in calcite grains, fossil fragments, and calcite cement, the limy quartzose sandstones grade laterally into arenaceous calcarenites.

In thinsection a typical arenaceous feldspathic calcarenite, such as from unit A 162, is a poorly sorted, laminated mixture of angular grains of quartz, chert, and whitish feldspar, with subrounded grains of calcite, cryptocrystalline limestone, and fossil fragments. Feldspars are altered almost entirely to sericite and kaolinite and are replaced in part by calcite. The chalky color of the feldspars may be due to this alteration and replacement. Glauconite, chlorite, and magnetite with hematite rims occur as scattered grains. Cement is crystalline calcite in anhedral grains averaging o.o6 mm.

Most of the calcarenites are silty and coquinoid; they are a poorly sorted, laminated mesh of small fossils, fossil fragments, and calcite grains. Elongate fragments are more or less parallel to the bedding. Individual grains are angular to rounded, 0.3-0.05 mm, many having a thin coat of limonite and brown carbonaceous material. Quartz is present as scattered angular silt-size grains and as euhedral authigenic crystals. Cement is cryptocrystalline calcite stained by brown carbonaceous material. Cement and clastic grains alike, as well as the authigenic quartz crystals, are cut by veinlets of crystalline calcite.

Calcilutites are chiefly silty and argillaceous—this is to be expected, as the term calcilutite has been applied only to laminated aphanitic limestones. Laminations are of the three normal types, listed in order of frequency: ( ) color alternations due to amounts of organic content, (2) alternations of relatively coarse and fine particles, such as coarse silt-size grains and fine silt-size grains, and (3) alternations of predominantly calcite laminae with those chiefly of quartz-silt and clay. Doubtless many of the nonlaminated aphanitic limestones were originally deposited as lime silts or lime muds.

In a typical dark-gray finely laminated calcilutite (A 153) the laminae are very irregular, wavy, and lenticular, range from I.0-0.02 mm in thickness, and are marked chiefly by thin streaks of carbonaceous material and clay, admixed with strings of iron oxide (magnetite, pyrite, hematite, and limonite) cubes and blebs, which average 0.005 mm in diameter. In hand specimen these carbonaceous ferruginous laminae are dark paper-thin lines dividing the thicker, lighter calcite-rich laminae. Calcite grains and fossil fragments are well sorted within individual laminae, range from very fine sand size to fine silt size, are cemented or admixed with calcite grains averaging 0.003 mm, and are coated with brown carbonaceous matter and clay (illite ?). Quartz occurs as scattered silt-size angular grains or as euhedral authigenic crystals, most of which are long, doubly terminated hexagonal prisms. Minute calcite veinlets cut across laminae and authigenic quartz alike. Small-scale contemporaneous deformation features (slump blocks, brecciation, folding) are common within the calcilutites and are confined to layers 1/2-1 inch thick between undisturbed layers. Pyrite cubes, up to 2 mm in diameter, altered in part to hematite, are common in the deformed zones.

Limestones are more varied than in older Pennsylvanian strata but have been grouped into 9 types (see table 5), excluding calcilutites and calcarenites. Thick-bedded cliff-forming coquinoid limestones are most numerous in the Rhodes and Hembrillo Canyons sections, where they constitute 73 and 58 percent respectively of the total limestones. Such limestones are almost absent in the Panther Seep beds of Ash Canyon. In the area between Sulphur Canyon and Hembrillo Canyon, and perhaps farther south, there are two horizons of biohermal reefs or patch reefs, as termed by Newell et al. (1953, p 97). The base of the lower biohermal reefs appears to be at the horizon of the biostromal limestones of R 169-170 and H 196-197 (HV 19). The upper reef horizon appears to be near H 20 5-206, about midway between the lower reef horizon and the top of the lower member of the Panther Seep formation. As exposed near Hembrillo Canyon (pl 3-C) the biohermal reefs cap small peaks that rise above shaly slopes. Within 2 1/2 miles along the strike, five reefs are exposed at the lower horizon and five at the upper horizon. One appears to be solid reeflike limestone from the lower to upper horizon, almost 450 feet thick. In most places the reef-flank beds, and probably parts of the reef core, have been eroded away, but the general outline appears to be ellipsoidal, with long axes not trending in any parallel direction. Maximum dimensions are 3,750 feet by 2,500 feet, and up to II 0 feet thick. Core rock is massive unbedded vuggy to dense, aphanitic to coarse-crystalline gray fossiliferous limestone, dolomitic in part. In places the lens-shaped reefs are bordered by crudely stratified porous calcarenites and coquinoid limestones, which dip rather gently away from the cores and grade laterally into the argillaceous limestones, calcareous shales, and sandstones typical of those measured in section H.

In thinsection these reef limestones and the thick-bedded coquinoid limestones are similar to those described from Desmoinesian strata, except for the almost complete lack of chert, a larger amount of algal remains and sparse to abundant angular silt-size grains of quartz and some feldspar.

Most of the Panther Seep limestones in Ash Canyon are dark gray, argillaceous, silty, carbonaceous, and thin-bedded; considerable thicknesses of similar limestones, which, however, are less carbonaceous and lighter gray, occur in the Hembrillo Canyon section. Microcoquina and micro-oolite lenses, as well as laminated calcilutite and calcarenite lenses, are common. Thinsections show much recrystallization and fossil fragments preserved as faint ghosts; the limestone is an unoriented mesh of irregular cloudy cryptocrystalline calcite masses, 0.32-0.08 mm in diameter, in part algal and in part oolitic, in a cement of anhedral elongate calcite crystals averaging o.006 mm long. Various amounts of fine quartz silt, clay, and carbonaceous material occur in or around the cryptocrystalline calcite. The microcoquina lenses are an unsorted, unoriented jumble of small fossils and fossil fragments of fantastic variety, range from 1.3-0.1 mm, and average 0.25 mm in diameter, excluding the flat tabular pieces. Cores of fossils are filled by crystalline calcite, which, along with some of the cement and cross-cutting veinlets, consists of anhedral crystals averaging 0.5 mm in diameter. Most of the cementing material is cloudy cryptocrystalline calcite and fine silt-size fossil fragments, enmeshed with carbonaceous material.

Thickness

The Panther Seep formation equivalents thicken southward from 200 feet in the Oscura Mountains to about 800 feet at Mockingbird Gap, 1,460 feet in Rhodes Canyon, 1,825 feet in Hembrillo Canyon, and 2,400 feet in Ash Canyon. The formation does not appear to be exposed at Bishop Cap, but uppermost beds crop out in the northern Franklin Mountains; only remnants of Virgilian beds remain in the Hueco Mountains beneath the Early Wolfcampian erosional surface. Virgilian beds are 800 to 1,000 feet thick in the Sacramento Mountains, and consist of lower dark-gray shales and interbedded argillaceous limestones which grade up into the upper nodular to massive limestones, conglomerates, arkosic sandstones, and pale reddish-brown to gray shales of Thompson's (1942, p 73) Fresnal group. To the southwest, in the Robledo Mountains, the Virgilian beds thin abruptly to 210 feet from 2,400 feet at Ash Canyon. In the Caballo and Mud Springs Mountains Virgilian strata are about 450 feet thick and are similar to the Virgilian beds in the Sacramento Mountains.

Fauna

Rocks of Virgil age are in the upper part of the *Triticites* zone and are characterized by its numerous species and by *Dunbarinella.* Numerous fusulinids were found in the Panther Seep formation of Rhodes Canyon, some in Hembrillo Canyon, and a few in Ash Canyon (pl 1). Fusulinids, along with many of the other invertebrates, apparently did not like the environment in which the calcareous and carbonaceous shales and argillaceous calcilutites were deposited. Newell et al. (1953, p 67) noted the frequency of fusulinids and suggested that they lived in shallow-water environments around the margins of, but not in, deep and stagnant basins. *Lissochonotes* sp. and *Marginifera* cf. M. *wabashensis* were identified in the Hembrillo Canyon section.

PERMIAN FORMATIONS

Sedimentary rocks of Permian age that crop out in the San Andres Mountains are the Bursum (?) formation, Hueco formation, Abo redbeds, Yeso formation, and San Andres formation. The Bursum, Hueco, and Abo formations are considered to be of Wolfcampian age; the Yeso and San Andres formations of Leonardian age, in the San Andres Mountains. The Abo redbeds interfinger southward with the Hueco formation, which contains Wolfcampian fusulinids. Flower has studied briefly a large fauna collected from the San Andres formation at its type locality west of Rhodes Pass; although the fauna consists largely of new, undescribed forms, Leonardian ammonoids were recognized in the upper beds. One should note that at the type locality the San Andres formation is only 600 feet thick and its upper contact is a pre-Triasssic erosion surface. The upper part of the San Andres formation in the Guadalupe Mountains of southeastern New Mexico contains Guadalupian fusulinids and apparently was eroded away or not deposited in the San Andres Mountains area.

Also noteworthy is a decision by the Geologic Names Committee of the U. S. Geological Survey, dated July 28, 1955, here quoted in part:

> The Chief Geologist has approved the recommendation by James Steele Williams that the age designation of the Wolfcamp series and strata of equivalent age in the United States be Permian without the query in the official nomenclature of the U. S. Geological Survey. Also approved . . . . the use of provincial series be continued as subdivisions of the Permian system in preference to lower, middle, and upper.

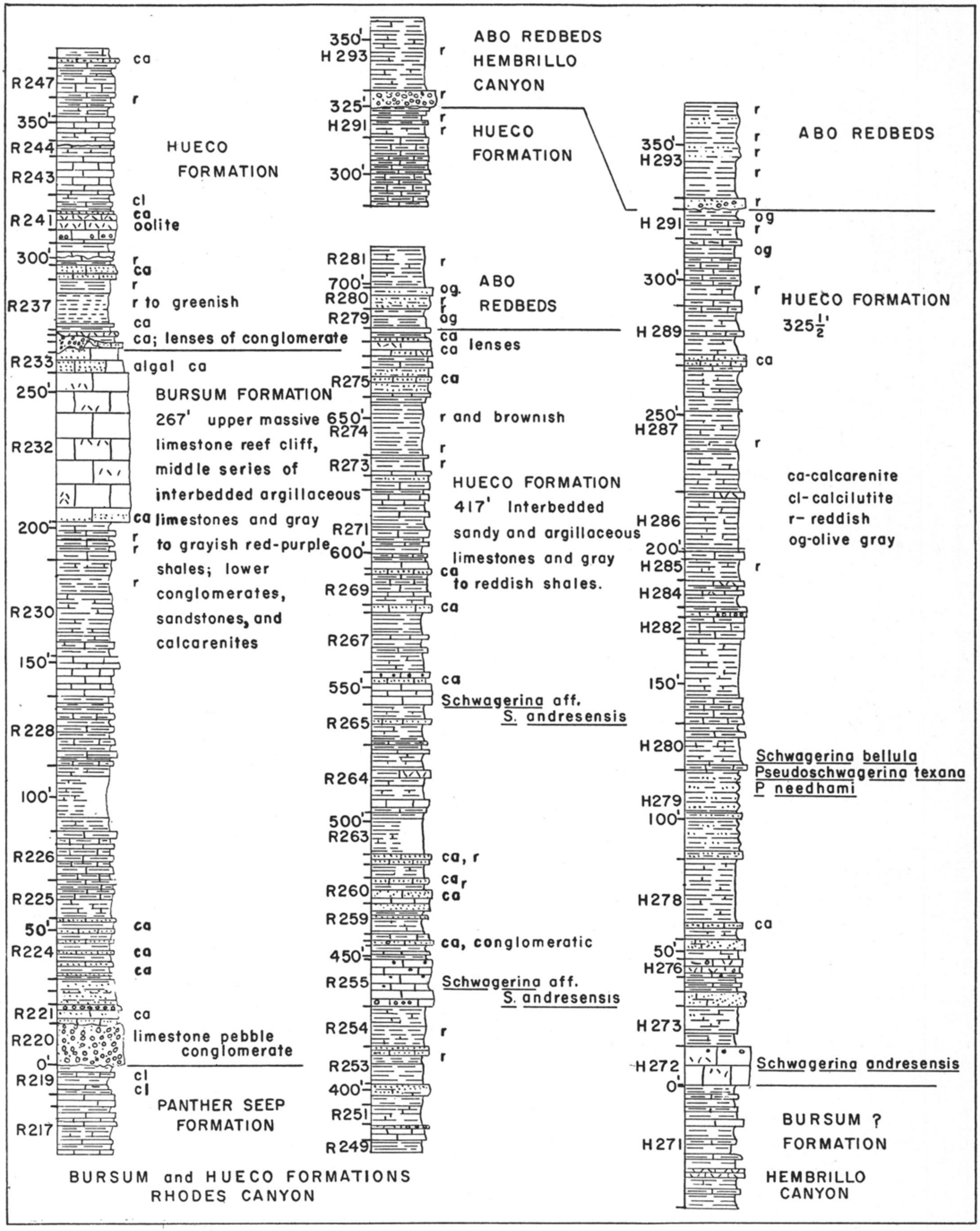
Prior to this decision the Wolfcamp was classed as Permian (?) in age (King, 1942, p 549) by the U. S. Geological Survey.

BURSUM FORMATION

Sedimentary rocks lithologically similar to those of the type Bursum were referred to the Bursum formation in Rhodes Canyon by Thompson (1954, p 8). As no fusulinids were found in the beds here called Bursum, they may be part of the Virgil series or the Hueco formation. Bursum fusulinids were found in somewhat similar beds near Mockingbird Gap by W. C. Warren (Lloyd, 1949, pl 2).

Lithology

The type Bursum formation in and near the Oscura Mountains (Wilpolt and Wanek, 1951; Kottlowski, 1952, p 6) consists of lower interbedded dark purplish-red and grayish-green shale, pinkish-gray arkose, and gray to greenish-gray limestones, capped by a thick, massive, light-gray, biostromal limestone. The lower reddish beds were mapped in places by Wilpolt and Wanek as an "Abo tongue," but are similar to reddish beds of Virgilian age in the Oscura Mountains. Thompson redefined (1954, p 18) the Bursum to exclude lower interbedded purplish shales and limestones with Virgilian fusulinids; as now defined, the formation at its type locality consists of a lower 48-65 feet of redbeds and limestones (Thompson, 1942, pp 7o, 8o, units 41-46; 1954, p 22, units 41-46) and upper massive to nodular limestones about 70 feet thick.



COLUMNAR SECTIONS OF BURSUM AND HUECO FORMATIONS IN RHODES AND HEMBRILLO CANYONS

Figure 8

In Mockingbird Gap a thick sequence of sandstones and conglomerates unconformable on Virgilian beds contains reworked Bursum-type fusulinids; the Bursum probably was removed in part by pre-Hueco erosion. About 5 miles to the east, in the southern Oscura Mountains, W. C. Warren (personal communication, with permission of the Standard Oil Co. of Texas) measured about 235 feet of interbedded redbeds, reddish arkosic sandstones, conglomerates, and limestones, which he called Bursum formation. Bursum fusulinids occur in limestones about 70 feet above the base.

In Rhodes Canyon Thompson (1954, p 22) correlated the massive cliff-forming biostromal limestone of R 232-233 with the upper massive limestone of the type Bursum and included in the formation as much as 12 feet of lower reddish shales and sandstones. At the place where he measured his section in 1942 (same locality as section R), the Bursum cliff is overlain by a thick limestone boulder-conglomerate, which was correlated with the basal Powwow of the Hueco formation. Mapping of the area has shown that the conglomerate is of relatively local extent. The 65-foot limestone cliff grades laterally into a lower 20-foot cliff and upper ledges of aphanitic medium light-gray limestone, silty calcarenites, and yellow-brown-weathering, crosslaminated, silty calcilutites, spotted with small moundlike algal reefs. This Bursum horizon has been traced to Cottonwood Canyon (north of Sulphur Canyon), but no farther south. It appears lithologically similar to the massive biostromal limestone at the base of the Hueco formation in Hembrillo and Ash Canyons.

The prominent limestone pebble-conglomerate of R 220-221 in the Rhodes Canyon area was found to be a persistent ledge unconformable on underlying Virgilian beds. It was, therefore, used as the base of a mappable unit here tentatively called the Bursum formation. In Rhodes Canyon (fig 8) the Bursum formation consists of a basal limestone pebble-conglomerate, about 22 feet thick (R 220-221), which grades up into 33 feet (R 222-224) of calcarenites, calcareous sandstones, and silty shale. The next 8z feet (R 225-228) is interbedded calcareous silty shale and silty limestone. Above is I 5 feet (R 229) of medium-gray laminated limestone ledges; then comes 50 feet (R 230-231) of gray calcareous shale with lenses of argillaceous limestone, and much olive-gray to grayish red-purple shale near the top. The uppermost bed is the 65-foot cliff (R 232-233) of massive medium light-gray to medium dark-gray, aphanitic to coarse-crystalline, porous to dense limestone, with scattered fragments and whole fossils, lenses of algae and coquina, and, near the top, algal calcarenite. In the basal beds are scattered clastic grains and granules of dusky-yellow argillaceous limestone.

This massive limestone is overlain in some places by a limestone pebble-conglomerate and elsewhere by algal calcarenite with lenses of pebble-conglomerate. Near section R, on the northeast side of Rhodes Canyon, the cliff-forming limestone has been channeled deeply, the channel having been filled by at least 40 feet of conglomerate (pl 2-A).

Beds tentatively assigned to the Bursum formation near Hembrillo Canyon (fig 8, pl 1, section H) consist of a basal conglomeratic sandstone, 10-15 feet thick (H 269), and upper (H 270-271) interbedded argillaceous to coquinoid limestones and calcareous shale, with nonpersistent lenses of silty very calcareous sandstone, 60-90 feet thick. The basal Hueco limestone appears conformable on the Bursum strata.

Beds at this horizon near Ash Canyon and Love ranch (pl 1, sections A and L) include calcareous conglomeratic sandstone and calcarenite, overlain by interbedded shales, sandstones, and argillaceous limestones, which are in turn overlain by grayish-black carbonaceous shales beneath the basal Hueco cliff. These strata may be equivalent to the Bursum as it is referred to in the other two canyons.

The Bursum beds are somewhat similar to underlying Panther Seep rocks and some of the overlying Hueco lithologic units. At Rhodes Canyon and northward they contain lenses of grayish red-purple shales and sandstones. The basal conglomerate and conglomeratic sandstones are distinct from any lower in the section but similar to the limestone boulder-conglomerates that occur sporadically at the base of the Hueco formation. The upper massive cliff-forming limestone of the Rhodes Spring area is similar to the massive coquinoid biostromal limestones below in Desmoinesian to Virgilian beds and in the overlying Hueco formation. In thinsection the limestone is an unsorted, unoriented jumble of fossils and fossil fragments partly to entirely replaced by cryptocrystalline to coarse-crystalline calcite. Scattered silt-size quartz grains are angular and cut by crystalline calcite veinlets.

Thickness

Beds assigned to the Bursum are 120-135 feet thick in the Oscura Mountains, 100-235 (?) feet thick near Mockingbird Gap, 267 feet thick in Rhodes Canyon, 75-100 feet thick in Hembrillo Conyon, absent (?) near Ash Canyon, absent to zo feet thick in the Hueco Mountains, absent in the southern Sacramento Mountains, but about 400 feet thick in the northern Sacramento Mountains, near Tularosa. In the Mud Springs and Caballo Mountains the Bursum formation may be about 50-60 feet thick; in the Robledo Mountains the formation may range from 100 to 300 feet in thickness and is predominantly marine limestones.

Fauna

Except detrital specimens, no fusulinids were found in beds called Bursum in the San Andres Mountains. A prolific brachiopod fauna was collected from coquinoid lenses in Rhodes Canyon but yielded mainly undescribed species of *Composita* and *Pugnoides*. Fusulinid fauna of the type Bur-sum in the Oscura Mountains consists of *Triticites creekensis, Schwagerina aff. S. grandensis,* and S. sp. This fauna is present in Bursum outcrops just east of Mockingbird Gap.

HUECO FORMATION

The Hueco formation is lithologically and faunally similar to the type Hueco formation in the Hueco Mountains. Thompson (1954) measured sections of the Hueco in Rhodes and Ash Canyons and described the fusulinids. The Hueco formation is of middle and upper Wolfcampian age and is a southern marine facies of the Abo redbeds.

Lithology

The Hueco formation consists chiefly of argillaceous limestones, cherty fossiliferous limestones, silty calcarenites, and gray fossiliferous shales. Near the top are reddish shales and calcareous siltstones; at the base in Ash and Hembrillo Canyons is a massive biostromal limestone.

In Rhodes Canyon the basal beds of the Hueco range from conglomeratic algal calcarenite to limestone cobble-conglomerate (fig 8). Locally these clastic beds overlie the Bursum (?) cliff with deep erosional unconformity. The bulk of the formation is of light-gray, greenish-gray, and grayish red-purple calcareous shales and arenaceous and argillaceous limestones and calcarenites, with minor amounts of calcareous sandstone. Two marker beds occur: R 255, a dark-gray cherty limestone, and R 266, a similar ledge-forming cherty limestone. The upper 57 feet is interbedded grayish-red to olive-gray siltstone, argillaceous limestone, grayish-red, olive-gray, dusky-yellow, and light-gray calcareous shale, and calcarenite. These upper beds are an intertonguing of Hueco and Abo lithologies. Redbeds below in the Hueco are typically pale red purple. The top of the Hueco is an arbitrary line, here drawn on the top of the uppermost persistent limestone bed (upper R 278), which is marked by imprints of brachiopods.

In Mockingbird Gap Thompson, in 1942, measured two units below the Abo redbeds: a basal 95 feet of conglomerate and sandstone, containing reworked Bursum formation fusulinids (lower Wolfcampian), and an upper 225 feet of interbedded argillaceous and fossiliferous limestone, shales, and sandstone. The lower unit may be Bursum strata; the upper marine beds are perhaps lower Hueco equivalents. A similar sequence about 235 feet thick was measured in the southern Oscura Mountains by W. C. Warren (Lloyd, 1949, pl 2), who referred both units to the Bursum formation. Warren collected lower Wolfcampian fusulinids from limestone beds 70 feet above the base.

In Hembrillo Canyon the basal Hueco bed is a massive biostromal limestone (H 272.) ranging greatly in thickness from about 1 0 to almost 40 feet. The rest of the formation (fig 8) is dominantly calcareous shale, reddish in the upper part, with beds of argillaceous limestone, calcareous siltstones, and a few calcareous sandstones and calcarenites. The uppermost strata are interbedded reddish to olive-gray shales and argillaceous limestones, overlain unconformably by a basal Abo reddish conglomeratic sandstone.

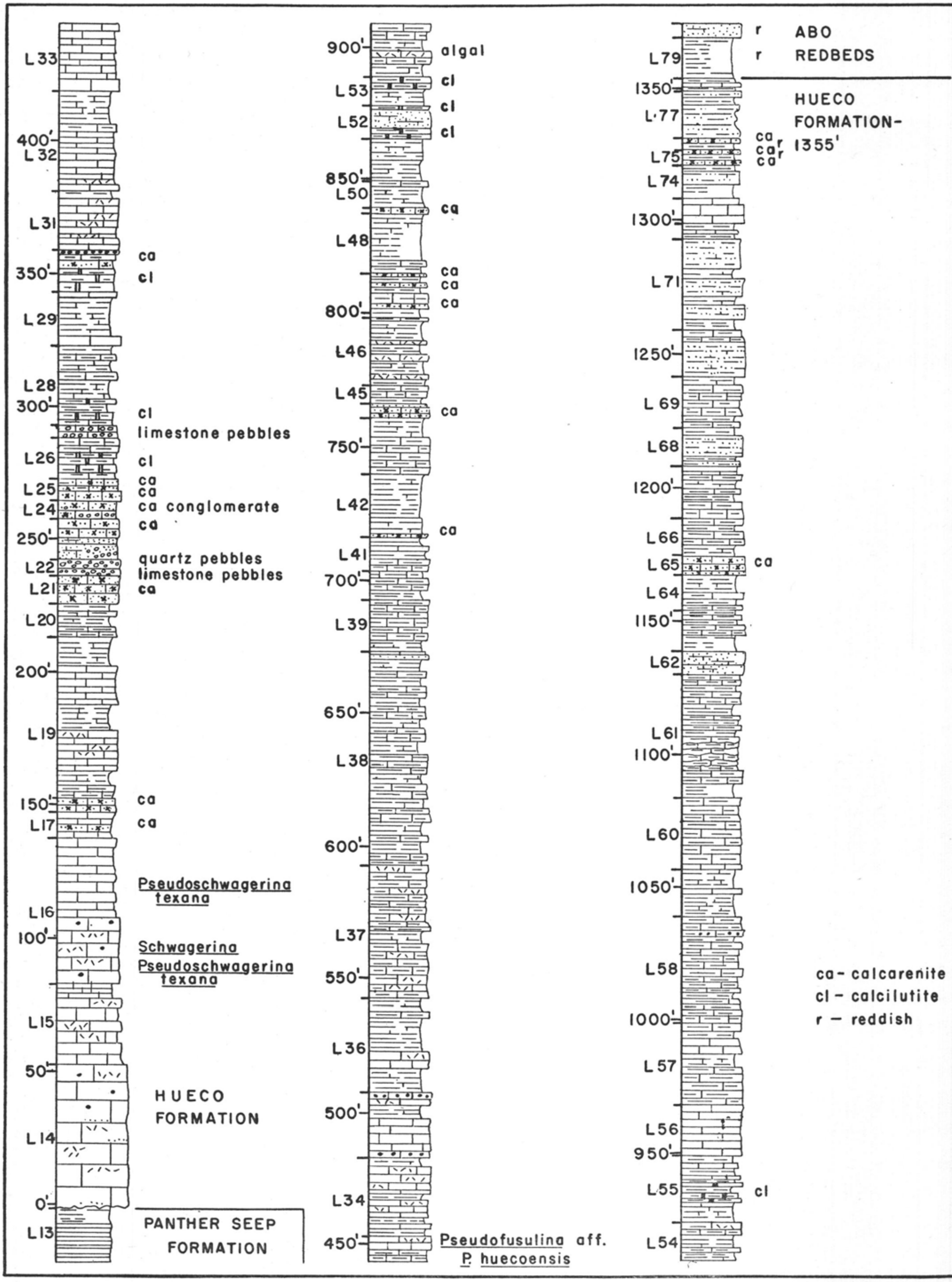
The Hueco thickens greatly southward from Hembrillo to Ash Canyons, the lower beds of the Abo redbeds interfingering with and grading into upper Hueco strata to the south. A typical southward transition from Abo facies to Hueco facies is from grayish-red calcareous siltstone into pink and olive-gray very calcareous siltstone, then into silty light-gray calcarenite, and finally into silty and argillaceous medium-gray limestone.

The basal Hueco bed near Ash Canyon and Love ranch is the massive cliff-forming limestone noted by Darton (1928, p 189) as "making the divide ridge extending from T. 20 S. (Bear Canyon) north to Sulphur Canyon." The lower 54 feet (L 14) of medium light-gray massive limestone forms a vertical cliff. Above is 174 feet (L 15-20) of medium-bedded to massive limestone, with scattered chert nodules, coquinoid lenses, several calcarenites, and, near the top, much calcareous shale. Then comes 46 feet (L 21-25) of arenaceous calcarenite, calcareous sandstone, and limestone pebble- and quartz pebble-conglomerates. Above is 85 feet (L 26-3o) of argillaceous silty limestone and calcareous shale, capped by a thin chert bed. Next is 165 feet (L 31-lower L 36) of medium- to medium dark-gray limestone with lenses and beds of calcareous marly shale, coquinoid lenses, and several thin cherty limestones. These grade up into interbedded silty dark-gray limestones and calcareous shales, about 193 feet thick (L 36-41), above which is 122 feet (L 42-49) of interbedded medium-gray to grayish-black shales and medium dark-gray carbonaceous argillaceous limestones with lenses of coquinoid and calcarenite. These are overlain by 109 feet (L 50-55) of calcareous to sandy shales, calcilutites, argillaceous and coquinoid limestones, and a calcareous sandstone. Next above is 20 feet (L 56) of medium dark-gray limestone, above which is 163 feet (L 56-61) of interbedded dark-gray argillaceous limestone and calcareous shale. The upper 223 feet (L 62-78) is similar interbedded argillaceous silty limestone and calcareous shale, with several lower sandstone ledges; near the top is much calcareous siltstone, calcarenite, and thin grayish-red shales. Contact with the overlying Abo is gradational and was picked at the top of the uppermost persistent limestone.

Limestones in the Hueco formation are similar to those of underlying Pennsylvanian strata. Cliff-forming or ledgy biostromal limestones are prominent in the lower part of the formation, but cherty beds are scattered throughout, thus contrasting with underlying Panther Seep limestones. Most of the Hueco limestones are argillaceous or silty and tend to be dark gray; especially in the southern part of the range, coquinoid calcarenite and calcilutite beds are common. In thin-sections the massive biostromal limestones are similar to those of the Pennsylvanian, except that they appear to be more algal and have more silt-size quartz and a larger amount of oolites and oolitic lenses. The calcarenites are arenaceous and silty and, for the most part, contain appreciable amounts of muscovite, biotite, chlorite, white plagioclase, carbonaceous material, and ferruginous films, as well as quartz, chert, limestone, and fossil-fragment grains. There is an intimate lateral and vertical intergradation from silty calcarenites to light-brown or olive limy siltstones and silty limy sandstones; with increase in the amount of hematite film on grains, the silt-stones and silty sandstones are typical Abo redbeds. Even the lighter gray beds of this type contain scattered cubes and grains, with a magnetite core and rims of hematite and limonite; typically, the clastic iron oxides are concentrated in paper-thin laminae that separate thicker alternating laminae of coarser and finer silt-sized quartz and calcite grains. In the redbeds, most of which have been grouped in the Abo, hematite is a significant part of the cementing material. Cement in the gray to brown silty calcarenites and limy siltstones is in part proportional to the type of dominant clastic grains and to the enclosing strata, suggesting that the cement is derived from the clastic grains and from overlying and underlying rocks. The higher the percent of quartz silt, especially if interbedded with shales and sandstones, the higher is the amount of silica cement; conversely, if elastic calcite grains are dominant, and the calcarenite is interbedded with limestones, calcite is the chief cement.

As the uppermost bed of the Hueco formation was chosen near the highest marine limestone, considerable amounts of interbedded redbeds are included in the upper part of the formation, which is typically of grayish-red color. Near Rhodes Canyon, however, some of the lower shales are purplish red; southward the amount of redbeds included in the formation decreases, being 12.6 percent near Rhodes Canyon, 6.6 percent near Hembrillo Pass, and insignificant near Love ranch. This indicates rapid marine and nonmarine alternations to the north, contrasting with lower marine and upper continental deposition near Love ranch.

Clastic ratios range from 2.12 for the Hembrillo Canyon section, and 1.01 for the Rhodes Canyon section, to 0.62 for the Ash Canyon-Love ranch area. Sand-shale ratios decrease northward, being 0.08 for Ash Canyon, 0.042 for Hembrillo Canyon, and o.036 for Rhodes Canyon. These sand-shale



Columnar section of Hueco formation in Love ranch area

Figure 9

ratios contrast with those of the Abo redbeds, which indicate a higher percentage of sand deposited in the Hembrillo Canyon area.

Thickness

The Hueco formation appears to be absent in the northern Oscura Mountains, is possibly 30o feet thick in Mockingbird Gap, 417 feet thick in Rhodes Canyon, and 326 feet thick in Hembrillo Canyon, thickens abruptly to 1,355 feet in Ash Canyon, and is 1,500 feet thick at the type locality in the Hueco Mountains, where the Powwow conglomerate, the basal Hueco member, lies with marked angular and erosional unconformity on all the older rocks from the Bursum formation down to the El Paso group. In the southern Sacramento Mountains a medial lens of Hueco limestone, about 200 feet thick, rests on lower Abo redbeds, with a basal conglomerate identical to the Powwow conglomerate, and underlies an upper lens of Abo redbeds. Thompson (1954, p 19) and Pray and Otte (1954, p 1296) traced this sequence southward, across several covered areas, to the Hueco Mountains, where the lower Abo grades into the Powwow conglomerate, the medial limestone thickens to become most of the Hueco, and the upper Abo is the Deer Mountain red shale member of the upper Hueco formation. In the Robledo Mountains, 25 miles southwest of Ash Canyon, the Hueco formation is about 1,700 feet thick and is divisible into three lithologic units: lower limestones about 890 feet thick; medial interbedded red siltstones, yellowish-brown shales and sandstones, and thin-bedded limestones, about 475 feet thick; and upper cherty limestones about 35o feet thick. The red siltstones are petrographically identical to red siltstones of the Abo redbeds in the San Andres and Caballo Mountains and are considered, therefore, to be tongues of the Abo. Northward, from the Robledo Mountains to the Caballo Mountains, there appears to be an abrupt change, the upper Hueco limestone pinching out northward or intertonguing downward into Abo redbeds, together with a thickening of the middle elastic unit of the Robledo Mountains and its complete transition into redbeds, and a wedging out of the lower Hueco limestones. Kelley and Silver (1952, p 96) noted a southward increase in thickness of their Magdalena group in the Caballo Mountains; perhaps some of the upper beds assigned to the Magdalena group in the southern Caballo Mountains are equivalent to the lower Hueco limestones of the Robledo Mountains.

Recent discovery of detrital fusulinids in the upper part of the Abo redbeds near Abo Pass suggests that tongues of Hueco limestone extended that far north—about 6o miles north of Mockingbird Gap. Thompson identified the fusulinids as *Pseudofusulina* similar to species from middle Wolfcampian horizons. The detrital fusulinids show no signs of wear but may have floated for many miles without being abraded. They occur, however, in limestone breccia-conglomerates in which the pebbles and cobbles are very angular, suggesting that these are intraformational conglomerates derived from marine limestones broken up and redeposited almost in situ.

Fauna

Fusulinids identified from Hueco strata in the San Andres Mountains are *Schwagerina andresensis, S.* aff. S. *andresensis, S. bellula, Pseudoschwagerina rhodesi, P. texana,* P. *needhami, P. morsei,* and *Pseudofusulina* aff. *P. huecoensis.*

ABO REDBEDS

The Abo redbeds thin southward, intertonguing downward into the Hueco formation, and are, therefore, considered to be of Wolfcampian age. Detrital fusulinids found in the upper part of the type Abo near Abo Pass are those typical of middle Wolfcampian faunas. Abo strata grade up into Yeso sedimentary rocks; in places, therefore, a small upper part of the Abo redbeds may be of Leonardian age.

Lithology

The Abo consists of dusky-red to dark reddish-brown shales and calcareous siltstones, with a few lenses of silty fine-grained sandstones. In the San Andres Mountains most of the rocks previously called sandstones are found, on close inspection, to be sandy siltstones.

In Rhodes and Hembrillo Canyons (see pl 1) hard calcareous to siliceous siltstones, cropping out as ledges or broken cliffs, are prominent in the upper part (R 297-314, H 305322) of the redbed series, whereas less resistant shales make up most of the lower beds (A 279-296, H 292-304), although there are ledges of fine-grained arkosic sandstone in the lower Hembrillo Canyon section. Near Love ranch the Abo redbeds are about evenly divided between shale slopes and siltstone ledges but appear to be the seaward equivalents of the coarser grained upper Abo of Hembrillo and Rhodes Canyons.

The Abo redbeds in Rhodes Canyon are typical of the formation except for the substitution of sandy siltstones for sandstones. Just above the gradational contact with the Hueco formation, there are some light olive-gray beds. Upper R 282 is a thin silty medium-gray limestone; R 288 includes a lenticular nodular limestone; and R 295 is a calcareous siltstone grading up from a thin, very silty limestone (R 294) and contains conglomeratic lenses with subrounded pebbles of limestone, quartz, and chert.

The Hembrillo Canyon section of the Abo redbeds differs in having a considerable number of beds of fine-grained arkosic sandstone and arkosic siltstone, as well as several medial olive-gray siltstones, with light-brown siltstones and silty sandstones near the top. The feldspars in the arkosic beds are heavily stained with hematite and are mostly silt-size, but appear to be chiefly orthoclase. The basal bed (H 292) is a calcareous limestone pebble-conglomerate unconformable on Hueco beds. In H 313 there are conglomeratic lenses, with the angular pebbles chiefly of reddish siltstone and only minor amounts of gray limestone.

At Love ranch Abo redbeds include many olive-gray, light-brown, and greenish-gray beds. In this area grayish-red calcareous siltstones were traced along the outcrop for several miles and were seen grading through transitional lithologies into silty Hueco limestones.

Clastic ratios approach infinity, as only a few, thin limestone beds are present. Considerable calcite occurs as interstitial material and as cement in siltstones and sandstones, along with hematite and clay. Many of the reddish shales contain pellets or small concretions of chalky limestone, 1/2-4 mm in diameter, as well as nodules and lenses of grayish-red to medium-gray silty limestone or limy siltstone. Some of the ledge-forming siltstones, especially those near Rhodes Canyon, contain scattered vugs partly filled by euhedral calcite crystals.

Sand-shale ratios are perhaps misleading, as most of the sand-size grains occur in laminae in shales or admixed with silt in siltstones. Even the beds called sandstones are chiefly of very fine-grained sand and silt. The small size of the elastic materials suggests that they have traveled long distances from source areas. The sandstones and siltstones near Hembrillo Canyon are arkosic in part but in other areas consist chiefly of angular quartz, with scattered muscovite flakes, magnetite cubes, and angular zircon. Crosslamination is mostly in simple sets (McKee and Weir, 1953, p 386), with the lower boundary of the sets generally a nonerosional surface. The sets are lenticular to tabular, with crosslaminae mostly straight to slightly concave, at a low angle (usually less than 4 degrees) and of medium scale, i.e., 1-20 feet in length.

Sand-shale ratios are: Rhodes Canyon section, o; Hembrillo Canyon section, o.o8; Love ranch section, o.o8; lower Hembrillo Canyon section (H 292-304), 0.13; the Abo redbeds in upper Hembrillo Canyon (H 305-322), 0.04. Of more significance are the ratios of sandstone plus siltstone compared to shale thicknesses, as follows: lower Rhodes Canyon, o.o6; lower Hembrillo Canyon, 0.21; upper Rhodes Canyon, 0.78; upper Hembrillo Canyon 1.52; total Rhodes Canyon, 0.32; total Hembrillo Canyon, 0.64; total Love ranch area, o.38. In Rhodes Canyon 2.5 percent of the Abo siltstones are not reddish; in Hembrillo Canyon, 9.3 percent; and near Love ranch, 20.5 percent. Many of these olive, greenish, light-brown, and grayish beds are coated by a surface film of hematite and are, therefore, inconspicuous. All the redbeds are more or less mottled by irregular olive to yellowish-brown patches where ferric iron has been reduced or removed. The study of thinsections and crushed fragments indicates minor ilmenite but numerous magnetite grains; magnetite grains are angular and roughly cube-shaped, with an outer irregular film or halo of hematite. In reduced patches magnetite is less abundant or is replaced by limonite. Olive and light-brown siltstones contain scattered ghosts of magnetite grains either entirely replaced by hematite and limonite or with a small core of magnetite (Miller and Folk, 1955, p 338). Many of the nonred siltstones are siliceous (pl 5-C) have a cement of chalcedony and calcite, and contain scattered euhedral crystals of dolomite. The olive, greenish, and tan beds are more numerous in the lower part of the Abo redbeds in all three sections, except for the arkosic sandstones in Hembrillo Canyon, which are reddish throughout the formation.

Conglomerates and conglomeratic beds are relatively persistent and thin, appearing to be thin blankets of cemented gravel rather than narrow fills of stream-cut channels. Fragments are mostly granule- or pebble-size subrounded to angular gray to reddish limestone, angular reddish siltstone, and minor subrounded chert and quartz in a matrix of calcareous hematitic siltstone. Many of the lenses are typical angular intraformational conglomerate or breccia.

Upper Contact

The upper contact is gradational, although relatively sharp, changing from hard dark reddish-brown ledge-forming siltstones of the Abo into soft friable orange, light-gray, or light-brown sands and sandstones of the Yeso formation. The basal slope-forming sands and sandstones of the Yeso formation would be included in the Abo redbeds by some geologists who locate the base of the Yeso formation at the base of the first marine limestone. These basal orange sands are litho logically dissimilar to Abo redbeds and are here considered as basal beds of the Yeso formation.

Thickness

Abo redbeds have not been carefully measured in most areas, so that many published thicknesses are only estimates. Wilpolt and Wanek (1951) reported 78o feet of Abo in the northern Oscura Mountains. Warren (Lloyd, 1949, pl 2) found 585 feet of Abo redbeds in the southern Oscura Mountains. We measured 835 feet of Abo redbeds in Rhodes Canyon. Southward the Abo redbeds thin to 613 feet in Hembrillo Canyon; this thinning is not due to downward interfingering into the Hueco, as the Hueco formation is also thin in the Hembrillo Canyon area. Southward from Hembrillo Canyon the Abo redbeds thin to 325 feet at Love ranch by intertonguing with the thickening Hueco formation.

Less than half the 475 feet in the medial elastic unit of the Hueco formation of the Robledo Mountains is of Abo-like lithology. Kelley and Silver (1952, p 100) estimated a range of 550-1100 feet of Abo redbeds in the Caballo Mountains, with a southward thickening. Their measured section shows 551 feet of Abo. If the Abo redbeds thicken southward in the Caballo Mountains, they thin amazingly abruptly south of the Caballo Mountains. In the Sacramento Mountains the Abo is about 1,100 feet thick in the northern part, near Tularosa (Pray, 1954, p 101), but thins to 500-200 feet in the southern part (latitude of Love ranch and Grapevine Canyon), where it includes a medial tongue of Hueco limestone.

Fauna

Fragments of fossilized plants were seen but not collected. Every limestone lens observed was carefully checked, but not even fresh-water invertebrates were found. The redbeds, however, interfinger southward into limestones bearing Wolfcampian fusulinid faunas.

YESO FORMATION

A relatively prolific fauna obtained from limestones in the middle part of the Yeso formation indicates a Leonardian age. Near Rhodes Pass the formation is divisible into the four members used by Wilpolt and Wanek (1951) in the eastern Oscura Mountains: (in ascending order) the Meseta Blanca sandstone member, the Tones member, the Canas gypsum member, and the Joyita sandstone member (see figs 1o, 1 1). The Canas gypsum member pinches out south of Rhodes Canyon, and no gypsum is present even in the Tones (?) member in the Love ranch area.

The type locality of the Meseta Blanca sandstone member is far to the north, in the Jemez River Valley, north of Jemez, New Mexico (Northrop and Wood, 1946), where it is light-orange or red crossbedded sandstone that crops out as rounded and overhanging cliffs. At the type section, however, the columnar section (no detailed description is given) shows a lower 115 feet of pink or orange slope-forming siltstone. Southward from the Jemez area the member has been mapped by Kelley and Wood (1946) in the Lucero Uplift, by Bates et al. (1947) in Gran Quivira quadrangle, by Wilpolt et al. (1946) in the Joyita Hills, eastern Los Pinos Mountains, and Chupadera Mesa, and by Wilpolt and Wanek

(1951) in the area east of Socorro to the northern part of the Oscura Mountains. From Abo Pass southward the sandstone member forms a slope above the Abo redbeds, the bold cliffs of the type locality being absent.

Owing to this lack of similar topographic expression some geologists would prefer not to use the term Meseta Blanca south of Jemez. The unit has been mapped as the Meseta Blanca sandstone member in the Oscura Mountains just north of the San Andres Mountains. Whether it is called Meseta Blanca or some new name, such as Rocking Bar B Ranch member, the unit here measured as the Meseta Blanca member is equivalent, at least in part, to the unit mapped as Meseta Blanca by Wilpolt and Wanek (1951). Certainly this unit is not the exact correlative of the type Meseta Blanca sandstone member, but neither are outcrops mapped as Meseta Blanca a few miles away from the type locality.

The beds here assigned to the Yeso formation thin sharply southward from 1,579 feet near Rhodes Pass to 324 feet near Love ranch. Massive limestones are prominent in the upper part of the formation near Rhodes Pass and Hembrillo Canyon. The interbedded limestones and siltstones in the Love ranch area here referred to the San Andres formation (following Darton, 1928, pp 19o-191) may be upper Yeso beds instead of San Andres strata.

Lithology

In the Rhodes Pass area the basal Meseta Blanca sandstone member is 354 feet (R 315-320) thick (see fig o) and consists of grayish-olive sandy siltstones and moderate reddish-orange, light-red, light-gray, and moderate orange-pink silty friable sandstones. In this lower sequence is carved the strike valley that marks the lower Yeso beds the length of the San Andres Mountains.

The basal bed (R 320 of the Torres member is a white to light-gray gypsum overlain by a 2-foot ledge of silty limestone (R 322). Above V2 feet of friable grayish-orange sandstone (R 323) is a 3 1/2-foot limestone bed (R 324) that caps low cuestas overlooking the valley cut in the Meseta Blanca member. The Torres member (R 321-379), about 935 feet thick, consists of interbedded gypsum, arenaceous to argillaceous limestone, light-red to grayish-orange friable sandstone, and light-gray sandy calcareous siltstone. Notable intervals include: R 345, an arenaceous light-gray limestone that caps high cuestas overlooking the strike valley eroded in the Meseta Blanca sandstone member; R 346, a 9o-foot bed of gypsum; R 348-349, 4o feet of silty fetid medium-gray limestones, some beds having numerous fossils; R 357, a silty argillaceous fossiliferous limestone; R 364, 79 feet of gypsum; R 371-372, medium-gray to medium dark-gray fossiliferous fetid limestone; and R 376-377, medium-gray silty limestones.

The Canas member (fig I I), 235 feet thick (R 38o-383), is chiefly massive light-gray-mottled medium-gray gypsum, with intercalated silty limestone and light-red friable sandstone in the lower part. The Joyita member (R 384), 55-109 feet thick, is pale reddish-brown friable calcareous sandstone, grading up into the basal "Glorieta" sandstone of the San Andres formation by a gradual change to yellowish colors.

The section of Yeso formation measured west of Hembrillo Pass is about 56 percent as thick as the Yeso formation at Rhodes Pass and contains much less gypsum. This thinning is in accordance with the southwestward thinning of the Yeso strata and a loss of evaporites as compared with the 4,2oo-foot section penetrated in the oil test (Standard Oil Co. of Texas, Heard No.) drilled on the Carrizozo Dome, about 5o miles northeast of Rhodes Pass. The 4,200-foot thickness is partly excessive, owing to steep dips of beds encountered in the drill hole.

The basal 44 feet (H 323) of the Yeso section at Hembrillo Pass (fig 12) is soft calcareous light-brown to light-red sandstone referable (?) to the Meseta Blanca sandstone member. The next 53o feet (H 324-344) is interbedded light-brown to light-red friable sandstone, whitish to medium-gray gypsum, and arenaceous silty medium-gray to dark-gray fetid limestone. Then comes 196 feet (H 345-basal 352) of limestone, carbonaceous to coquinoid in the lower parts, and thin- to massive-bedded, medium-gray to dark-gray, fetid, and vugular in the upper part, which forms ledgy cliffs capping a prominent cuesta. In the slope below the San Andres formation are three units: a lower slope of interbedded thin silty limestones and calcareous siltstones, 20 feet thick (upper H 352); a medial 50-foot series (H 353) of ledges of silty dark-gray limestones; and an upper 52 feet (H 354) of moderate reddish-orange soft calcareous sandstone (Joyita member?), which grades up into the yellowish "Glorieta" sandstone at the base of the San Andres formation.

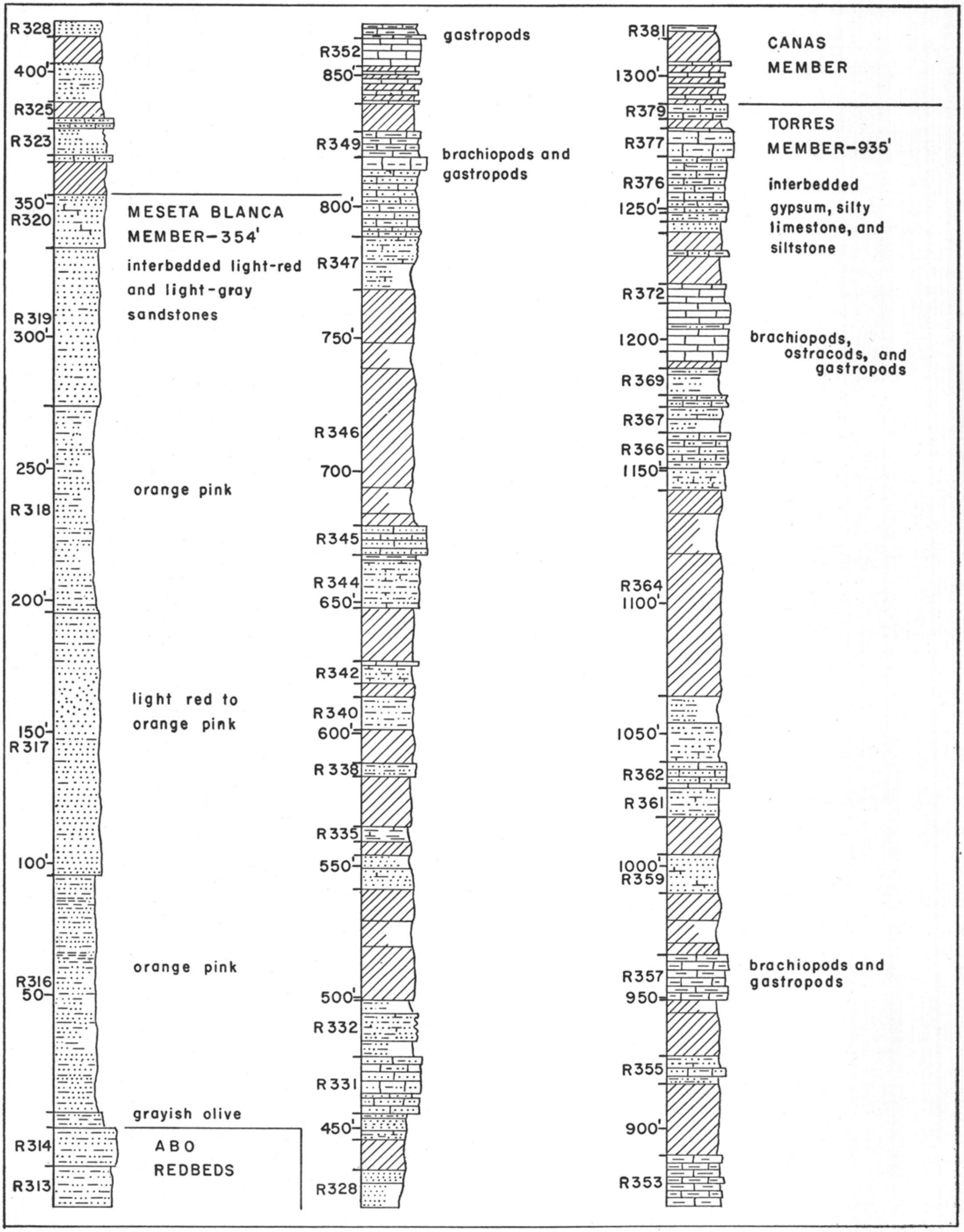
The Yeso section near Love ranch (fig 13) is only 20 percent as thick as the Rhodes Pass section and 36 percent as thick as the Hembrillo Pass section. The lower 120 feet (L 104-108) resembles the Meseta Blanca sandstone member, being composed of pale-red, grayish-red, and greenish-gray to moderate orange-pink friable sandstone; light-gray silty calcareous claystone; and greenish-gray to pale-red sandy calcareous siltstone. The upper 204 feet (L 109-116) consists of siltstone, with a 1-foot ledge of argillaceous limestone at the base, and an upper sequence (L 113-116) of dolomitic to calcic argillaceous fetid dark-gray limestones, with several thick beds of light-brown, grayish-yellow, and pale-red friable sandstone. The Glorieta (?) sandstone is conglomeratic, massive, and light brown to grayish yellow, and overlies Yeso limestones.

The overlying San Andres formation is atypical, consisting of interbedded argillaceous fetid limestones and yellowish to pale-red sandstones and siltstones. These San Andres beds, near Love ranch, may be equivalent to limestones in the upper Yeso formation in the Hembrillo and Rhodes Pass sections.

The total thickness of gypsum beds decreases southward from about 635 feet north of Rhodes Pass to 178 feet near Hembrillo Pass and absent south of Love ranch. Many of the gypsum beds are contorted, folded, and slumped; as a result, there probably are inaccuracies in the measurement of their thicknesses. The gypsum ranges from massive and coarse crystalline to laminated and aphanitic. Laminae, lenses, and beds of argillaceous limestone, calcareous silt-stone, and silty sandstone are intercalated with gypsum. Gyp-. sum also occurs as laminae, veinlets, and scattered to abundant anhedral crystals in limestone, siltstone, and sandstone beds. In thinsection the gypsum is a cryptocrystalline to fine-crystalline mosaic of indistinct fibrous gypsum, with scattered to abundant porphyroblasts, tabular to euhedral, averaging

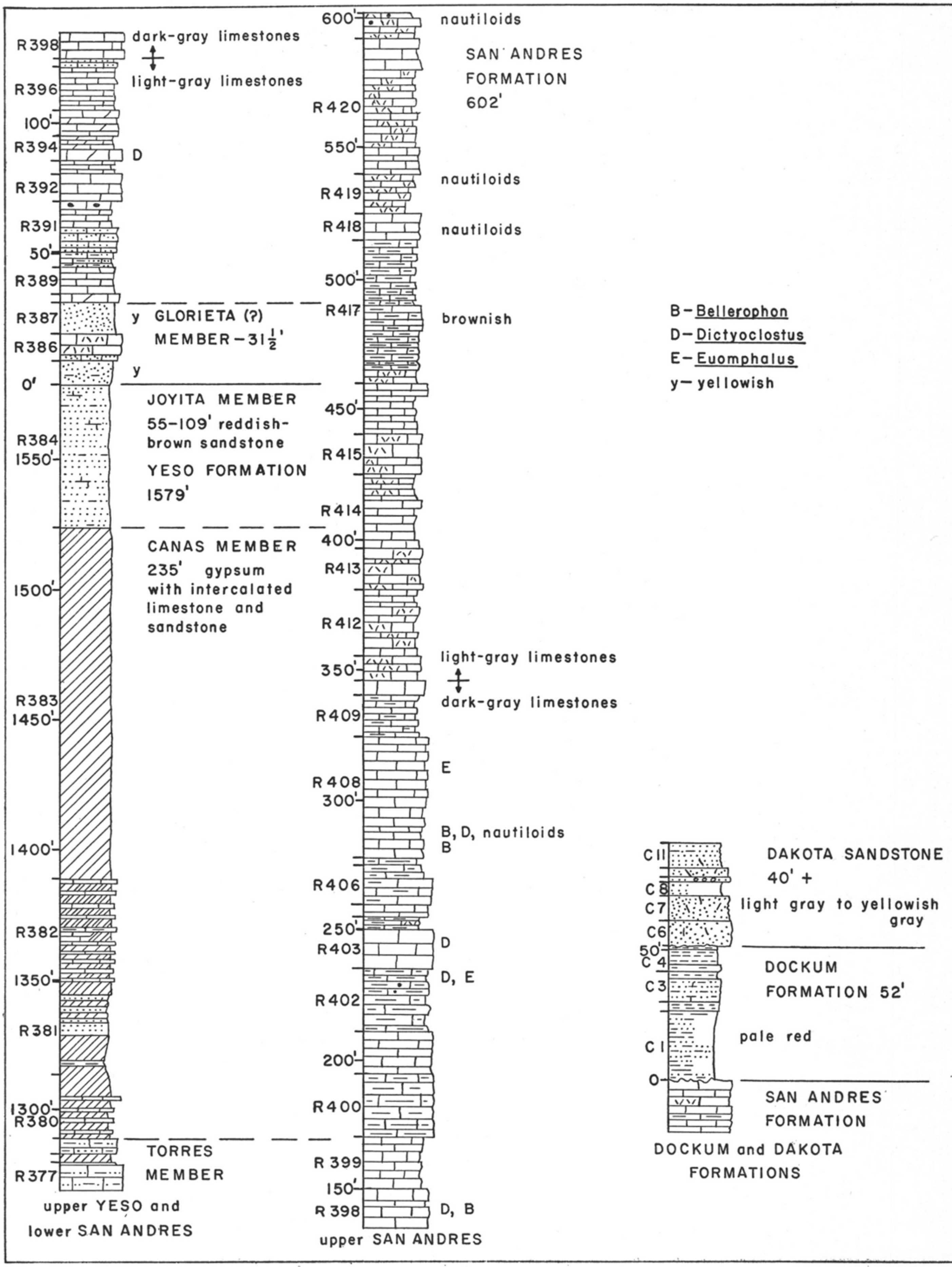
mm in diameter. Gypsum occurring as laminae or between closely spaced laminae of other lithologies tends to form tabular crystals perpendicular to the lamination.

Limestone beds in the Yeso formation total 265 feet north of Rhodes Pass, 432 feet near Hembrillo Pass, and only 35 feet south of Love ranch. The large amount of limestone in

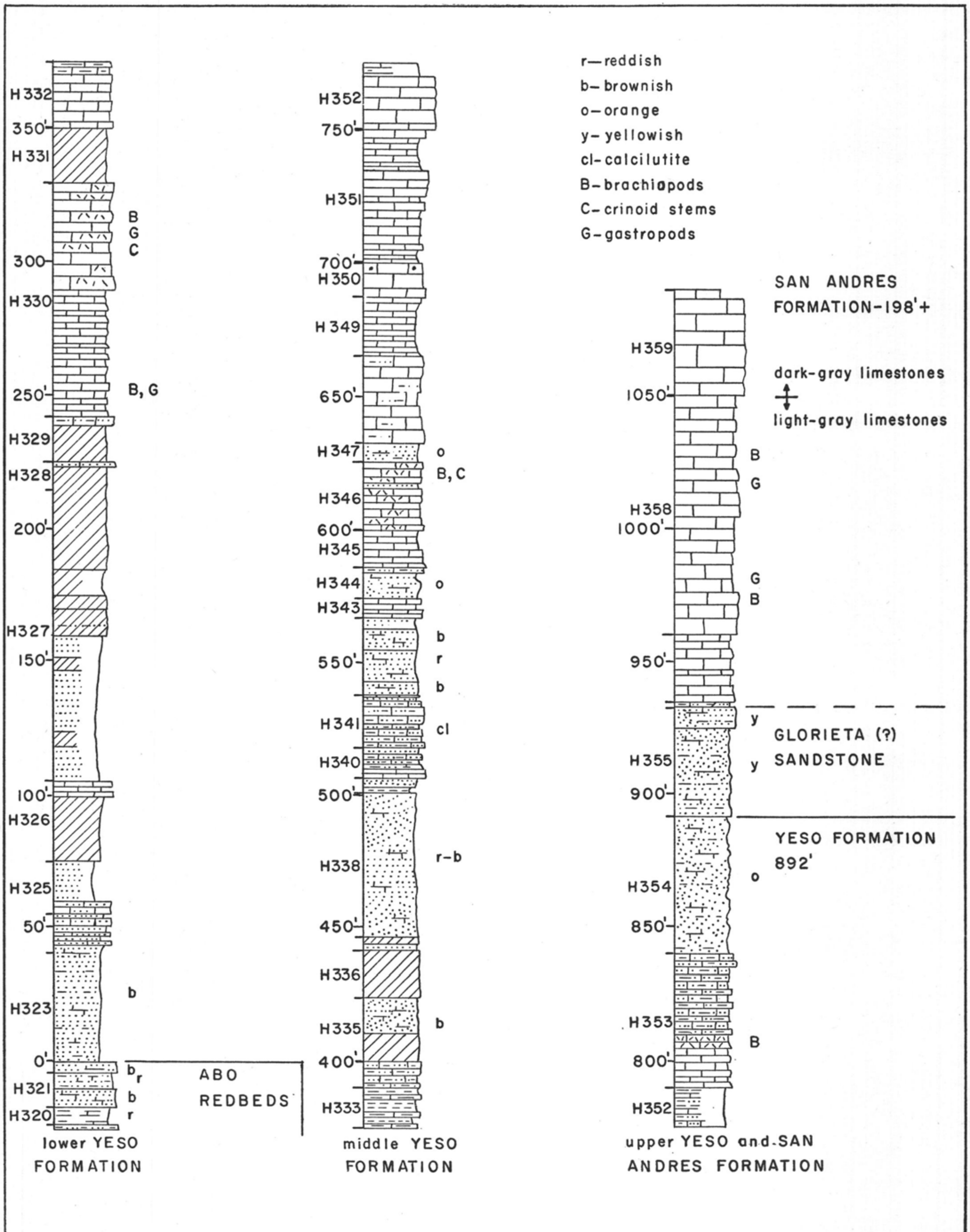


Columnar section of lower part of Yeso formation in Rhodes Canyon

Figure 10

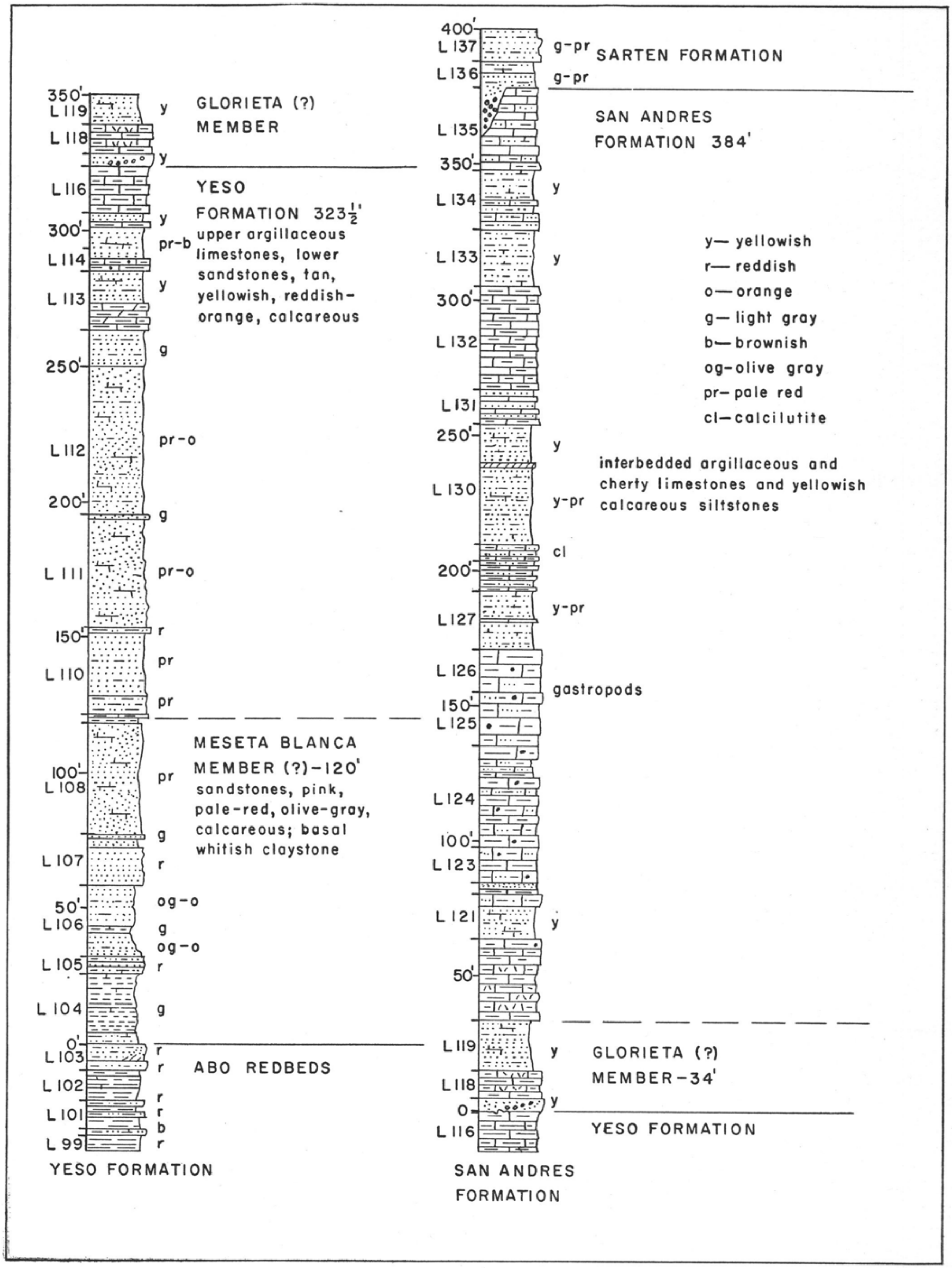


COLUMNAR SECTIONS OF UPPER YESO, SAN ANDRES, DOCKUM, AND DAKOTA FORMATIONS IN RHODES CANYON AREA



COLUMNAR SECTIONS OF YESO AND SAN ANDRES FORMATIONS IN HEMBRILLO CANYON

Figure 12



Columnar sections of Yeso and San Andres formations in Love ranch area

Figure 13

the upper part of beds here attributed to the Yeso formation near Hembrillo Pass may be either a limestone facies of the predominantly gypsiferous upper Yeso near Rhodes Pass or equivalent to the lower part of the San Andres formation at the same location. Surface mapping is needed to clarify these relationships. Basal limestones of the Yeso formation are arenaceous and silty and grade into calcareous siltstones. Limestones in the Hembrillo Pass and Love ranch sections are mainly dark gray, with much included clay, carbonaceous matter, and ferruginous silt. North of Rhodes Pass the limestones of the Yeso formation are chiefly light to medium gray, containing relatively less clay, but much clean quartz silt and carbonaceous material. Chert is rare, occurring in only a few beds as scattered chert flakes or as small light-gray nodules. The limestones typically are porous, fetid, vugular; vugs are filled by euhedral calcite or gypsum crystals. In thinsection limestones are seen to be principally recrystallized coquinas, with fossils, fossil fragments, algal masses, and elastic limestone grains outlined by rims of carbonaceous material. Both replaced fossil fragments and cement are a mosaic of anhedral calcite crystals averaging 0.01 mm in diameter, much stained by brownish carbonaceous material. Vague lamination is produced by crude sorting of fragments, but chiefly by streaks predominantly of clay and carbonaceous material. Dolomite rhombs and angular silt-size quartz are scattered throughout; veinlets and porphyroblasts of medium-crystalline calcite are common.

Clastic ratios are: Rhodes Pass, 0.75; Hembrillo Pass, 0.46; and Love ranch, 8.13. The low ratio for the Yeso formation in the Hembrillo Pass area reflects the large amount of limestone in that section. Sand-shale ratios do not afford a true picture of the ratio between sand-sized elastic grains (excluding calcite) and silt and clay-sized particles, as almost all the sandstones are very fine grained and silty, whereas the siltstones contain much fine-grained sand. Labeling these rocks as silty sandstones or as sandy siltstones is matter of visual interpretation; only a few mechanical analyses were made. Of considerable significance, however, is the minor amount of beds labeled shale or claystone, ranging from 8.1 percent of the total Yeso strata in the Love ranch area down to 0.8 percent of the Rhodes Pass section. The clay-particle beds are near the base of the formation in Rhodes Pass and near Love ranch, where they are distinctive light-gray to whitish calcareous claystones intercalated with siltstones. These whitish claystones would be a striking marker horizon, except that they are exposed in only a few outcrops.

Sand-shale ratios, based on ratio of sandstone to combined total of siltstone, shale, and claystone, are 1.5 for Rhodes Pass, 24.6 for the Hembrillo Pass area, and 5.8 for Love ranch. These ratios contrast with those of the Abo redbeds, which are no greater than 0.08. Most of the sandstones and siltstones in the Yeso formation are fine grained to fine silt-size grains. The grains are angular to subangular, with some conspicuous sliverlike grains; the grains are mostly (estimated 85-95 percent) "igneous" quartz (no strain shadows), with minor amounts of muscovite, calcite (subrounded), plagioclase, orthoclase, chlorite, magnetite with hematite and/or limonite halo, scattered zircon, apatite, and ilmenite. Grains are rimmed and cemented by hematite, calcite, limonite, and minor gypsum; the iron oxides also form irregular streaks subparallel to laminations. Feldspars are partly to wholly replaced by sericite, kaolinite (?), illite (?), and calcite. These fine-grained elastic rocks are friable, crosslaminated like the Abo siltstones, and of various pastel colors (light red, reddish orange, pinkish gray, yellowish orange, light gray, light brown, and olive), with the orange to pink colors dominant. These colors contrast with the dusky red to grayish red of the underlying Abo redbeds, except near Love ranch, where 15 percent of the elastic beds are the "dirty red" typical of the Abo redbeds.

The Yeso elastics appear to be shallow-marine-water deposits; the Abo redbeds, chiefly continental or near-shore sediments. The Abo elastic beds contain more hematite and less calcite; they are dominantly finer grained than the Yeso elastic beds (excluding detrital limestones), yet include coarse-grained sandstones and conglomerate beds that are absent in the Yeso strata. Abo redbeds to the north, near Abo Pass, consist of about 70 percent shale and 30 percent sandstone and arkose (Bates et al, 1947, p 27), with a sand-shale ratio of 0.43, which is considerably higher than the sand-shale ratio of the Abo redbeds in the San Andres Mountains and lower than that of the Yeso formation. The elastics of the Yeso formation appear to be derived from a source similar to that of the Abo, but much of the clay fraction has been winnowed out, carried southward, and deposited as part of the siliceous shales of the Bone Springs formation in the Delaware Basin and as similar beds in the Marfa Basin.

Thickness

The Yeso formation thins rapidly southward from 1,580 feet near Rhodes Pass, and 892 feet near Hembrillo Pass, to 324 feet at Love ranch. Much of the thinning is due to a loss of gypsum beds. To the north Wilpolt and Wanek (1951) reported about 1,695 feet of Yeso in the eastern Oscura Mountains, consisting of : basal Meseta Blanca sandstone member, 355 feet; Torres member, 1,000 feet; Canas gypsum member, 210 feet; and Joyita sandstone member, 130 feet. Pray (1954, p 101) reported 1,200-1,800 feet of Yeso in the Sacramento Mountains. The 4,200 feet of Yeso penetrated by the oil test (Standard Oil Co. of Texas, Heard No. ,) on the Carrizozo Dome to the northeast is in part thickened by steep dips, but includes many halite beds which are not reported from outcrops. A ,600-foot interval of the Yeso formation drilled through was almost 75 percent salt. To the northwest, east of Socorro, Wilpolt and Wanek (1951) measured 590 feet of Yeso; Kelley and Silver (1952, p 102) estimated 600 feet of Yeso in the northern Caballo Mountains and 180-250 feet in the southern part of that range. The San Andres formation in the southern Caballo Mountains resembles in places the upper limestone beds of the Yeso formation in the Rhodes and Hembrillo Pass areas.

To the south and southwest, in New Mexico, Cretaceous sedimentary rocks or Tertiary volcanic rocks and volcanic sediments rest unconformably on the Hueco formation, and no Yeso or San Andres beds are present.

Fauna

Although many geologists have considered the Yeso formation to be barren in this area, as contrasted with abundant faunas found in the formation in the southeastern part of New Mexico, Lee and Girty (1909, p 29) collected numerous fossils from the upper Yeso limestones near Rhodes Pass. We collected a prolific fauna from the middle and upper Yeso limestones from the Rhodes Pass section. The Yeso faunas are largely undescribed; accordingly, identifications are tentative. A zone with prominent *Euphemites,* a lirate bellerophontid gastropod, is an excellent horizon marker in the penultimate limestone of the section. *Pseudomonotis, Myalina, Pleurophorus,* and *Schizodus* are the most common pelecypods. Cephalopods include *Pseudorthoceras, Domatoceras,* and *Steareoceras,* as well as Tainoceratidae that have not been observed in the overlying San Andres faunas. Various productid brachiopods, along with *Meekella,* are common. No fusulinids were found.

The molluscan fauna is different from that collected from the San Andres formation, but this may be due to environmental differences. The nautiloids of the two formations are close, and some may be conspecific. Flower believes both formations are of Leonardian age in the San Andres Mountains.

SAN ANDRES FORMATION

The type locality of the San Andres formation is west of Rhodes Pass, just south of N. Mex. Highway 52 (Lee and Girty, 1909, p 29). Needham and Bates (1943, p 1665) re-measured the formation and listed a somewhat detailed description. The base of their measured section is now partly covered by debris, and so the lower part of our section was measured about a mile to the west. Ammonoids collected from the upper part of the formation indicate a Leonardian age.

North and east of the San Andres Mountains there is a prominent mappable unit, the Glorieta sandstone, which is considered a formation by most geologists, and a member of the San Andres formation by the U. S. Geological Survey. The distinguishing features are light-gray to yellowish color and siliceous cement. The Glorieta (?) sandstone in the San Andres Mountains is atypical, being lenses of friable poorly cemented yellowish-brown sandstones, which grade down into the reddish sandstones of the Yeso formation and are interbedded with lower limestones of the San Andres formation. We here consider the Glorieta (?) sandstone as a doubtful basal member of the San Andres formation; the sandstone is not a mappable unit in the San Andres Mountains.

Lithology

The San Andres formation, with the exception of the basal yellowish sandstones, consists of gray to dark-gray, medium-bedded to massive, fetid fossiliferous petroliferous limestones. The type section near Rhodes Pass (fig I) consists of a basal Glorieta (?) unit 32 feet thick (R 385-387), which is a lower 9 feet of yellowish silty calcareous sandstone, a medial 11 feet of arenaceous dolomitic medium light-gray limestone, and an upper 12 feet of friable yellowish sandstone. Above is 93 feet of light-gray limestones (R 388-397), with some dolomitic beds; units H 390, 391, and 397 are arenaceous, with lenses of calcarenite and calcareous sandstone. From R 398 to R 410 is 221 feet of dark-gray limestones, massive-bedded, with some argillaceous and carbonaceous beds. The upper 256 feet (R 411-421) is chiefly light-gray limestone, massive to thin-bedded, with a thick sequence of argillaceous limestone (R 417) and numerous porous coquinoid beds with abundant faunas.

The section of San Andres formation west of Hembrillo Pass (fig i 2) is thin; all except the lower 198 feet has been removed by Quaternary erosion. At the base, grading up from the reddish-orange sandstones at the top of the Yeso, is 41 feet of Glorieta (?) sandstone (H 355); moderate-yellow to dark yellowish-orange silty calcareous hard to friable crosslaminated sandstone. The basal 2 feet (H 356) of the limestone beds is silty dolomitic light-gray limestone, with lenses of oolitic calcarenite. Above is 25 feet (H 357) of thin- to medium-bedded light-gray limestone overlain by 90 feet (H 358) of cliff-forming medium-gray limestone. Uppermost beds left by erosion are 40 feet (H 359) of medium dark-gray massive limestone. Here the lower light-gray limestones are 115 feet thick, as compared to 93 feet near Rhodes Pass.

The section measured near Love ranch is different (fig 13). There are numerous thick beds of yellowish to pale-red sandstones and siltstones in the San Andres formation, and several yellowish sandstones in the upper Yeso strata; the contact, therefore, is only an arbitrary line. The basal Glorieta-like sandstone (L 117) is 5 feet thick, conglomeratic, silty, and light brown to grayish yellow. Above is I0 feet of dark-gray argillaceous limestone (L 118) with basal conglomeratic and breccia lenses. Then comes 19 feet (L 119) of calcareous silty yellowish friable sandstone—a repetition of Glorieta-like sandstone. Above is 30 feet (L 120) of dark-gray argillaceous limestone with coquinoid lenses, overlain by 12 feet (lower L 12I) of grayish-yellow friable silty sandstone. The slope-forming sandstone is overlain by 95 feet (L 121-126) of dark-gray silty slightly cherty medium-bedded limestones, which crop out as ledges and ledgy cliffs capping the westernmost cuesta. The remaining 213 feet (L 127-135) is interbedded grayish-yellow to grayish-pink silty sandstones, calcareous sandy siltstone, silty dark-gray limestones, and laminated calcilutites. A single I-foot bed of gypsum occurs in L 130. These beds are overlain with erosional and angular unconformity by the Lower (?) Cretaceous Sarten formation.

Most of the limestones of the San Andres formation are porous and fetid; petroleum stains were noted in many places. When these limestones are dissolved in HCI, the solution is darkened at once with sapropelic material, which then makes **up** most of the insoluble residue. Most of the limestones in the Yeso formation yield a residue of silt or clay, with only minor amounts of oily and sapropelic material.

Determination of isolated outcrops of limestone on a litho-logic basis is difficult when it is possible for the strata to be Pennsylvanian limestones or parts of the Hueco, Yeso, or San Andres formations. Many of the lower Pennsylvanian limestones are very cherty, and they are relatively pure calcic limestones. Panther Seep limestones are interbedded with much elastic material and are chiefly either massive reeflike beds or are dark-gray argillaceous limestones; chert is almost entirely absent. Limestones of the Hueco formation in the San Andres Mountains are similar to those of the Pennsylvanian except for interbeds of reddish shales. Hueco limestones differ from those of the Panther Seep formation, which they most resemble, in that some of the Hueco limestones are cherty. Yeso limestones are dark gray and argillaceous, or olive to light-gray-weathering silty limestones, typically porous, fetid, and vugular. Limestones in the San Andres formation are medium-bedded to massive, fetid petroliferous limestones, dolomitic in part. Vugs filled by white euhedral crystals of calcite are prominent in many of the limestones of the San Andres formation; filled vugs also occur in upper Yeso limestones, but many contain gypsum crystals instead of, or together with, calcite.

Clastic ratios merely reflect the thickness of the Glorieta (?) sandstone member except for the Love ranch section of the San Andres formation. Clastic ratio for the formation at Rhodes Pass is 0.36, but probably as much as l00 feet of the upper limestones has been removed by erosion. Clastic ratio for the Hembrillo Pass area is 0.26; here again at least 200 feet of the formation has been removed by erosion. Clastic ratio for the Love ranch section is 0.62, much of the increased amount of elastics being in the upper part of the formation.

The basal sandstones are silty and calcareous; dark yellowish orange, moderate yellow, or light brown, to light gray; friable and porous. Beds are thin and lenticular, crosslaminated, and weather to a slope except for upper massive ledges west of Hembrillo Pass. The basal sandstone bed in the Love ranch section is conglomeratic, with angular pebbles and cobbles of limestone in a matrix of silty calcareous sandstone containing lenses of well-sorted crosslaminated light-brown sandstone. In thinsection the basal sandstones are subangular grains of silt to fine-grained quartz in a cement of limonite-stained cryptocrystalline calcite. Other minerals are rare.

Clastic beds in the middle and upper parts of the beds herein called San Andres formation near Love ranch are calcareous pale yellowish-brown to grayish-pink siltstones with numerous sandy laminae, and calcareous silty sandstones, very fine-grained, friable, porous, greenish-gray, yellowish, and pinkish. Ratio of sandstone to siltstone (sand-shale ratio) is 1.11 an approximation, as the elastic grains are concentrated in the fine-sand to silt size. No individual sandstone beds occur above the basal sandstone (i.e., Glorieta ?) in the Rhodes or Hembrillo sections, but in the lower part of the sections arenaceous limestones are persistent. One of these horizons, about 120 feet above the base of the formation near Rhodes Pass, is a conspicuous marker bed of distinctive "salt and pepper" color, an arenaceous limestone with lenses of arenaceous calcarenite and very limy sandstone. Thinsections show as much as 20 percent subrounded quartz grains, averaging 0.2-0.3 mm in diameter. The calcite grains and cement have been recrystallized entirely into two types that are interlaminated and intermixed: anhedral crystals averaging 0.03 mm, and cryptocrystalline calcite heavily stained by brownish carbonaceous material. This intermixing of the clear calcite and cloudy calcite causes the megascopic "salt and pepper" mottling.

Many of the limestones throughout the San Andres formation contain scattered quartz grains and laminae of calcareous siltstone. In thinsection much scattered quartz silt is seen. Almost all the limestones, even those that appear to be coarsely coquinoid, are recrystallized, so that they are a mosaic of anhedral calcite crystals averaging 0.01-0.005 mm in diameter, with much intermixed brownish carbonaceous material and, in some beds, much clay. Scattered dolomite rhombs occur, which, along with the recrystallized calcite, are cut by veinlets of relatively coarse crystalline calcite (anhedral crystals averaging 0.15 mm). Many of the fossils and fossil fragments are shown only by faint outlines or by concentrations of carbonaceous material. In some of the limestones the fossils have been replaced by relatively coarse crystalline calcite as compared with the fine mosaic matrix. A few of the limestones are almost entirely a relatively coarse mosaic of calcite crystals averaging 0.15 mm and larger. Even the predominantly micrograined limestones contain scattered porphyroblasts of calcite that range up tor mm in diameter. Limestones appearing to be medium to coarse crystalline on the outcrop are composed mostly of micrograined calcite aggregates.

The limestones are for the most part medium- to massive-bedded and crop out as ledges or cliffs. This uniform thick-bedding and resistance of outcrops contrasts with all lower strata down through the Devonian beds, somewhat resembling that of the Fusselman and Montoya dolomites. Chert, however, is relatively sparse. West of Rhodes Pass chert is present in only a few beds, occurring as scattered yellowish-orange and light-brown flakes. Two horizons of silicified fossils are present and appear sufficiently persistent to be marker horizons. One horizon, about 490 feet above the base, contains small silicified fossils, chiefly gastropods and brachiopods, that weather moderate brown; the other horizon, near the top of measured section R, is marked by larger fossils partly to wholly silicified to bluish-gray chert. In the lower beds of the San Andres formation south of Love ranch are widely scattered laminae, thin lenses, and small nodules of medium-gray chert that weather light brown; in the medial beds are numerous moderate-brown silicified fossils.

Color on fresh surface is about evenly divided between light to medium gray and medium dark to dark gray near Rhodes Pass, but is arranged so that there is a lower light-gray unit (R 388-397), a medial dark-gray sequence (R 398-409), and an upper predominantly light-gray sequence. The beds west of Hembrillo Pass are mainly light gray, as beds above the basal part of the medial dark-gray sequence have been removed by erosion. The limestones in the San Andres formation near Love ranch, however, are mostly dark gray. They are also more silty than those in the two northern sections, and at least part of the limestones in section L is recrystallized laminated calcilutites.

Fauna

The San Andres limestones contain a very large fauna, largely undescribed and, because it occurs in hard limestone, rarely collected. We collected chiefly from the Rhodes Canyon section. The lower beds yielded little besides productids, largely *Dictyoclostus invesi* and D. *bassi; D. indicus,* absent in the lower beds, appears at about the middle in unit R 403. At about unit R 412 scaphopods appear and dominate certain beds to the exclusion of almost all other forms. The upper beds, from R 417 upward, contain a varied molluscan fauna with prolific nautiloids *Domatoceras, Stearoceras, Stenopoceras, Pseudorthoceras, Mooreoceras,* a new cyrtoconic genus, and others; also, the ammonoids *Perrinites* and *Pseudogastrioceras,* indicative of Leonardian age. Numerous and varied gastropods and pelecypods were collected but are largely undescribed species and genera. Despite considerable lateral search, no fusulinids were found in the San Andres formation.

Thickness

The San Andres formation thins southward from 600 feet at Rhodes Pass to 384 feet near Love ranch. Both at the Rhodes and Hembrillo Pass localities the top is an erosion surface, but in the Sun Oil Co. test wells drilled 20 miles northwest of Rhodes Pass the San Andres formation is 650700 feet thick beneath Dockum redbeds. Several miles east of the mountains near Hembrillo Pass an oil test reportedly penetrated only 485 feet of the San Andres formation including basal 32 feet of Glorieta sandstone, between the Dakota (?) sandstone and Yeso formation. To the north, on the east slope of the Oscura Mountains, Wilpolt and Wanek (1951) measured about 440 feet of the San Andres formation, including 45 feet of Glorieta sandstone at the base. In the Oscura Mountains-Chupadera Mesa area the San Andres formation contains many thick gypsum beds. Pray (1954, p 101 101) reported about 500 feet of San Andres limestones in the central Sacramento Mountains; the formation thins southward and thickens to more than 1,000 feet eastward. Kelley and Silver (1952, p 104) reported 780 feet of San Andres formation in the north part of the Caballo Mountains and estimated 550650 feet in the southern part. Their measured section is noteworthy in containing 32 percent of yellowish or pale-red sandstones, and covered intervals that are probably underlain by friable sandstones.

No limestones correlative with the San Andres formation, notwithstanding Dunham's (1935, p 167) report, occur in the Robledo, Franklin, or Hueco Mountains. Southeast of the Hueco Mountains, on the Diablo Plateau, Lower Cretaceous conglomerates rest unconformably on Hueco strata (King, King, and Knight, 1945).

TRIASSIC ROCKS

DOCKUM FORMATION

North of Rhodes Pass, near Cain ranch, the San Andres limestones are overlain by poorly exposed pale reddish-brown calcareous siltstone, claystone, and shale, here referred to the Dockum formation. These redbeds are absent south of Rhodes Pass.

Lithology

The lower 27 feet (see fig 11) of the Dockum formation is mostly covered, but the soft pale-red silty shale and claystone rests unconformably on San Andres limestones. Unfortunately, most of the San Andres formation is cut out by faulting at this locality; therefore, no pre-Dockum thickness of the San Andres formation was obtained. The upper 25 feet (C 2-5) of the Dockum is interbedded pale reddish-brown, light-gray, greenish-gray, grayish-red, and light yellowish-gray calcareous claystone and calcareous micaceous siltstone with laminae of silty feldspathic sandstone.

The Dockum strata occurring near Carthage and at the north end of the Jornada del Muerto are described by Wilpolt and Wanek (1951) as "maroon and light-gray sandstone, siltstone, and shale interbedded locally with limestone-conglomerate lenses." In the same area the upper part of the San Andres formation is an orange-red silty sandstone containing local thin beds of dark-gray limestone. The redbeds near Cain ranch more nearly resemble the Dockum strata. Where the Dockum and upper San Andres elastic unit have been observed in the area east of Socorro, the Dockum redbeds are rather micaceous, whereas the upper Permian beds contain only minor amounts of mica; in contrast, numerous crystals, laminae, and veinlets of gypsum occur in the upper San Andres formation elastic beds, though gypsum is rare in the Dockum redbeds.

Typical siltstone as seen in thinsection is of angular quartz silt containing many grains in the form of sliverlike fragments, some admixed rounded grains, and much muscovite and chlorite, cemented by calcite, clay, and hematite. Magnetite occurs as scattered to numerous angular grains, with hematite rims or completely altered to hematite. Lenses and laminae rich in altered feldspars are predominantly of orthoclase. Some of the claystone is greenish-gray to light-gray kaolinitic silty calcareous clay; much of the claystone is stained by, and admixed with, hematite.

Thickness

About 52 feet of the Dockum formation was measured near Cain ranch, but the redbeds are absent south of Rhodes Canyon. Wilpolt and Wanek (1951) estimated 500 feet of the Dockum near Carthage. Robert F. Schmalz (1955, p 22) reported 340 feet of redbeds above San Andres limestones and below the Dakota sandstone in the Three Rivers area on the northeast side of the Tularosa Valley. The two Sun Oil Co. test wells 20 miles northwest of Rhodes Pass reportedly penetrated 100-180 feet of Dockum redbeds.

Fauna

No fossils were seen in the Dockum formation. Wilpolt and Wanek (1951) suggested that the Dockum is equivalent to the Chinle formation and Santa Rosa sandstone. The lower part of the Dockum near Cain ranch and the redbeds near Three Rivers may be of Permian age.

JURASSIC ROCKS

Jurassic sedimentary rocks are not known to occur anywhere near the San Andres Mountains and have not been reported in southern New Mexico, although a thin sequence of variegated shales below the Dakota sandstone near Capitan, east of Sierra Blanca, may be of Jurassic age (J. E. Allen, personal communication.)

CRETACEOUS SEDIMENTARY ROCKS

Previously only Upper Cretaceous sedimentary rocks have been reported in the San Andres Mountains. During this study possible Lower Cretaceous strata were found at the south end of the range near Love ranch unconformably overlain by the Dakota (?) sandstone. Cretaceous units in and near the San Andres Mountains are the Sarten formation, Dakota (?) sandstone, Eagle Ford (Mancos) formation, and Mesaverde formation.

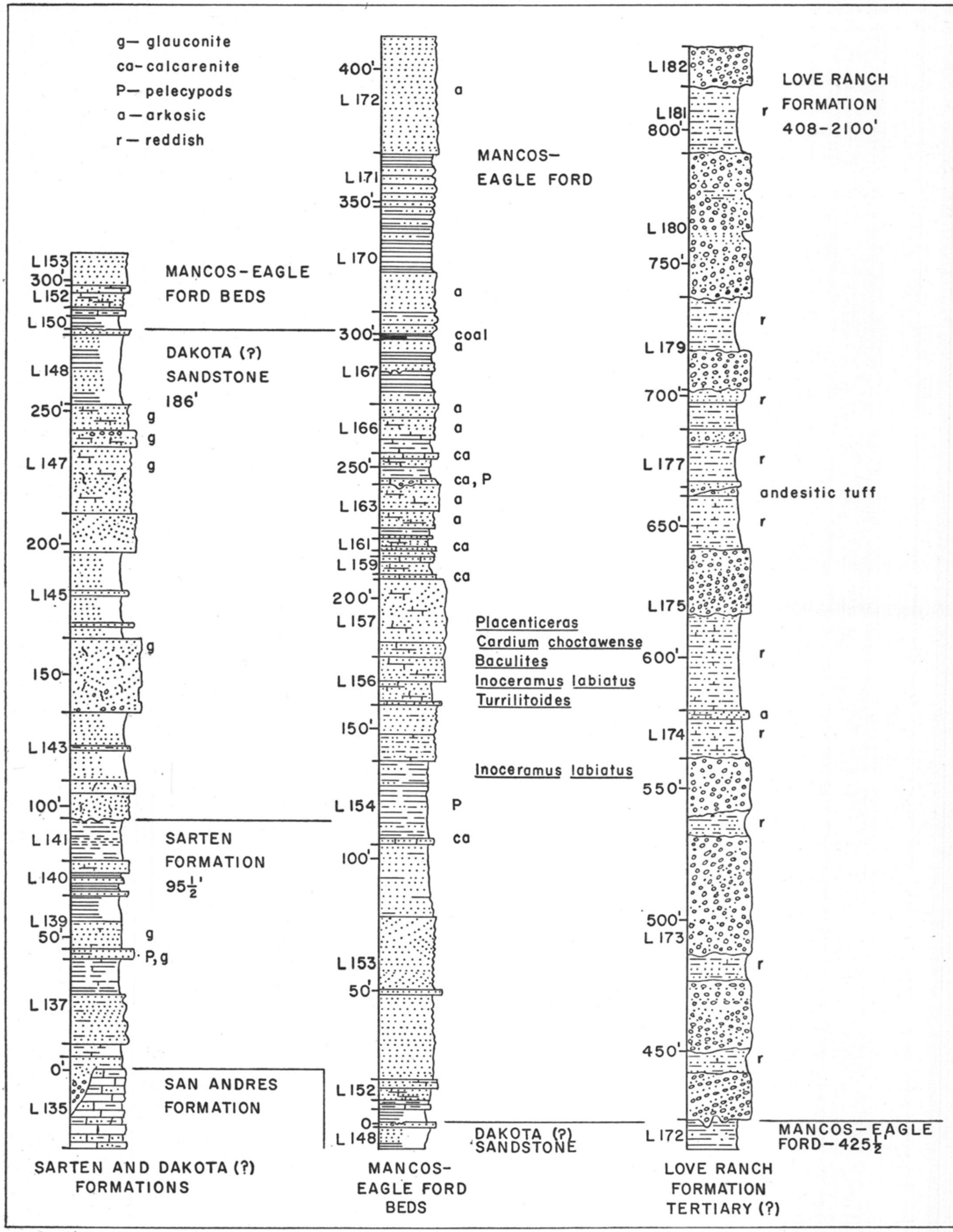
SARTEN FORMATION

The name Sarten formation was given by Darton (1916, p 43) to a sandstone containing Comanchean fossils in the Cooks Peak area. Darton (1928, p 38) believed the Sarten formation correlative with the Beartooth quartzite of the Silver City area; southward, in the East Potrillo Mountains and in other ranges to the southwest, the formation is underlain by older Comanchean beds.

The sandstone called Sarten by Darton is similar in lithology to the sandstone labeled Dakota in central New Mexico. Jicha (1954, pp 26, 34) described the Sarten sandstone in the Cooks Peak area as 300 feet of light-gray massive sandstone, mostly quartzitic, with medial thin interbeds of fossiliferous sandy shale and marl. Lower Cretaceous fossils were collected from the Sarten formation near Cooks Peak.

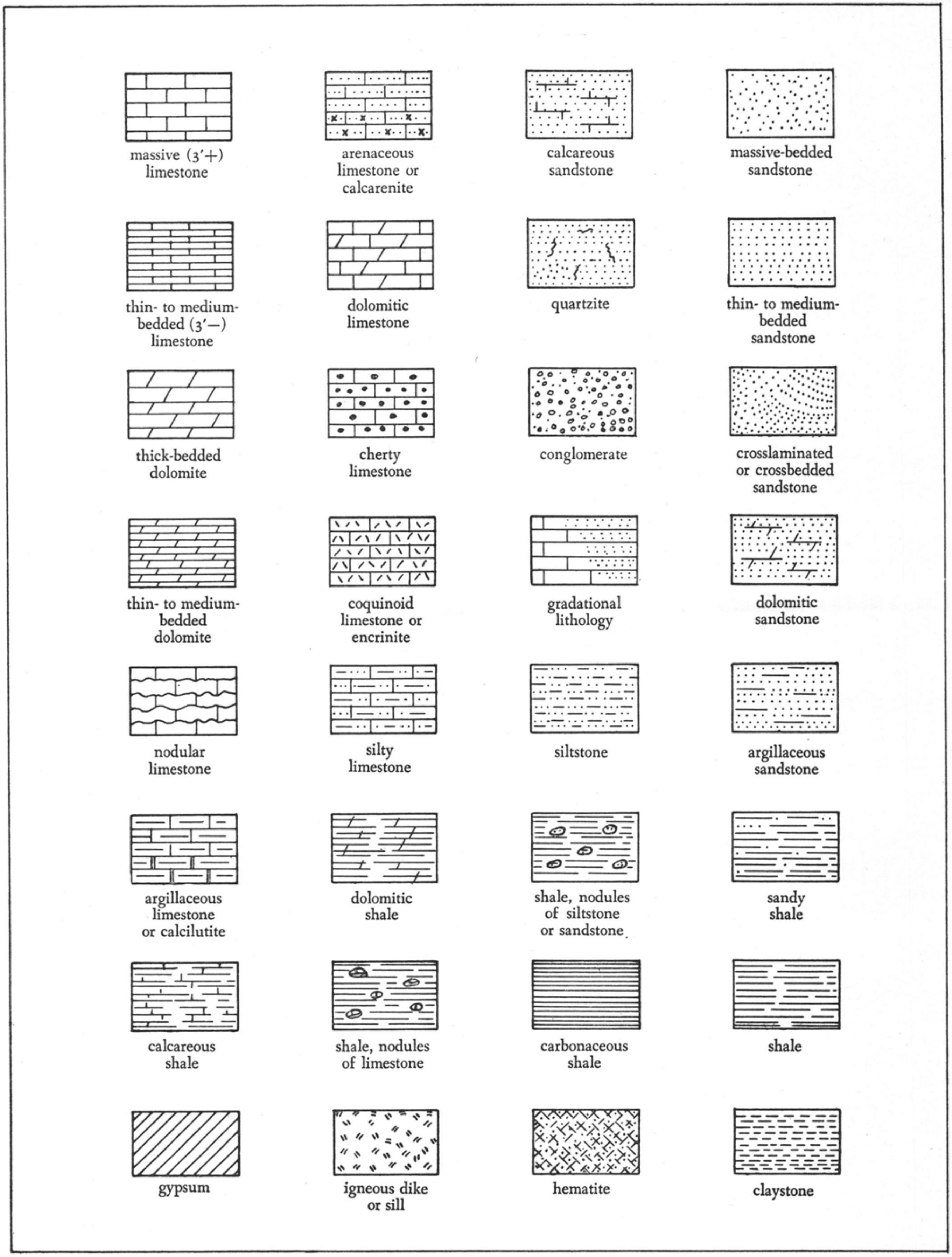
Known outcrops of the Sarten formation occur in a limited area on the west side of the San Andres Mountains near section L (fig 7). Here the formation rests with erosional and slight angular unconformity on the San Andres formation; within 50 feet along the strike, in one place, the basal Sarten beds truncate 18 feet of the uppermost San Andres limestones.

To the southeast, along the New Mexico-Texas state line, shales, limestones, marls, and basal sandstones of the upper



Columnar sections of Sarten, Dakota, Eagle Ford, and Love Ranch formations in Love ranch area

Figure 14



Lithologic symbols used in columnar sections

Figure 15

Comanchean Washita group crop out in the Cornudas Mountains (Adkins, 1932, p 354) unconformably on Yeso strata, and on the northeast edge of the Hueco Mountains, at the Camaleche tanks (sec. 24, T. 26 S., R. 10 E.), similar beds also overlie the Yeso formation (West Texas Geol. Soc., 1950, p 0). South of these exposures, southeast of the Hueco Mountains, on the Diablo Plateau, the Hueco formation is overlain by the Campagrande conglomerate and the Cox sandstone, of probable upper Trinity age; these are overlain in turn by the Finlay-Edward limestone of Fredericksburg age (King, King, and Knight, 1945), which southward underlie the Kiamichi formation, of upper Fredericksburg age, and the Washita group. Comanchean beds thicken rapidly to the south, reflecting onlap of the Early Cretaceous seas onto a large landmass that occupied most of southwestern and south central New Mexico. Near El Paso, which is almost due west of the Cretaceous outcrops on the Diablo Plateau, Bose (1906) measured about 800 feet of strata of the Washita group overlying about 165 feet of beds of Fredericksburg age, with more than 200 feet of basal clastics of possible Trinity age. The uppermost Washita unit, the Buda formation, is overlain by a sandstone called Woodbine or Dakota by Adkins (1932, p 409), and the Dakota (?) sandstone is succeeded by at least 350 feet of shales and flaggy sandstones of the Eagle Ford formation. The Eagle Ford formation may be as much as 750 feet thick in the Juarez and southern Franklin Mountains, in the former area including coal beds that have been mined sporadically.

The section on the Cerro de Muleros, the laccolithic peak west of El Paso, is as follows (Bose, 1906; Adkins, 1932, p 368), in descending order:

Unit no.	Description	Thickness (feet)
	GULF SERIES	
11.	*Eagle Ford group,* limestone-flag facies, interbedded dark-gray to reddish calcareous shales, hard thin even-bedded limestones, and flaggy limy sandstones; *Inoceramus labiatus*	350-750
10.	Woodbine sandstone, light-gray, quartzitic, cross-bedded, resistant, unfossiliferous	200-800
	COMANCHE *SERIES*	
	Washita group	
9.	Buda formation, limestones with lenses of yellowish shale	90
8.	Grayson or Del Rio formation, yellowish calcareous shales with lenses of hard limestone; *Exogyra whitneyi, Hemiaster calvini*	75
7.	Main Street formation, basal reddish-brown quartzitic sandstone, medial interbedded marly shales and arenaceous limestones, upper thin-bedded calcareous shaly sandstones and sandy limestones; *Exogyra arietina, E. whitneyi? Hemiaster calvini*	310
6b.	Pawpaw formation, sandy marl; *Alectryonia quadriplicata*	80
6a.	Weno formation, bluish-black clay with pyritic micromorphs; *Pervinquieria, Neokentroceras*	40
5.	Denton formation, marl and nodular dark bluish-gray soft limestone; echinoids *Pyrina, Phymosoma, Holectypus*	50
4.	Duck Creek formation, basal shaly limestone, upper marly shale, basal zone with ammonites *Desmoceras, Beudanticeras, Puzonsia*	100-150
	Fredericksburg group	
3.	Kiamichi formation, sandy massive limestone, gray calcareous sandstone, brown and yellowish marls, and black shales; *Oxytropidoceras (Adkinsites) belknapi, Gryphaea navia*	80
2.	Goodland formation, basal hard whitish limestone, rest calcareous clay and manly limestone used for production of cement; *Gryphaea marcoui, Exogyra texana*	85
	Fredericksburg or *Trinity group*	
1.	Sandstone, unfossiliferous, base not exposed	200 (?)

Lithology

The Sarten formation herein refers to intercalated yellowish-brown to purplish silty sandstones; sandy gray fossiliferous shales; brown fossiliferous calcareous sandstones, coquinoid in part; olive-gray glauconitic sandstones; and black carbonaceous shales (see fig 14). At the base are nonpersistent conglomeratic lenses with pebbles up to I 0 mm in diameter, chiefly of light-brown to black chert, with some quartz and silicified limestone pebbles. Several beds contain fragments of marine fossils—gastropods, pelecypods, and oysters; at the top of unit L 138 is a sandy coquina of pelecypods and oysters, unfortunately too broken and too poorly preserved to be positively identified as to species. Grains of glauconite occur in the sandstones of units L 138 and 139. Black carbonaceous shales are prominent in the upper part of the formation; imprints of oysters were seen on float from the blackish shales.

The contact with the overlying Dakota (?) sandstone is exposed only in a few places, because the basal resistant ledges of Dakota (?) quartzitic sandstone crop out as steeply dipping ledges above the Sarten slope, and many sandstone slabs slump down over the Sarten outcrops. L 141, the upper Sarten unit, thickens and thins where the overlying Dakota (?) beds thin and thicken.

Clastic ratio is, of course, nearly infinity, although there is much calcareous and phosphatic fossil material in clastic lenses. Sand-shale ratio, though variable because of the lenticular nature of the beds, is about 1.01. The sandstones are chiefly fine grained, calcareous to siliceous, and fossiliferous, some beds being glauconitic, silty, and ferruginous. Even the basal conglomeratic lenses contain admixed marine fossil fragments. The conglomerate is of relatively small pebbles (up to 10 mm), chiefly of resistant rocks, such as chert, quartz, siliceous siltstone, and silicified limestone; pebbles are rounded. The lower sandstones are silty, thin, and evenly laminated; in thinsection they are seen to be chiefly angular fine- to very fine-grained quartz, with notable amounts of muscovite, magnetite, and hematite, as well as chlorite and clay (illite?), cemented by silica. Upper calcareous sandstones contain up to 40 percent calcite as cement, grains, and fossil fragments, together with scattered glauconite partly altered to limonite, and rounded to subangular quartz sand; patches and laminae are cemented by iron oxides. Though most of the shale beds, above the lower sandy shales, are grayish black and carbonaceous, they are intercalated with calcareous fossiliferous sandstones and contain limy nodules and lenses. Some lenses of grayish-green claystone occur near the top of the formation.

The lithology of the Sarten formation near Love ranch is considerably different from that of the type Sarten sandstone in the Cooks Peak area, more nearly resembling parts of the Comanchean section at El Paso in being similar to the distinctive Main Street formation of the Washita group. As the Comanchean (?) outcrops near Love ranch, herein labeled Sarten formation, are a shoreward expression of those near El Paso (a marginal continental-marine facies) they should be of slightly younger age than the similar facies at El Paso and are probably time equivalents of the Grayson and/or Buda formations, which at El Paso are marine shales and limestones.

Thickness

As measured near Love ranch in section L, the Sarten formation is 951/2 feet thick. We are reasonably sure that no Cretaceous outcrops occur southward in the Organ, Robledo, and northern Franklin Mountains until near El Paso. The strata there exposed below the Dakota (?)-Woodbine sandstone are somewhat dissimilar to the Sarten beds of section L but probably are seaward correlatives. Jicha (1954, p 26) reported 300 feet of the Sarten sandstone near Cooks Peak. Lower Cretaceous strata are as much as 21,000 feet thick in the Little Hatchet Mountains in southwestern New Mexico (Lasky, 1947, p), as compared to more than 1,165 feet measured near El Paso (Bose, 1909).

Fauna

Numerous fragments, molds, and casts of oysters, other pelecypods, and gastropods, occur in the Sarten formation but are too broken for specific identification, although many of the pelecypods resemble *Inoceramus comancheanus.* The beds exposed in the Love ranch area are referred to the Lower Cretaceous chiefly because they are below a Dakota-like sandstone, which in most areas is considered basal Upper Cretaceous or uppermost Lower Cretaceous. Corroborative evidence is the Beartooth quartzite or Sarten sandstone of the Silver City and Cooks Peak areas, which is lithologically similar to the Dakota (?) sandstone of Love ranch, and which contains Lower Cretaceous fossils near Cooks Peak. The fossils are believed of Fredericksburg age by Cobban and Reeside (1952, pl 1) but considered of Washita age by Stanton (Dar-ton, 1917, p 6) and of uppermost Fredericksburg age by Adkins (1932, p 281).

DAKOTA (?) SANDSTONE

The light-colored quartzitic crossbedded resistant sandstone here referred to the Dakota (?) sandstone occurs in two areas visited on the west flank of the San Andres Mountains and is reported by Darton (1928, p 191) to crop out at several other localities north of Cain ranch. Near Cain ranch scattered outcrops of Dakota (?) sandstone capping Dockum red-beds were found throughout a large pediment area in the eastern part of T. 11 S., R. 2 E. (fig 5). In most places the resistant quartzitic sandstone of the Dakota (?) caps a low hill or underlies a few feet of pediment gravel, whereas the reddish Dockum is exposed only in gullies.

South of Ash Canyon, from Lion Den Canyon to Bear Creek (fig 7), scattered hogback ridges of Dakota (?) sandstone crop out on the extreme west edge of the San Andres Mountains. Here the Dakota (?) sandstone is unconformable on the Sarten formation and is overlain by Mancos-Eagle Ford strata.

Lithology

The Dakota (?) sandstone is a light-gray quartzitic crossbedded ledge-forming sandstone, with interbeds of silty greenish-gray nonresident sandstones. Near Cain ranch (figs *5, 11*), in a narrow gully, about 31/2 feet of relief was observed on the underlying Dockum redbeds. The basal contact usually is found to be covered in the Love ranch area, but the Dakota (?) sandstone appears to fill in swales in the upper beds of the Sarten formation. The sandstone is typically light gray to yellowish gray, speckled by dark yellowish-orange limonitic spots. Tiny ferruginous silt galls, scattered light brown feldspars, and leucoxene grains stained white to yellow brown occur in the quartzose sandstone. The upper part of the exposed strata contains lenses of thin-bedded shaly sandstone above a conglomeratic bed marked by subrounded pebbles, up to 25 mm in diameter, of quartz, chert, siltstone, limestone, and rhyolite. The top of the section is the erosional pediment surface.

In the Love ranch area the entire Dakota (?) sandstone is exposed (see fig 14) and consists of three thick hogback-forming quartzitic sandstones, with interbedded less resistant sandstones. The quartzitic sandstones are light gray to almost white, are speckled by spots of limonitic silt and white leucoxene, and weather to a casehardened light brown. They are crossbedded to crosslaminated, with grains almost entirely of fine- to coarse-grained subrounded quartz, and with quartz and leucoxene cement. The slope-forming greenish-gray sandstones are silty to fine grained, with a cement of calcareous and/or siliceous, ferruginous silt. At the base of the most prominent ledge (L 144) are pebbly lenses with subrounded to subangular pebbles, 3-10 mm in diameter, of chert, quartz, and reddish Abo siltstone. Near the top of this unit are lenses of glauconitic sandstones which occur also in L 147; moreover, a few lenses of grayish-black shale are intercalated with glauconitic sandstones in L 148. The basal carbonaceous shales of the overlying Eagle Ford beds rest unconformably on the Dakota (?) sandstone, with several feet of relief apparent in the small area of the outcrops.

In thinsection (pl 5-D) the sandstones are typically of subangular to rounded quartz grains, with much quartz cement as secondary growths on the clastic grains. Scattered grains of chert and altered feldspar (chiefly orthoclase) occur, but many of the beds are almost wholly quartz. Dust rims on the original grains are of iron oxides, mainly limonite and leucoxene. In some beds and laminae leucoxene is abundant as grains and cement, constituting perhaps as much as 10 percent of the rock, but with associated calcite and limonite. The leucoxene appears to have been derived from ilmenite; rare skeletal ghosts of ilmenite grains remain. The spots of limonite that are prominent on outcrops are probably remnants of ilmenite alteration. Intergranular porosity is distributed irregularly but appears to range from 5 to at least 10 percent and to increase inward from the exposed surface of the rocks.

Siltstone lenses near the base of the formation in the Love ranch area are dark yellowish-orange eye-catching marker beds, where exposed. They are composed of angular quartz silt cemented by iron oxides and clay (illite ?). The greenish-gray sandstones as slope-forming units are fine grained to silty, with platy to thin bedding and crosslamination, contrasting with the massive lenticular crossbedded light-gray to tan siliceous sandstones. Cement in the greenish beds is iron oxides, calcite, and some leucoxene, although these three are subordinate to chalcedony and quartz. Scattered to abundant glauconite occurs, much of it altered to limonite.

Thickness

The 40 feet measured near Cain ranch is only the lower part of the Dakota (?) sandstone. In the two Sun Oil Co. test wells drilled 20 miles northwest of Rhodes Pass, however, only about 50-70 feet of Dakota (?) sandstone was reported, although as much as 335 feet of sandstone and shale may be Dakota (?) equivalent. Wilpolt and Wanek (195i) reported 71 feet of Dakota (?) sandstone in the Carthage coal field;

Kelley and Silver (1952, p 110) noted 245 or 219 feet in the Caballo Mountains. The Dakota (?) sandstone measured near Love ranch is 186 feet thick; the Sarten sandstone and/or Beartooth quartzite near Cooks Peak is a similar lithologic unit and is about 300 feet thick. The equivalent lithologic sequence is not present in the Robledo, Organ, northern Franklin, Hueco, or Sacramento Mountains, although in the Three Rivers area, on the east side of the Tularosa Valley, Schmalz (1955, p 27) reported about 280 feet of Dakota (?) sandstone. Near El Paso Bose (1909, p 18) measured 200-800 feet of Woodbine or Dakota (?) sandstone.

Fauna

No fossils were seen in Dakota (?) sandstone beds in the range. The Lower Cretaceous marine fauna present in the Sarten sandstone and/or Beartooth quartzite in the Cooks Peak area brings into question the Upper Cretaceous dating attributed to this distinctive lithologic unit in southern New Mexico. The glauconite that is abundant in the upper part of the Dakota (?) sandstone near Love ranch suggests marine deposition and may indicate that these southern beds are of a slightly different age and different depositional environment.

EAGLE FORD FORMATION

Except in the vicinity of Love ranch, where the basal contact is a fault plane or is in most places covered by alluvium, Mancos shales or equivalent Eagle Ford beds were not observed anywhere near the San Andres Mountains. At one locality, section L (figs 7, 14), 81/2 feet of carbonaceous shales and limestones (L 50-151) unconformably overlies the Dakota (?) sandstone; overlying beds are similar to rocks measured as units L 152-153 about a mile to the south. However, there may be a considerable interval between the beds of unit L 151 and those of L 152.

Darton (1928, pp 191-192) noted these Mancos-Eagle Ford beds near Love ranch and listed a fauna identified by T. W. Stanton as Benton, lower Mancos shale. The sequence is broken by faults. Therefore, Darton, as well as Dunham (1935, p 168), overlooked the Sarten and Dakota (?) formations and the lower 325 feet of the Benton beds; as did we, until the relationships were revealed by the mapping of the Love ranch area.

Lithology

In section L (fig 14) a basal 51/2 feet of grayish-black carbonaceous shale (L 50) rests on the Dakota (?) sandstone. The shale is overlain by 3 feet of intercalated arenaceous limestone, calcilutite, and blackish shale (L 151), which are in turn overlain by beds similar to the sandstones and subgraywackes of L 152 and L 153. Basal L 152 is a very calcareous olive-gray silty sandstone containing irregular concretions of hard limy sandstones and spherical concretions of silty limestone. The overlying beds are interbedded and gradational olive-gray calcareous subgraywackes, sandstones, and carbonaceous shales, marked by numerous plant imprints, a coal lens (L 158), and fossiliferous lenses of calcarenite and silty limestones. Many of the upper sandstones are arkosic, containing varying amounts of light-gray feldspars. Most of the sandstones may be classified as graywackes, depending upon which sedimentary petrologist's classification is used. The Eagle Ford beds are overlain near Love ranch, with pronounced erosional unconformity, by Tertiary conglomerates.

The limestones near the base of the Eagle Ford formation range from brown silty calcilutite of interlaminated and intermixed calcite and limonitic clay, speckled by sparse to abundant angular quartz silt; through recrystallized micro-oolitic limestone composed of spherical oolites, mm in diameter, and scattered quartz silt; to laminated argillaceous limestone, in which laminae of fibrous calcite crystals, length perpendicular to lamination, alternate with microcrystalline calcite mixed with illite (?) and limonite. The calcarenite beds and lenses grade vertically and laterally into fossiliferous calcareous sandstones and range from relatively unsorted coquinas of carbonaceous, phosphatic, and calcareous fossil fragments, of which pelecypods, gastropods, oysters, ammonoids, and brachiopods are most common, to well-sorted arkosic arenaceous calcarenites.

Shales in the lower part of the formation are black and carbonaceous, with olive-black silty laminae and lenses. Shales are more abundant near the top and are dark olive gray and sandy, carbonaceous in part, with some laminae and lenses of coal.

Conglomeratic lenses consist chiefly of small angular to subrounded pebbles of fossils, fossil fragments, limestone, chert, and quartz. The clastic beds are for the most part horizontally stratified, although some of the sandstone and calcarenite beds fill narrow channels cut as much as 2 feet deep in underlying strata. Some of these beds are crosslaminated in simple sets, the basal planes being nonerosional, although some sets are of the trough type with basal curved surfaces of erosion. The shape of most sets is tabular; crosslaminae are straight to gently concave, inclined at low angle, and of medium scale, i.e., cross strata 1-20 feet in length (McKee and Weir, 1953, pp 385-388).

Sandstones range from impure arenites, in which the clay matrix approaches 1 0 percent, to graywackes, in which clay constitutes more than 10 percent of the rock (Williams, Turner, and Gilbert, 1954, p 290). These rocks contain only small amounts of the angular elongated splinter grains, are not microbreccias, and are composed chiefly of subrounded to subangular mineral fragments rather than rock fragments. They are dark greenish and contain much clay and carbonates, as well as carbonaceous matter, chlorite, brown and black biotite, and scattered magnetite and muscovite. Clastic grains, in order of abundance, are: quartz (not strained), calcite, ferruginous clay or silt galls, feldspars, chert, and some fragments of limestone and siltstone. In the upper subgraywackes and impure sandstones, feldspars are numerous and are altered or fresh; plagioclase (more calcic than albite) dominates, with some orthoclase and microcline. Cement is a mixture of calcite, carbonaceous material, clay, chlorite, and iron oxides. Arenaceous beds containing numerous carbonaceous plant imprints and woody and coaly stems are intercalated with arenaceous beds that are more calcareous and that contain fragments of marine fossils and lenses of limy siltstone cementing fossil coquinas.

Most of the limestone beds are arenaceous calcarenites, but the clastic ratio of 37.6 reflects neither the actual clastic nature of most of the sediments, which would yield a clastic ratio near infinity, nor the amount of precipitated and clastic calcite in the sandstone and subgraywacke beds, which, if all counted as "limestone," would lower the clastic ratio to about 5. Sand-shale ratio is 2.3 for the entire formation. If the formation is split into a lower part of units L 50-L 157 and an upper part of L 158-L 172, the sand-shale ratio for the lower beds is 3.1 and for the upper beds 1.8.

The predominance of sandstone and/or subgraywacke should be noted; this is not a facies similar to that of the typical Mancos shales. The general lithology, including the lenticular coal bed, though closely resembling that of the Mesaverde sandstone, is more similar to that of the shales, sandstones, and arenaceous limestones called the Colorado shale in the Cooks Peak area and the Eagle Ford formation near El Paso.

Thickness

Disregarding lithology, the beds contain a lower Mancos-Eagle Ford fauna and therefore can be compared with thicknesses of the Mancos shale to the north, the Eagle Ford formation to the south, and the Colorado shale of the Silver City and Cooks Peak areas. Near El Paso the Eagle Ford formation is listed as more than 750 feet thick (Nelson, I950, p 39). Near Cooks Peak the Colorado shale is at least 295 feet thick, though the top is eroded (Jicha, 1954, p 54). Fossils of Benton age were collected from this formation near Cooks Peak. In the Caballo Mountains Kelley and Silver (1952, p 1 I I) estimated the Mancos shale to be 350-450 feet thick, consisting of a lower 42 feet of dark-gray to black shale, with intercalation of limestone beds 1-4 inches thick, and an upper 400 feet of dark-gray shale containing olive-drab siltstones and shales and a few thin limestones. The Western Drilling Co. No. Guame (Sec. 21, T. 16 S., R. 2 E., west of Hembrillo Pass on the east side of the Jornada del Muerto) drilled through 455 feet of Mancos shale. The two Sun Oil Co. test wells, drilled 20 miles northwest of Rhodes Pass, may have penetrated as much as 520 feet of Mancos shale. Northwest of the San Andres Mountains, in the Carthage coal field, Wilpolt and Wanek (1951) reported three members of the Mancos shale: a lower 295-340 feet of dark-gray to gray calcareous shale, with several thin limestone beds containing a Greenhorn fauna (middle Benton); a middle 240 feet of light-buff sandstone interbedded with light-gray, red, and lavender shale, capped by a prominent brown sandstone; and an upper 225-290 feet of gray to blue-gray calcareous shale containing large septarian concretions. Total thickness near Carthage is 760-870 feet. In the Three Rivers area, on the east side of the Tularosa Valley, Schmalz reported (1955, p 28) at least 525 feet of Mancos shale; perhaps m00 feet, depending on where the Mancos-Mesaverde contact is drawn.

Fauna

Fossil fragments are numerous in the Love ranch section of the Eagle Ford formation; near the middle of the formation a prolific well-preserved fauna occurs in concretions in calcareous sandstones and in calcarenites and silty limestones. These fossils were identified by Alexander Stoyanow, of the University of Arizona and the University of California (Los Angeles), who lists the abundant index fossils as: *Baculites (Sciponoceras) gracilis, Inoceramus labiatus, Cardium choctawense,* and *Placenticeras* cf. P. *pseudoplacenta* var. *occidentale.* Forms of *Turrilitoides* also are present. Stoyanow correlates the beds with the Britton clay of the Eagle Ford, including both the *Baculites (Sciponoceras) gracilis* and *Inoceramus labiatus* zones. A similar fauna was collected from the Colorado shale in the Cooks Peak area (Jicha, 1954, p 27). In the Cerro de Muleros, near El Paso, Bose (1906, p 9) collected *Inoceramus labiatus* from the Eagle Ford formation.

MESAVERDE FORMATION

No outcrops of the Mesaverde formation occur in or near the San Andres Mountains, although the strata have been penetrated by oil tests in the Jornada del Muerto. Kelley and Silver (1952, p III) estimated the Mesaverde to be about 2,500 feet thick near the northern Caballo Mountains, where the formation consists of olive-brown conglomerate, sandstone, siltstone, shale, and local coal beds. In the Carthage coal fields Wilpolt and Wanek (1951) noted 987 feet of the Mesaverde formation that had been penetrated by drilling, but the top is an erosional surface. In the Three Rivers area of the Tularosa Valley Schmalz (1955, p 31) noted 700-800 feet of Mesaverde, with the top an erosional surface. The Mesaverde formation is not exposed, or is absent, in southern New Mexico south of the central part of the Caballo Mountains, although about 470 feet of sandstones and sandy shales were found above Mancos shale and below alluvium in the Western Drilling Company No. I Gaume, west of Hembrillo Pass.

MCRAE FORMATION

The McRae formation, named by Kelley and Silver (1952, p 115), crops out in the structurally low area between the Caballo and Fra Cristobal Mountains. Basal beds of the post-Mesaverde sequence that underlies thin pediment gravels near Aleman may be part of the McRae formation. The formation has been studied and mapped by Bushnell (1955, pp 9-17), who subdivided it into a lower Jose Creek member and an upper Hall Lake member. In places basal beds of the formation are sharply unconformable on the Mesaverde formation; in other places the contact appears transitional. *Triceratops* is reported from the lower part of the Hall Lake member, and from siliceous siltstones in the Jose Creek member plant fossils were collected by Hugh Bushnell that have been identified by Roland W. Brown (U. S. Geological Survey; personal communication) as *Sequoia reichenbachi* (Geinitz) Heer, *Sabalites sp., Ficus trinervis* Knowlton, and *Viburnum marginatum* Lesquereux. Concerning the age of the flora, Brown noted: "All of the identified species have a long range in the Upper Cretaceous. The general aspect of the collection suggests late Mesaverde age."

Bushnell (1955, p 5) estimated a maximum thickness of 3,300 feet for the formation at its type locality on the east side of Elephant Butte reservoir (Hall Lake). Although the fossils are from the lower strata, the fact that no significant breaks have been seen in the Hall Lake member suggests that the entire formation is probably latest Cretaceous in age.

The basal Jose Creek member consists of a lower brown to greenish shaly sequence and upper tan to dark-brown sandstones with a few intercalated tan siliceous siltstones—quite similar to Mesaverde strata, except that the sandstones have a higher percentage both of chloritic and ferruginous silt and of lithic fragments and feldspars. Conglomeratic lenses in the Jose Creek member contain numerous pebbles and cobbles of andesite not found in the Mesaverde formation. At several localities, such as near Elephant Butte dam, the Jose Creek member appears to grade into vent agglomerates and associated intrusive-extrusive intermediate volcanic rocks and volcanic sediments.

In places at the base of the Hall Lake member, the upper member of the McRae formation, are distinctive conglomerates which continue as lenses up into the lower part of the member. The conglomerates consist chiefly of rounded to sub-angular cobbles of quartzite, with lesser amounts of granite, quartzose schist, and scattered andesite, in a matrix of light-gray friable arkosic tuffaceous sandstone. The bulk of the Hall Lake member is purplish, purple-brown, and chocolate-brown (colors do not match any on the standard rock-color chart) tuffs, tuffaceous siltstones, and argillaceous siltstones, with lenses of hard light-olive, light purplish-gray, and light-gray arkosic volcanic sandstones or graywackes. Grains are angular fragments of clear quartz, pink, white, and glassy feldspars, muscovite, biotite, chlorite, magnetite, altered mafic minerals (augite, hornblende ?), felsite, epidote, and propylitized andesite (as well as andesine). The matrix is siliceous chloritic argillaceous silt. Conglomeratic lenses, except those in the lower beds, are chiefly of purplish to greenish andesite pebbles and cobbles, subrounded to subangular. Pebbly sandstones composed of angular grains of reddish-orange felsite, greenish altered andesite, light-brown micro-dine, and quartz are striking marker horizons.

West of Aleman, on the east central side of the Jornada del Muerto, sandstones of the Mesaverde formation are overlain by a light-gray arkosic conglomeratic sandstone that contains numerous pebbles of andesite and a few scattered pebbles of quartzite and granite. Next above is purple to light-gray tuff and tuffaceous sandstone, overlain by a brecciaconglomerate of andesite boulders in a friable calcareous tuff matrix. These three units total about 60 feet in thickness, are overlain by a thick sequence of redbeds, and may be a southward thinned lens of the McRae formation. Andesites in the McRae formation near Elephant Butte reservoir are typically propylitized, and mafic minerals are relic augite altered to calcite, iron ores, chlorite, and sphene, with plagioclase feldspars being sodic andesine. The andesites that crop out near Aleman, however, are relatively fresh, the mafic minerals are chiefly biotite, and the plagioclase is oligoclase. These latter andesites resemble mid-Tertiary (?) andesites that occur in the Dona Ana, Robledo, and Organ Mountains, at Cooks Peak, in the Animas Hills, and in the Palm Park formation in the southwestern foothills of the Caballo Mountains.

There has been considerable speculation as to how much of the Jornada del Muerto is underlain by the McRae formation. Reconnaissance of outcrops and examination of cuttings from a few oil tests drilled in the Jornada suggest that rocks similar to those of the McRae formation do not extend south of Aleman but may occur as a thin blanket as far northeast as Deep Well (9 miles north of Engle), where dark greenish-gray volcanic sandstones, tan siliceous siltstones, and andesite tuff-breccias overlie nonvolcanic Mesaverde sandstones and dip about 6° WSW. These Mesaverde outcrops are quite close to the west side of the Jornada; near the geographic center (not topographic center) of the Jornada, about the middle of T. I I S., R. 1 E., limestones of the San Andres formation crop out and dip 4° SW. The McRae beds, therefore, seem to be concentrated in the present structural basin, the Cutter sag, on the west side of the Jornada del Muerto, between the Caballo and Fra Cristobal Mountains.

TERTIARY ROCKS

Tertiary sedimentary and volcanic rocks crop out in the San Andres Mountains only in the southwestern foothills near Love ranch. Intrusive igneous rocks of probable Tertiary age occur throughout the range. Tertiary volcanic and sedimentary rocks occur at scattered localities on the west side of the Jornada del Muerto, in the Cerro Colorado near Carthage, at Little San Pasquel Mountain, in the Rincon Hills at the south end of the Caballo Mountains, at San Diego Mountain (Tonuco Mountain), and in the Dona Ana Mountains. Near the center of the Jornada and westward Tertiary volcanic and sedimentary rocks crop out from Aleman to Point of Rocks (fig). Tertiary rocks are probably not thick beneath Quaternary deposits in any part of the Jornada del Muerto, unless the upper part of the McRae formation is of Tertiary age, in which case thick sections would be found only west of Engle.

Quaternary and Tertiary (?) sedimentary rocks are rather thick in the Tularosa Valley, where 780 to more than 1,800 feet of relatively unconsolidated rocks has been penetrated by drilling. The age of the lower part of these beds is not known. Along the east side of the Tularosa Valley, in the Godfrey Hills, northeast of Tularosa, Schmalz (1955, p 33) reported possible Tertiary sediments beneath the thick Sierra Blanca volcanic sequence. Similar sedimentary beds have been named the Cub Mountain formation by Bodine (1956, p 8) from outcrops near Carrizozo. These beds are apparently conformable on Mesaverde strata and may be late Cretaceous in age.

LOVE RANCH FORMATION

Near Love ranch (fig) as much as several thousand feet of intercalated boulder-conglomerates and reddish siltstones overlies the Mancos-Eagle Ford beds with pronounced erosional unconformity. No fossils, except for faint imprints of plant fragments, were seen, although a careful search was made. These beds were noted by Darton (1928, p 192), although his cross-section (pl 41-G) is inaccurate. A thin tongue of these conglomerates and redbeds occurs along the west edge of the Organ Mountains (Dunham, 1935, p 52) and at the south end, in Target Canyon. Similar reddish siltstones, with basal boulder conglomerate and many interbeds of silty gypsum, occur in the southern Robledo Mountains but are not present in the intervening Dona Ana Mountains.

The Love Ranch formation is here named for the exposures northwest of Love ranch, as herein described in Section L and illustrated in Figure 14, units L 173-182. Although only the basal 408 feet has been measured in detail, these exposures are typical of the formation. The formation may be as much as 2,100 feet thick, but beds above the measured section are more than half covered; as the formation is involved in thrust faulting, the total thickness is uncertain.

Lithology

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. The beds are about evenly divided between coarse conglomerates and reddish-brown siltstones; the conglomerates, however, appear to form the bulk of the formation, because they crop out as resistant ledges and cliffs, whereas the siltstones in many places are covered. Conglomerates are more numerous in the lower part of the formation.

The conglomerates consist of 50-90 percent pebbles, cobbles, and boulders, angular and tabular to subrounded, up to 2 feet long, of limestones, red and greenish-gray shales, sandstones, and siltstones. The fragments appear to have been derived by erosion of strata from the Eagle Ford formation down to the Hueco formation, in the Love ranch vicinity; on the west side of the Organ Mountains, the conglomerate beds at the base of the Love Ranch formation truncate steeply dipping Hueco and Pennsylvanian beds and are composed chiefly of cobbles and boulders of those rocks, along with a few fragments of Lower Paleozoic rocks. In the Organ Mountains area, the Love Ranch formation is overlain by rhyolitic to latitic tuffs that include pebbly sandstone lenses containing fragments of schist, quartzite, and granite, in addition to materials derived from Paleozoic strata. All the coarse clastic material appears to have been derived from nearby sources, suggesting initiation of the San Andres and Organ Mountains fault blocks as early as prevolcanic Tertiary time, perhaps Eocene-Oligocene but, more likely, early Miocene.

The matrix of the resistant conglomerates is greenish-gray calcareous sandstone or arenaceous calcarenite. Grains range from fine grained upward, are angular to subrounded, and are chiefly of calcite, fossil fragments, quartz, chert, and rock fragments, cemented by calcite. The beds are crossbedded to horizontal bedded, although their present dip ranges from 9 to 23 degrees, and are overturned in places.

The siltstones are calcareous to limy, reddish brown, and blocky, with medium-gray laminae and streaks, and scattered rounded grains, 0.2 mm, of frosted quartz. In thinsections the siltstones are seen to be about 60 percent angular quartz, calcite, and chert, with grains and cement of hematite, and scattered magnetite, tiny clay galls, and hematite-stained clay. Intercalated with the siltstones are lenses and beds of limy grayish-red, very dusky-red to greenish-gray coarse-grained, poorly-sorted crossbedded sandstone. There are a few scattered grains of feldspar, chiefly microcline, but many of the beds look arkosic on the outcrop because of the abundance of hematite-stained calcite "laths," which do not effervesce freely upon application of dilute HCI, partly because they are protected by a hematite film. As in all these clastic beds, the amount of calcite-limestone grains or fragments and calcite cement often was found to exceed 50 percent, and the rocks should be labeled calcarenites or calcirudites. There are two distinct types of grains: (1) angular to subrounded, first-generation detritus in which calcite or limestone and chert predominate; (2) rounded, second or later generation grains, chiefly quartz, with some of quartzite. A few striking grains of quartz were observed that have an inner angular core surrounded by a secondary growth rim which formed an almost euhedral crystal, whose crystal faces have been rounded by subsequent wear.

Thickness and Distribution

Outcrops of the Love Ranch formation are known in the foothills of the San Andres Mountains, northwest of Love ranch, along the west side of the Organ Mountains, between Fillmore and Baylor Canyons, and on the south end of the Organ Mountains, in Target Canyon. Somewhat similar rocks occur at the same stratigraphic horizon in the Robledo Mountains, in the southern Caballo Mountains, on San Diego Mountain, in the Rincon Hills, near Aleman, on the Cerro Colorado near Carthage, in the Godfrey Hills near Three Rivers, and near Carrizozo. The Love Ranch formation may be as much as 2,100 feet thick at the type locality near Love ranch but is only 100 feet and less in the Organ Mountains. Basal Tertiary conglomerates, red silty clay, and gypsum in the Robledo Mountains are about 300 feet thick; the Palm Park formation in the Caballo Mountains is about 900 feet thick; the Baca formation in the Cerro Colorado is 625 to 1,000 feet thick; and the Cub Mountain (?) formation in the Godfrey Hills is more than 150 feet thick.

Age and Correlations

No identifiable fossils were found in the Love Ranch formation, although faint imprints of plant fragments occur. In most places the basal beds are erosionally unconformable on underlying strata, which range from the Eagle Ford formation down to Pennsylvanian beds. This does not preclude, however, the possibility that the Love Ranch formation is of Upper Cretaceous age. Redbeds and associated coarse clastics in this stratigraphic position have been considered in most cases as early Tertiary in southern and central New Mexico, although fossil proof is scant or lacking.

The limestone conglomerates, red silty clays, and gypsum that occur at or below the base of the Tertiary (?) volcanic rocks in the Robledo Mountains unconformably overlie the Hueco formation but have yielded no fossils. Identifiable fossils have not been found in the Palm Park formation of the Caballo Mountains, in the redbeds near Aleman, nor in the prevolcanic clastics of the Cub Mountain formation near Three Rivers and Carrizozo. The Cub Mountain formation is conformable with underlying Mesaverde beds and is in part lithologically similar to the Mesaverde, and thus may be of Cretaceous age. An Eocene fossil was found (Gardner, 190, p 454) in the Baca formation near Carthage; Eocene-Oligocene fossils occur in the Galisteo formation (Stearns, 1943, p 0) in north central New Mexico; and Upper Cretaceous fossils have been collected from the lower part of the McRae formation near Elephant Butte reservoir.

The McRae beds have been described above; they differ from the Love Ranch, Baca (near Carthage), and Palm Park formations and the redbeds near Aleman and in the Robledo Mountains. The McRae beds are tightly cemented by silica and chloritic silt, whereas the Tertiary and Tertiary (?) redbeds, i.e., Baca, Palm Park, and Love Ranch formations, are cemented by calcite and hematite, are for the most part porous and friable, and show various shades of grayish red in contrast to the purplish and chocolate-brown siltstones and light-gray to olive sandstones of the McRae formation. Clastic grains to boulders of calcite and limestone are abundant in the Tertiary redbeds but are almost absent in the McRae strata. These lithological differences are due mainly, of course, to the difference in source rocks but may have significance in correlation. Quite likely these different units in the various areas were deposited as relatively local deposits in separated basins or near isolated mountain masses and were not contemporaneous. Perhaps, however, they fall into two penecontemporaneous groups: (1) McRae and Cub Mountain formations, of late Cretaceous age; (2) Love Ranch, Baca (near Carthage), and Palm Park formations, as well as the redbeds in the Robledo Mountains, on San Diego Mountain, in the Rincon Hills, and near Aleman, which may range in age from Eocene to early Miocene.

The Baca formation, as exposed on the west side of the Cerro Colorado, near Carthage, consists of intertongued grayish-red sandstones and moderate-red silty claystones and clayey siltstones. The sandstones are pebbly to conglomeratic, poorly sorted, friable, and medium to very coarse grained. The grains are angular to subangular, chiefly of clear and frosted quartz and calcite, with minor amounts of white chert, jasper, muscovite, biotite, some scattered clear prismatic plagioclase, and chlorite; many of the grains are angular sliver-like shards. Cement is calcite and hematite. Pebbles and cobbles are chiefly of Permian and Pennsylvanian limestones and sandstones, with some fragments of Precambrian schist, quartzite, and granite. Andesite pebbles are absent to rare but increase in amount upward in the formation and southward toward Little San Pasquel Mountain. A few lenses of pinkish to medium-gray andesitic tuff breccia occur in the lower part of the formation.

From outcrop distribution and sparse drilling data, the southward limit of the Baca formation appears to be near Little San Pasquel Mountain. Northward outcrops continue to the Joyita Hills, where the redbeds have been correlated by Wilpolt et al. (1946) with the type Baca formation on the west side of the Rio Grande Depression, west of the Ladron Mountains, a distance of about 3o miles from the Joyita Hills.

West and south of Aleman, where pediment gravels have been dissected on the west central side of the Jornada del Muerto, Mesaverde strata are overlain by about 6o feet of light-gray sandstones, tuffs, and andesite breccia-conglomerate, which may be credited to the McRae formation. Above is ca. 200-500 feet of in terlensing grayish-red poorly sorted sandstones and dusky-red clayey siltstones. Numerous andesite pebbles are scattered throughout the sandstones and silts. The sandstones are medium to coarse grained, the grains being angular to subangular and composed of clear and frosted quartz, calcite, limestone, white to gray chert, jasper, orange microcline feldspar, white plagioclase, muscovite, black biotite, magnetite, andesite, chlorite, small clay galls, and a few rounded grains of glauconite. As much as 4o percent of the matrix is calcite and hematite-stained silt; angular sliverlike grains are common.

The type Palm Park formation, on the southwest side of the Caballo Mountains, consists of: ( ) basal poorly sorted intertonguing boulder fanglomerates, coarse pebbly calcareous sandstones, and moderate-red siltstones; (2) medial gray to grayish-red purple latitic tuff; and (3) upper grayish-pink to grayish-red tuffaceous sandstones and siltstones, with a few beds of light-brown algal limestone. Pebbles, cobbles, and boulders in basal beds are chiefly Paleozoic and Precambrian rock types with lesser amounts of andesite in a calcareous matrix of light-gray to grayish-red sand or grayish-red silt. Southward, in Rincon Hills and on San Diego Mountain, the Palm Park redbeds contain more andesitic-latitic debris and are much more indurated and better sorted. The Palm Park formation at its type locality is probably very near its source; the basal beds are chiefly from underlying rocks, poorly sorted, and very coarse grained.

In the Rincon Hills and at San Diego Mountain only the upper beds of the Palm Park formation are exposed and consist of grayish red-purple volcanic sandstones and moderate-red claystones, with numerous lenses of pebble-conglomerates and beds of grayish-blue to grayish-purple andesitic and latitic tuffs. The sandstones are medium to very coarse grained; the grains are angular to subangular, their composition varying greatly from sandstones with a high percentage of clear, milky, and frosted quartz and of plagioclase feldspars to sandstones containing a predominance of plagioclase feldspars and andesite grains. Cement is of calcite, hematite, **and minor** clay and gypsum; there are minor amounts of chlorite, muscovite, biotite, sanidine, and magnetite.

The Palm Park and similar redbeds, such as those near Aleman, may not extend in subsurface very far west of the Rio Grande, do not crop out south of San Diego Mountain, and do not seem to be present north of Aleman, although the redbeds near Aleman probably underlie a considerable part of the Jornada del Muerto in the Point of Rocks area.

TERTIARY VOLCANIC ROCKS

Thick sections of Tertiary volcanic rocks occur in the Dona Ana, Robledo, and Organ Mountains and the Sierra de las Uvas southwest of the San Andres Mountains, at San Diego Mountain and Point of Rocks to the west, at Cerro Colorado to the northwest, and in the Sierra Blanca to the east, but only one area of outcrop, occupying about 1 square mile, occurs in the San Andres Mountains. Southwest of Quartzite Mountain, north of Organ, on the west edge of the range, the Orejon andesite of Dunham (1935, p 54) is faulted against the Hueco formation. The generalized volcanic sequence in the Dona Ana, Robledo, and Organ Mountains has been described by Kottlowski (1953, p 145) and Dunham ([1]935 pp 51-59) and compared to the volcanic sequence in south central New Mexico by Jahns, Kottlowski, and Kuellmer (1955, pp 92-95). There are three generalized units southwest of the San Andres Mountains: ( ) lower andesitic to latitic tuffs and breccias, and purplish welded rhyolite tuffs, which have been intruded by monzonitic masses, and which are about 2,800 feet in thickness in the Robledo and Dona Ana Mountains; (2) light-gray to pinkish arkosic, pumiceous, and tuffaceous sandstones interbedded with pumice, rhyolite, quartz latite tuffs, vitrophyre flows, and banded rhyolite flows and domes; these light-colored pyroclastics are about 1,600 feet thick in the Cerro Colorado near Carthage, about 1,55o feet thick near the Caballo Mountains, and more than 800 feet thick in the Sierra de las Uvas, Robledo, and Dona Ana Mountains; (3) basaltic-andesite, as much as 145 feet thick north of the Robledo Mountains, where it caps extensive areas of the Sierra de las Uvas, as well as at Point of Rocks and the Cerro Colorado.

There is probably not more than a few hundred feet of volcanic rocks in the subsurface of the Jornado del Muerto except near the Dona Ana Mountains, San Diego Mountain, Point of Rocks, Elephant Butte reservoir, and the Cerro Colorado. Tertiary volcanic rocks crop out on the northeast side of the Tularosa Valley only in the Godfrey Hills and Sierra Blanca; on the southwest flank, only in the Organ Mountains. They have been encountered in drillings only on the northeast side of the valley, although intrusive igneous rocks crop out in the Jarilla Mountains.

INTRUSIVE ROCKS

Three types of intrusive rocks, as far as has been observed, occur in the San Andres Mountains. Greenish-gray hornblende andesite sills and dikes were found intrusive chiefly into lower Pennsylvanian beds. In places the sills apparently pushed apart the sedimentary beds, causing a thickening of the section; in other places, such as Hembrillo Canyon (section H, unit 143), part of the sedimentary rocks appear to have been assimilated. The andesites (pl 5-B) are porphyritic, with sparse to abundant phenocrysts of zoned plagioclase and altered hornblende in a trachytic matrix of plagioclase laths and scattered magnetite cubes. Hornblende is mainly altered to magnetite, chlorite, and calcite; calcite is scattered throughout the rock as an alteration product and fillings. Phenocryst plagioclase averages Ab52, calcic andesine; groundmass plagioclase appears to be more sodic, ranging up to oligoclase.

Two extensive rhyolite sills occur, one capping Salinas Peak and adjoining ridges, the other capping Quartzite Peak, south of Love ranch. The sills exhibit columnar jointing and in places flow lines. Both are intruded into lower Pennsylvanian rocks. The microscopic mineral composition, determined by Ming-Shan Sun, of the Bureau staff, is 43 percent quartz, 49 percent orthoclase (including minor sodaclase), 6 percent muscovite, 1 percent magnetite, and I percent secondary calcite. Crystals range from 0.02 to 0.14 mm in long diameter. The rock is similar to the high-potassium rhyolites near Radium Springs, capping Lookout Peak in the Robledo Mountains, northwest of Las Cruces.

At the south tip of the San Andres Mountains, just north of the town of Organ, are outcrops of monzonite and quartz monzonite of the Organ Mountains batholith, which has been described by Dunham (1935, pp 6o-81).

SANTA FE GROUP

The reddish to buff calcareous sandstones and sands of the Santa Fe group, along with overlying recent alluvium, probably do not exceed 400 feet in thickness beneath the Jornada del Muerto surface west of the San Andres Mountains. The Santa Fe strata along the Rio Grande Valley in southern New Mexico, ranging from 1,025 to more than 1,990 feet thick, have been described briefly by Kottlowski (1953, pp 144-148; 1955, pp 88-91).

Sedimentary rocks resembling the Santa Fe group occur in the Tularosa Valley (east of the San Andres Mountains), where they are predominantly clays with large amounts of gypsum. The Cenozoic deposits thicken erratically southward; an oil test well drilled 6 miles northwest of Tularosa penetrated about 78o feet of clay and sand above the Yeso formation, whereas to the south, in the Hueco Basin (east of El Paso), 3,000-4,920 feet of relatively unconsolidated sediments was encountered in oil tests. Along the east side of the Tularosa Valley, crudely alined from the Jarilla Mountains to Tularosa Peak (fig 1; 8 miles slightly south of west from Tularosa), are scattered hills of Permian strata and Tertiary intrusives, near which the bolson fill is relatively thin, suggesting that these hills are upper peaks of a buried fault-block ridge. The age of the basin deposits is not established but, analogous to similar deposits along the Rio Grande Valley near El Paso and northward, most of the beds in the Tularosa Valley may be of later Pliocene and Pleistocene age.

QUATERNARY ROCKS

Alluvium, ranging from silt to boulder gravel, occurs in all the canyon bottoms in the San Andres Mountains. In places, such as in Rhodes Canyon, several periods of cut-and-fill are evidenced by paired and nonpaired terraces along canyon walls. Rock-protected terraces occur along the southwest margin of the range, near Love ranch, behind (east of) cuestas of San Andres limestones, Dakota (?) sandstone, and Love Ranch conglomerates. The amount of alluvium within the range is insignificant, but in the bordering basins a considerable part of the upper relatively unconsolidated sediments may be of Quaternary age. Probably not more than 400 feet of such bolson deposits occurs in the Jornada del Muerto, but thicknesses may be greater in adjoining parts of the Tularosa Valley.

JORNADA BASALT FLOW

Basaltic rocks were not seen within the San Andres Mountains but cover two large areas in the adjoining basins, one as a long, sinuous flow on the northeast side of the Tularosa Valley, the other as a rectangular blanket on the northwest side of the Jornada del Muerto. The flow in the Tularosa Valley, the Carrizozo malpais, has been described by Allen (1951, pp 9-11). It is about 44 miles long, 1-5 miles wide, and has an area of about 127 square miles; thicknesses range from 25 to 70 feet, and the volume is about one cubic mile. The flow is barren, fresh, and uneroded, and is believed to have been extruded within the last thousand years from the single crater near its north upper end.

The Jornada basalt flow occupies a rectangular-shaped area, about 20 miles from east to west and II miles from north to south, and was extruded almost equally in all directions from its central cone. On the west edge, however, the lava spilled over the west rim of the Jornada del Muerto and flowed down into the Rio Grande Valley, where the basalt now crops out with its base slightly below the level of the present flood plain. On this west edge (the east slope of the Rio Grande Valley) the basalt has been almost drowned by Recent sand, blown up from the sand flats of the Rio Grande by the prevailing westerly winds. The lava, therefore, has been extruded in relatively recent times, although it appears slightly older than the Carrizozo malpais.

The surface area covered by the Jornada basalt is about 168 square miles, including parts hidden by a thin sheet of windblown sand and clay. Most of the basalt is from 5o to 100 feet thick; the volume is about 2.54 cubic miles.

In thinsection (pl 5-A) the vesicular basalt is seen to have an intersertal to hyalopilitic texture of euhedral to subhedral olivine crystals and plagioclase laths in a matrix of brownish-black glass. Olivine and plagioclase crystals vary greatly in size from 1 mm to microlites; in places the olivine forms clustered clots. Rims and fractured parts of olivine crystals are altered to reddish-brown iddingsite; cubes of magnetite are common in and near the olivine. Plagioclase appears to be sodic labradorite about An 55. The glassy matrix has a refractive index lower than balsam and probably approaches palagonite. Calcite and zeolites occur on rims of the cavities. The irregular distribution of the two chief minerals and the glassy matrix make a Rosiwal analysis speculative, but the approximate composition is: olivine, 14-20 percent; labradorite, 49-43 percent; magnetite, 2 percent; palagonite and microlites, 41-35 percent. The percentage of calcite and zeolites is not included as they are secondary minerals filling cavities and not replacing the primary minerals. A few scattered grains of ilmenite and apatite occur; some of the microlites may be pigeonite.

Structure

As the purpose of this report is the description and interpretation of the stratigraphic succession revealed by three intensively studied sections in the San Andres Mountains, no attempt has been made to delineate or explain the geologic structure. Determination of the structure must await the detailed geologic mapping of this region. In order that the sections might be measured correctly, faults were carefully noted but were not necessarily followed throughout their length, as would be true in a standard mapping project. A brief review of the regional structure is given, however, to provide background for the interpretation of stratigraphy.

In general, the San Andres Mountains may be considered as the westward dipping limb of a broadly anticlinal structure whose axis follows the Tularosa Valley, converging in Mockingbird Gap between the San Andres Mountains and the eastward dipping rocks of the Oscura Mountains. The main eastward dipping limb of this structure is the Sacramento Mountains and the long, gentle slope into the Pecos River Valley. The sedimentary rocks of the San Andres Mountains dip westward beneath the younger rocks and valley fill of the broadly synclinal Jornada del Muerto. The Tularosa Valley can be interpreted as a depressed or collapsed crest of the anticlinal structure between two major fault zones which follow the margins of the valley at either side. These marginal fault zones are still active, as evidenced by the Recent fault scarps in alluvium along their course. As most of the valley is covered by recent accumulations of detritus, the complexity of the fault pattern in the valley can be only surmised.

As might be expected, the San Andres Mountains were not uplifted evenly throughout, so that there are sags and corresponding points of major uplift. The range is cut also by faults whose throw amounts to several hundred feet at one or more points on their strike, and whose trend may be either parallel or oblique to that of the frontal fault zone. The throw on the frontal fault zone, by contrast, doubtless amounts to thousands of feet.

Considered as a unit, the San Andres Mountains is an elongate tilted fault block, uplifted vertically 1-2 miles along an east-bounding fault zone, with the tilted beds dipping 10-20° W. The relatively minor transverse, oblique, and longitudinal normal faults show displacements ranging from 100-700 feet; drag folding of shaly or thin beds along the minor faults occurs at many places. Several small tilted fault blocks occur east of the main east-bounding fault zone; for example, the Henderson ranch fault block at the mouth of Rhodes Canyon is a miniature San Andres range, a westward tilted fault block with steep east-bounding fault-line scarp; on the west side Virgilian limestones are down-faulted against El Paso dolomites of the main-range fault block. At the northern and southern ends of the range some of these smaller eastern frontal blocks are tilted eastward, which suggested to Darton (1928, p 193) that the San Andres Mountains are an anticlinal uplift faulted extensively along their east side.

The main east frontal fault zone trends slightly west of north from Ash Canyon to Rhodes Canyon. North of Rhodes Canyon the fault zone is offset to the east by oblique faults, and trends northeast to Sheep Mountain, where the trend is again west of north. The northeastward curve in the range, and resulting bulge from Rhodes Pass to Salinas Peak, is due to a series of north-northwest oblique normal faults, and perhaps in part to the location of the Salinas Peak rhyolite sill or laccolith. The eastward bulge near Bear Canyon, in the southern part of the range, resembles parts of a faulted anticline but may be in part a reflection of the Organ Mountains monzonite batholith. The Bliss-Precambrian contact is topographically low near Rhodes Canyon, west of the main eastern fault zone, and rises both to the northeast and south-southeast, indicating a structural sag in the Rhodes Canyon area.

The general north-south trend of the San Andres Mountains continues southward in the Organ and Franklin Mountains, although obscured and modified by the Organ Mountains monzonite batholith. The range is terminated at Mockingbird Gap by an oblique structural trend, which probably angles across the northern part of the Tularosa Valley from the northern part of the Sacramento Mountains, or may be a continuation of the buried fault-block ridge which is evidenced by the string of hills from Tularosa Peak to the Jarilla Mountains. At Mockingbird Gap the northern tip of the San Andres Mountains forms the west dipping limb of a faulted anticline of which the Oscura Mountains and their frontal hills are the east dipping limb.

There has been relatively recent movement along the frontal fault of the San Andres-Organ-Franklin Mountains chain, as noted by Reiche (1938,PP 44o-444). This recent faulting is expressed by a pronounced irregular zone of fault scarps that cut alluvial fans along the east side of the ranges at distances up to 2 miles east of bedrock outcrops. Most of the fault scarps trend nearly north-south but are offset in en echelon patterns. Some of the scarps are relatively unmodified; others have been cut by gullies and reduced by sheet-wash erosion. Observed scarps range from 14 to 65 feet high, although others seen on aerial photographs and topographic maps are up to zoo feet high. In several places, on narrow remnants of alluvial fans between deep arroyos, there are series of low parallel scarps, 4-15 feet high, downstepped toward the Tularosa Valley. In deeply cut arroyos that transect the fault scarps there are in places cut banks which expose the faults, which in most cases are as much as 3o feet downslope from their gently rounded scarp. The upthrown side in most observed outcrops has a thin brownish soil cap, on which desert pavement is developed. Below the soil is fanglomerate whose top several inches is leached irregularly, with the basal part being cemented by caliche; the fanglomerate lies erosionally unconformably on laminated fine-grained sands and silts, which contain scattered pebbles, as well as galls and lenses of reddish-brown clay, and resemble shallow-stream and mud-flat deposits. The eastward downdropped side is in most places partly calichified boulder and silt fanglomerate, not bedded or sorted, capped by brownish silt and sand apparently washed down from the upthrown block.

Dunham (1935, p 142) reported a high-angle thrust fault near San Augustin Pass, by which the Precambrian granite was thrust over lower Pennsylvanian rocks. In places, such as west of Salinas Peak, the oblique normal faults are twisted for short distances to become high-angle reverse faults. In the Love ranch area a sharp north trending anticline occurs along the west flank of the range in Hueco limestones, is locally overturned, and is broken by a high-angle reverse fault. Also, just south of Love ranch, an eastward ridge of steeply dipping Dakota (?) sandstone overlies the Eagle Ford beds, which in turn rest on the Love Ranch conglomerates. Cross-bedding in the Dakota (?) sandstone is upside down. These rocks are in a small rotated fault block. Nearby are hills composed almost entirely of Love Ranch conglomerates and red-beds; capping several of the higher peaks, however, are klippen of marbleized fossiliferous Hueco limestone. This thrusting is post-Love Ranch formation; if the Love Ranch formation is of early Tertiary age, the thrusting is early Tertiary or younger.

The Jornada del Muerto is, in broad terms, an asymmetrical syncline, with the deepest part on the west side and with a southward plunge. From east to west the number of small and large faults increases, although this may be due to lack of knowledge of the bedrock on the east side of the syncline, which is in most places covered by alluvial fans that slope gently westward from the San Andres Mountains. In the area north of Rhodes Pass, where the west edge of the San Andres Mountains turns from its north-northwest trend to a ragged northeast line, there are many faults with north to northwest strike that extend into the Jornada, where they are hidden by the alluvial fans. A few miles east of the two Sun Oil Co. oil tests (Victoria Land & Cattle Co., Nos I, 2; see fig 1, nos I and 2) there are pedimented outcrops of San Andres limestones that occur at elevations of 1,300-1,500 feet higher than the San Andres formation in the oil tests. Although this difference in elevation could be due to northwestward dip of the San Andres limestones, the dip of the outcropping beds is southwest, suggesting a fault zone with north-northwest strike between the outcrops and the oil tests. If extended north-northwest, this suggested concealed fault would pass under the crater of the Jornada basalt flow and would join the fault that is the south boundary of the Little San Pasquel Mountain fault block.

Interpretation of Stratigraphic Sequences

Precambrian rocks record a long and diversified history, on which we can but speculate from the scattered outcrops seen. The amphibolites, phyllites, talc argillites, and other metamorphic rocks in the Hembrillo Canyon area were deposited originally as sediments and volcanic rocks, metamorphosed, intruded by two types of granite, tilted to almost vertical, cut by numerous strike dip-slip faults, truncated by erosion, and buried beneath quartzose sands during the late Precambrian or possibly Cambrian time. Three generalized types of intrusive granites appear to be younger than the metamorphosed sequence in the center of the San Andres Mountains but contain inclusions and roof-pendants of several types of schists that are of higher metamorphic "grade" than those near Hembrillo Canyon.

Precambrian rocks are truncated by a remarkably even erosional surface, which shows in most places only a few inches of relief. Relatively unweathered fragments of Precambrian rocks and minerals derived therefrom occur in the Bliss sandstone. The hematitic glauconitic calcareous to siliceous sands of the Bliss sandstone contain marine faunas and were deposited on shelf areas over a relatively long period of time, with irregular periods of nondeposition. In places in south central New Mexico this deposition of sandy beds began in middle Croixian, upper Franconian time; in other areas, in earliest Ordovician time. Gradation is almost complete from the elastic beds of the Bliss up into the marine limestones of the El Paso group. Thin-bedded calcarenites, laminae of quartz silt, reefs, oolitic beds, and massive aphanitic limestones are typical of El Paso deposition, which took place throughout Canadian time. Flower (1955, p 67) believes that the El Paso group, when deposited, was in continuity with the Ellenburger limestone of Texas, the Manitou limestone of Colorado, and the Garden City beds of Utah. The El Paso group thins northward from its maximum thickness at El Paso; successively lower beds have been removed northward by post-El Paso erosion, which in the San Andres Mountains was chiefly pre-Montoya, but northward was pre-Onate. Development of a karst topography on upper beds of the El Paso group is evidenced by masses of collapse breccia, which include blocks from the overlying Cable Canyon sandstone.

The basal member of the Montoya group, the Cable Canyon sandstone, has been interpreted as a separate elastic phase of Trenton deposition or as a basal sandy phase of the Upham dolomite. The sandstone was deposited upon a surface bared to erosion during Chazyan and Black River time and appears to thicken southward in the San Andres Mountains, although thin or absent in the Robledo and Franklin Mountains. The source of the quartz sands, however, was probably from the north. Except where removed by pre-Onate erosion, at the north end of the range, the massive coralline and crinoidal Upham dolomite and cherty Aleman dolomite vary erratically in thickness in the San Andres Mountains. The Upham is of upper Trenton age, the Aleman of Richmond age; separating the two dolomites should be a hiatus representing Covington time. As Flower (1953, p 68) has noted, however, the correlation is complex and is tied into the interplay of boreal and austral faunas whose correlative elements have not as yet been determined adequately. The Cutter dolomite is late Richmond in age and includes clayey and silty lenses; it is overlain disconformably by Fusselman dolomite, but in the San Andres Mountains is relatively uniform in thickness as far north as Sulphur Canyon; northward the Cutter dolomite is thinned by pre-Onate erosion.

The Fusselman dolomite apparently was deposited chiefly in Middle Silurian (Niagaran) time, with early Silurian (Alexandrian) time represented only by local deposits, such as noted by Pray (1953, p 1913) in the Sacramento Mountains. Dolomitization of the beds and accompanying obliteration of fossils complicate the problem of age determinations. Upper Silurian (Cayugan), Early Devonian, and early Middle Devonian times were periods of erosion or nondeposition in this area, so that the uppermost Middle Devonian Onate formation bevels all earlier rock units from south to north. The Fusselman dolomite, for example, is about 84o feet thick in the southern Franklin Mountains, more than 210 feet thick in the Organ Mountains, about 95 feet thick in Ash Canyon, and 61 feet thick in Hembrillo Canyon, and has been removed completely by erosion about 6 miles south of Rhodes Canyon.

As has been noted by many geologists, deposits of Upper Devonian time in south central New Mexico contrast with older sediments, in that they change from predominant carbonate deposits to those of calcareous siltstones, shales, argillaceous limestones, and some silty sandstones. In southeastern New Mexico, however, Lower Devonian limestones and dolomites occur and are overlain by Middle (?) and Upper Devonian shales called Woodford or Percha. The Devonian rocks exposed in the San Andres Mountains appear to be a relatively thin transgressive blanket deposited on a shelf area east and northeast of the Lea County area that was a marine basin in earlier Devonian time. The Upper Devonian facies formations thin to the north in the range because of pre-Lake Valley erosion.

Northern New Mexico is pictured on most paleogeographic maps as a positive area undergoing erosion during most of pre-Pennsylvanian time. Little or no evidence of shoreward facies to the north has been found in pre-Devonian rocks. Along the chain of ranges from the Franklin to the Oscura Mountains there is a northward thinning of the Bliss sandstone and the El Paso group, the latter thinning being due to pre-Montoya erosion; it is perhaps significant that the basal Montoya group unit is clean dolomitic quartz sand resting on successively older beds northward. The Montoya group dolomites and Fusselman dolomite thin northward only because of pre-Onate erosion, and again the Onate formation rests on successively older beds northward. This surface of erosional unconformity is second in prominence only to the pre-Lower Pennsylvanian surface; the top of beds underlying the Onate is an undulating, knobby, ridged, and channeled surface coated in most places by ferruginous silica.

In north central New Mexico scattered remnants of Mississippian sediments rest on Precambrian rocks and are unconformably overlain by Pennsylvanian strata (Armstrong, 1955). Pre-Mississippian post-Precambrian sedimentary rocks are not reported in that area, although they may have been deposited and later removed by erosion during late Silurian and/or early Devonian time. Quite likely, north central New Mexico was a low positive area during the deposition of Upper Devonian beds in the San Andres Mountains, as the Devonian units are somewhat more elastic northward in the range.

Early Mississippian (Kinderhookian) rocks are shaly limestones and marls apparently deposited in a shallow basin, or basins, extending from the Ladron Mountains (8o miles north-northwest of Mockingbird Gap) southeastward to the Sacramento Mountains and to Lea County, and south from the Ladron Mountains to Lake Valley (65 miles west of Ash Canyon). These Kinderhookian strata, called the Caballero formation in southern New Mexico, and Caloso formation (Kelley and Silver, 1952, p 86; Armstrong, 1955, p 32) in the Ladron Mountains, are relatively conformable on underlying Devonian beds but have been left, after pre-Lake Valley erosion, as continuous outcrops only in the southern San Andres and Sacramento Mountains. Rocks of Early Middle Mississippian (Osage) age were deposited in an irregular belt across southern New Mexico, with the northernmost eroded edge in the Ladron Mountains. They rest unconformably on underlying strata and in the San Andres Mountains thin northward and southward from the thick sections in Ash and San Andres Canyons. Jones (1953, p 19) has suggested that the southward thinning is a thinning of the Lake Valley crinoidal limestone facies, and that perhaps the Lake Valley grades southward into the Rancheria and Las Cruces black argillaceous limestone facies.

Rocks of Late Middle Mississippian (Meramec) age were probably deposited in two areas of New Mexico, north central (Armstrong, 1955) and southeastern. Lloyd (1949, p 43) has indicated that the northern boundary of Rancheria strata, subsurface and outcrop, begins at the southeast corner of Curry County and extends southwestward to Ash Canyon. The northern boundary of Late Mississippian (Chester) rocks, the Helms formation in southeastern New Mexico, is not far south of that drawn for the Rancheria formation. Most of New Mexico appears to have been subjected to erosion during late Mississippian and early Pennsylvanian time.

Pennsylvanian beds overlie Mississippian strata with irregular and, in places, deep erosional unconformity throughout the San Andres Mountains, but in the southern Oscura Mountains the basal Pennsylvanian elastics abruptly truncate Mississippian and Devonian strata, intersect the erosional planes at the bases of those two systems, and rest on Precambrian rocks. Early Pennsylvanian, Morrowan (?), rocks occur chiefly to the south, in the Hueco and Franklin Mountains, where they rest on late Mississippian (Chester) strata and thin northward. Thicknesses and distribution of Middle and Upper Pennsylvanian rocks indicate considerable variance in deposition and erosion and/or nondeposition, with the principal positive areas being the Pedernal to the east, the Zuni to the northwest, and the Florida to the southwest. During Virgilian time the Panther Seep beds—dark calcilutites, silty calcareous sandstones, and gypsum—were deposited in a north-south basin that occupied about the same area as the present San Andres Mountains and western parts of the Tularosa Valley.

Early Wolfcampian time was an era chiefly of erosion in southern New Mexico and westernmost Texas, where the basal Powwow conglomerate of the Middle Wolfcampian Hueco formation truncates rocks from Ordovician to early Wolfcampian in age. In places, such as the Robledo Mountains, uppermost Pennsylvanian Virgilian beds extend without apparent break into Lower Wolfcampian Bursum strata; northward, in the San Andres Mountains, Bursum beds contain more carbonate than is true of the type Bursum of the Oscura Mountains, which is a sequence of interbedded redbeds and limestones. Northwestward from the Hueco Mountains the Hueco limestone is a northward thinning lower limestone wedge intertonguing with an upper northward thickening Abo redbed wedge; to the west, in the Robledo Mountains, the redbeds extend as a medial tongue in the Hueco; to the east, in the Sacramento Mountains, the Hueco limestones are a medial northward pinching-out limestone tongue within Abo redbeds. These outcrops indicate a complex land-sea relation during Wolfcampian time, and probably during early Leonardian time also, although younger Hueco-Abo deposits are predominantly continental to the north and marine to the south.

The bulk of Leonardian deposits are those of the Yeso and San Andres formations, although most of the San Andres formation in the Guadalupe Mountains area to the southeast has been considered as Guadalupian by many geologists. Yeso beds record northward advancement of shallow lagoonal marine waters from the marine basins that existed to the south during Wolfcampian time, and that were continued in Leonardian time as shown by the deposition of the Bone Springs formation in the Delaware and Marfa Basins. The pinkish fine-grained sands of the Yeso formation contrast with the reddish conglomerates, sandstones, and siltstones of the Abo redbeds and probably were deposited on level low plains, over which marine waters spread at frequent intervals to deposit the gypsum and silty limestones of the Yeso formation. Outcrops of the Yeso formation near Love ranch, in the southwestern San Andres Mountains, are the southwesternmost known outcrops of the Yeso formation in New Mexico. The western limit of Yeso outcrops projects northwestward from Love ranch to the southern Caballo Mountains and then to the Sierra Cuchillo, before being concealed beneath the Cenozoic volcanics of the Mogollon region. This line is also the western boundary of known San Andres formation outcrops in this latitude. Kuellmer reports (personal communication) that Cretaceous (?) black shales rest on Abo redbeds in the Black Range near Kingston. The Sarten sandstone overlies the Abo-Lobo redbeds at Cooks Peak (Jicha, 1954, p z6), and the Tertiary volcanics overlie the Hueco formation in the Robledo, Organ, and Franklin Mountains. Redbeds in the Florida Mountains, interbedded with the Hueco formation, are probably tongues of Abo redbeds.

Southeast from Love ranch Yeso outcrops occur in the northern part of the Hueco Mountains; in Texas, east of the Hueco Mountains, they grade into beds attributed to the Bone Springs formation. West of this northwest trending line, from the northern Hueco Mountains to the Sierra Cuchillo, the absence of Yeso and San Andres formations appears partly due to subsequent erosion and partly to thinning of these units to the southwest. In the Big Hatchet Mountains, however, Robert Zeller reports (personal communication) about 5,25o feet of Permian rocks, with the lower 1,75o feet of basal limestone overlain by brown siltstone and shale (Abo equivalent ?), and the upper 3,500 feet of limestone, dolomite, gypsum, and cherty limestone capped by dolomite. These upper beds may be in part Yeso and San Andres formations equivalents.

If any of the San Andres formation in the San Andres Mountains is Guadalupian in age, it represents the last recorded Paleozoic sea of the south central New Mexico area. Jurassic rocks are absent in this area, and Triassic rocks occur only at the north end of the range. Early Mesozoic sediments probably were not deposited in much of this area, which at that time was mostly a low landmass subject to erosion. Lower Cretaceous seas from the south advanced northward onto a landmass believed (Eardley, 1951, pl 15) to extend from northwest to southeast across New Mexico. The shoreline of this early Cretaceous sea crossed the present San Andres Mountains not far north of Ash Canyon; relationships of transgressive overlap between El Paso and Love ranch are probably similar to those shown by Adkins (1932, p 292) for the region from the Cornudas Mountains to Quitman Gap, in Texas, where the Lower Cretaceous section thins greatly northward, successively younger Cretaceous beds overlap Permian strata, and a basal sandy facies is progressively younger to the north. Dakota-Woodbine sandstones were probably once present over most of New Mexico; the sandstone called Dakota (?) in the southern San Andres Mountains grades up into near shore marine sandstones and carbonaceous shales of the Eagle Ford formation, an interbedding of the black-shale facies and "flag" facies of that formation. Eagle Ford equivalents are lacking eastward in southeast New Mexico and the west Texas plains country; northward they grade into the Mancos shale, and northwestward into the Colorado shale of the Cooks Peak and Silver City areas. Upper sandy beds of the Colorado formation near Silver City may be equivalents of the Mesaverde formation, which in south central New Mexico is not known to crop out south of the east central Caballo Mountains.

The McRae formation apparently has a limited extent—between Engle and Elephant Butte, and perhaps Io miles north and 10 miles south. Much of the coarse debris in the McRae formation, other than volcanic fragments, was derived from Precambrian rocks. East of the McRae outcrops Precambrian igneous and metamorphic rocks are beneath thick piles of Paleozoic sedimentary rocks, except in the structurally high areas of the present-day mountain ranges. The source of the McRae quartzite, granite, and quartzose schist cobbles was most likely from the west, probably from uplifts parallel to the Rio Grande structural trend. The presence of Precambrian debris suggests initiation of block faulting in latest Cretaceous or early Tertiary time. The present distribution of outcrops in the ranges west of the Caballo Mountains, in the Black Range, Animas Hills, and Sierra Cuchillo, suggests that this westward source upland of the McRae formation was confined to a narrow north-south belt near the west edge of the present Rio Grande Valley, centering perhaps near the Mud Springs Mountains. As a relatively large amount of vertical uplift would be needed, block faulting is suggested, but Laramide thrusting could have produced the same effect. Most of the coarse quartzite conglomerate beds of the McRae formation are in the lower part of the Hall Lake member and are below beds dated as uppermost Cretaceous on the basis of *Triceratops*. Beds that appear to be even higher in the formation are involved in thrusting in the southern part of the Fra Cristobal Mountains; this thrust faulting is similar to that dated as Laramide by Kelley and Silver (1952, p 136). Perhaps original deformation was by overturning and thrusting, followed closely by block faulting.

The Cenozoic period in the vicinity of the San Andres Mountains was a time characterized by block faulting, volcanic activity, intrusion and mineralization, and subaerial erosion and deposition. The major Basin and Range block faulting may have begun in Eocene time, as suggested by the occurrence of Eocene fossils in the Baca formation, near the north end of the Jornada del Muerto, and by the nature of deposits in the Love Ranch formation. Continuation of block-fault movements into the Recent is indicated by the numerous fan scarps that occur at the base of the fault-block mountains, such as the San Andres, Organ, and Caballo Mountains. Erosion of the ranges uplifted throughout Cenozoic time was recorded by the deposition of the various Cenozoic sequences that have been described from south central New Mexico, of which the Love Ranch formation is fairly typical.

Interpretation of Significant Oil Tests in the Region

To aid exploration for petroleum in the surrounding basin areas, the records of significant and pertinent oil tests on file with the New Mexico Bureau of Mines and Mineral Resources are summarized and interpreted in comparison with the detailed information on the stratigraphic succession in the San Andres Mountains. Descriptions are provided for 21 test wells, 16 of which are located on the regional index map, Figure 1. Data are summarized in Table 6.

The Standard Oil Co. of Texas, Heard No. 1 Federal (Lincoln County, sec. 33, T. 6 S., R. 9 E.), was drilled about 3o miles northeast of Mockingbird Gap, on the Carrizozo Dome, to a depth of 8,050 feet. Formations penetrated, from top to bottom, are: (1) lower 70 feet of San Andres formation; (2) 145 feet of Glorieta sandstone; (3) 4,255 feet (!) of Yeso formation, including many halite beds; (4) 1,410 feet of Abo redbeds; (5) 135 feet of Powwow arkosic beds, with Hueco-like brachiopods; (6) 395 feet of Bursum formation; (7) 1,350 feet of Pennsylvanian strata; (8) 290 feet of Precambrian diorite and gneiss. The basal 1,745 feet of the sedimentary section has been called Pennsylvanian by most geologists, with the "Powwow" equivalent included in the Abo redbeds. The Pennsylvanian sequence is unusual by reason of the numerous redbeds and arkosic sandstones that occur; these indicate the nearness of the deposits to the Pedernal landmass.

Sun Oil Co., Victorio Land & Cattle Co. No. 1 (Sierra County, sec. 33, T. 1 0 S., R. 1 W.; table 6, fig 1, no. 1), was drilled on the basis of seismic data near the axis of the Jornada del Muerto (about 17 miles northwest of Rhodes Pass), to a depth of 6,053 feet. Formations penetrated, from top to bottom, are: (1) valley fill, 100 feet; (2) Mesaverde-Mancos beds, 610 or 910 feet; (3) Dakota (?) sandstone, 35o or 5o feet; (4) Dockum redbeds, 180 feet; (5) San Andres formation, 65o feet; (6) Glorieta sandstone, 5o feet; (7) Yeso formation, 1,230 feet; (8) Abo redbeds, 705 feet; (9) Pennsylvanian strata, 1,815 feet; (10) Montoya group, 110 feet, including 3o feet of basal Cable Canyon sandstone; (1 1) El Paso group, 130 feet; (12) Bliss sandstone, 7o feet; (is) Precambrian granite, 53 feet. The test was completed as a water well for the Victorio Land & Cattle Co., the water horizons being at a depth of 1,000 feet, in the Dakota (?) sandstone, and 1,318 feet, in the upper part of the San Andres formation.

Cuttings are available from depths of 710-6,05o feet; no break was seen on the gamma-ray log to separate the Mesaverde sandstones from Mancos shales. Between depths of 710 and 1,oro feet are interbedded dark-gray shale and gray pyritiferous sandstone, with lower thin dark-gray limestone, reddish arenaceous shale, and light-gray to red sandstone. This sequence, at least the lower part, appears similar to outcrops mapped as Dakota (?) sandstone in nearby mountain ranges, but the overlying Mancos shale contains similar sandstone and limestone beds, as mapped in the Cerro Colorado, near the north end of the Jornada del Muerto. The basal 50 feet of the Dakota (?) sandstone is typical light-gray siliceous sandstone. The underlying redbed sequence attributed to the Triassic Dockum formation consists of an upper 120 feet of dark-red claystone, moderate-red fine-grained sandstone, and pale-red siltstone, with some pale-green lenses. Basal 6o feet is light-gray sandstone, consisting of rounded and frosted quartz grains, with thin interbeds of dark-red silty sandstone and siltstone; this lower interval may represent the Santa Rosa sandstone. The San Andres formation is medium- to dark-gray and brownish-gray aphanitic to fine-crystalline limestone, with minor chert; there are a few thin beds of calcareous siltstone in the upper part and several thick beds of light-gray sandstone in the basal 3o feet. The Glorieta sandstone, 5o feet thick, is light-gray very fine- to medium-grained pyritiferous sandstone, with subrounded to well-rounded quartz grains.

The Yeso formation is about 1,230 feet thick and can be subdivided into the members recognized in the San Andres and Oscura Mountains. The upper Joyita member is pale-red very fine-grained sandstone, with a few thin beds of gypsum, 140 feet thick. The Canas gypsum member is about 23o feet thick and consists of an upper 45 feet of interbedded dark-gray arenaceous limestone and white gypsum, and a lower 185 feet of white to dark-gray mottled gypsum, with a few thin beds of dark-gray arenaceous limestone. The Torres member is 470-57o feet thick, depending on where the base is picked, and consists of medium- to dark-gray arenaceous to argillaceous limestone, white to dark-gray gypsum, and some beds of pale reddish-brown to brownish-gray sandstone. The basal Meseta Blanca member is 290 or 390 feet thick and consists of pale reddish-brown, pale-red, and light-gray very fine- to fine-grained sandstone, with a few thin lenses of light-gray gypsum and dark-gray arenaceous limestone near the top. Abo redbeds are 705 feet thick, with an upper 56o feet of dark-red shale and siltstone and thin lenses of moderate reddish-brown siltstone and arenaceous limestone; then 4o feet of interbedded pale-red to light-gray silty sandstone and light-gray aphanitic arenaceous limestone, underlain by 6o feet of dark-red silty shale and argillaceous siltstone, with thin lenses of limestone pebble-conglomerate. The basal 85 feet is grayish-red to medium-gray, silty to medium-grained micaceous sandstone, with a few thin beds of silty shale.

Pennsylvanian sedimentary rocks are 1,815 feet thick, although some of the upper beds may be referable to the Hueco or Bursum formations. There is, however, little indication of interbedded redbeds and limestones such as are typical of the type Bursum formation or the upper Hueco formation at Rhodes Pass. Probable Virgilian equivalents are about 1,005 feet thick, as follows in descending order: (1) 105 feet of gray to dark-gray arenaceous limestone; (2) 210 feet of light-to dark-gray aphanitic limestone; (3) 5o feet of dark-gray silty shale; (4) 3o feet of light- to medium-gray aphanitic limestone; (5) 3o feet of light-gray medium-grained arkosic micaceous sandstone; (6) 25o feet of interbedded light- to dark-gray arenaceous limestones and calcareous shales; (7) 240

TABLE 6. SIGNIFICANT OIL TESTS IN THE REGION

No. on index map	Name of well	Location	Date	Total depth (feet)	Surface formation	Bottom formation	Remarks
Off map	Standard Oil Co. of Texas, No. 1 J. F. Heard	Lincoln County; 1,980′ NL, 1,980′ WL, sec. 33, T. 6 S., R. 9 E.	1951	8,050	San Andres	Precambrian	Drilled on surface structure
1	Sun Oil Co. No. 1 Victorio Land & Cattle Co.	Sierra County; 660′ SL, 1,980′ WL, sec. 25, T. 10 S., R. 1 W.	1952	6,053	Mancos ? below alluvium	Precambrian	Water in Dakota and San Andres
2	Sun Oil Co., No. 2 Victorio Land & Cattle Co.	Sierra County; 1,980′ NL, 660′ EL, sec. 27, T. 10 S., R. 1 W.	1952	6,352	McRae ? below alluvium	Precambrian	Water in Dakota and San Andres
3	Thomas J. Gartland, No. 1 Maggie Brister; formerly Drew-Matthews	Sierra County; 2,010′ SL, 1,988′ EL, sec. 8, T. 12 S., R. 4 W.	1955	8,585	Santa Fe below gravels	Precambrian	25°-60° dips, faults, sill
Not plotted	Thomas J. Gartland, No. 1 Garner Federal	Sierra County; 660′ SL, 1,980′ EL, sec. 11, T. 12 S., R. 5 W.	1950	6,524	Santa Fe below gravels	Volcanic rocks and sediments	Shows of gas reported
4	Summit Exploration, No. 1A Mims; formerly J. H. Blackstone	Sierra County; 1,980′ SL, 660′ WL, sec. 2, T. 13 S., R. 4 W.	1954	6,195	Gravels and Santa Fe group	Pennsylvanian	1,986 feet of Cenozoic rocks
5	Tularosa Basin Oil Co., No. 2 Belmont	Otero County; sec. 34 (?), T. 13 S., R. 7 E.	1926	3,965	Yeso below valley fill	Lower Permian or upper Pennsylvanian	Data uncertain
6	McCall Drilling Co., No. 1 Park Bowers	Sierra County; NE¼ sec. 19, T. 14 S., R. 2 W.	1927	1,540 or 2,910	Mesaverde	Permian ?	Data uncertain
7	McCall Drilling Co., No. 2 Park Bowers	Sierra County; sec. 32, T. 14 S., R. 2 W.	1931 ?	2,900 ?	Mesaverde	Permian ?	Data uncertain
Not plotted	Barney Iorio, No. 1 Fee	Sierra County; N½NW¼SE¼ sec. 25, T. 14 S., R. 5 W.	1941	2,100	Santa Fe group	Thurman	Hot mineral water
8	F. W. Carr, No. 1 Gentry State	Sierra County; 640′ NL, 1,620′ EL, sec. 32, T. 15 S., R. 3 W.	1953	5,418	Pennsylvanian	Pennsylvanian ?	Steep dips, faults
9	Western Drilling Co., No. 2 Guame Federal	Now Sierra County; 1,855′ SL, 2,385′ EL, sec. 21, T. 16 S., R. 2 E.	1953	3,507	Mesaverde ?	Abo	
10	Bruton Development Co., No. 1 Guame	Now Sierra County; 1,987′ SL, 660′ EL, sec. 21, T. 16 S., R. 2 E.	1950	2,202	Mesaverde	Yeso	
11	Plymouth Oil Co., Evans No. 1 Federal	Otero County; 660′ NL, 660′ WL, sec. 15, T. 20 S., R. 9 E.	1954	7,585	Yeso below valley fill	El Paso	Steep dips, sill
Off map	Sun Oil Co., T. J. Pearson No. 1	Otero County; 800′ SL, 800′ EL, sec. 35, T. 20 S., R. 10 E.	1954	4,468	Basal Hueco	Montoya	
12	Al Parker, Simmons No. 1A Federal	Dona Ana County; 220′ SL, 1,100′ EL, sec. 35, T. 22 S., R. 5 E.	1944	3,104	Alluvium	Tertiary ? bolson deposits	Driller's log only
13	Al Parker, State No. 1	Dona Ana County; center NW¼SE¼ sec. 15, T. 23 S., R. 5 E.	1944	4,260	Alluvium	Tertiary ? bolson deposits	Driller's log only
14	Picacho Oil & Gas Syndicate, Armstrong No. 1	Dona Ana County; center NW¼NE¼ sec. 15, T. 23 S., R. 1 W.	1941	3,196	Volcanic rocks below alluvium	Hueco or intrusive	
15	Viking Oil & Development Co., Cox No. 1	Dona Ana County; 200′ WL, 1,100′ NL, sec. 26, T. 23 S., R. 5 E.	1932	3,224	Alluvium	Tertiary ? bolson deposits	Driller's log only
16	Snowden & Clary, No. 1 State; formerly Clary and Ruther	Dona Ana County; NW¼NW¼NW¼ sec. 36, T. 23 S., R. 2 E.	1949	2,585	Hueco below alluvium	Pennsylvanian ?	
Off map	R. H. Ernest, Located Land No. 1	Otero County; 330′ SL, 330′ EL, sec. 20, T. 25 S., R. 7 E.	1942	3,941	Hueco below 2,182 feet of Tertiary ?	Pennsylvanian	Gypsum beds in Virgil

feet of light- to medium-gray aphanitic limestones, with thin interbeds of dark-gray silty shale; (8) 90 feet of grayish-red, pale-purple, and greenish-gray silty shale interbedded with light- to dark-gray arenaceous to calcic limestones and a few thin beds of pale-yellow sandstone. Probable Missourian beds are about 170 feet thick, although the lower rocks attributed to Virgilian age may be older. Missourian correlatives are light- to dark-gray aphanitic silty to relatively pure calcic limestones and a few thin beds of dark-gray fine-grained sandstone and light- to dark-gray silty shale. Desmoinesian equivalents are probably 370 feet thick, consisting of: ( ) an upper 10o feet of light- to medium-gray aphanitic limestones with scattered chert nodules and a few thin beds of light-gray shale; (2) medial 20 feet of dark-gray shale; and (3) basal 25o feet of light- to medium-gray aphanitic limestones, with abundant chert nodules and a few thin lenses of dark-gray to black shale. Derryan strata are 27o feet thick, with an upper 225 feet of interbedded dark-gray to black arenaceous shale, light-gray shale, medium-gray arenaceous limestone, and light-gray very fine-grained sandstone; then 3o feet of light-gray medium- to coarse-grained and pebbly sandstone, and a basal 15 feet of white chert pebble-conglomerate.

The Montoya group consists of an upper 8o feet of light-to medium-gray fine-crystalline Upham dolomite and a basal 3o feet of light-gray fine- to very coarse-grained siliceous Cable Canyon sandstone. The El Paso group consists of 130 or 175 feet of light-gray fine-crystalline arenaceous dolomite and light-gray fine-grained calcareous sandstone; the Bliss sandstone, top uncertain, is 70 or 25 feet thick, of light-gray fine- to medium-grained glauconitic sandstone, resting on pinkish, coarse-grained granite.

Sun Oil Co., Victorio Land & Cattle Co. No. 2 (Sierra County, sec. 27, T. Io S., R. W.; table 6, fig 1, no. 2), was drilled about 1 1/2 miles west-northwest of its No. I well and 300-400 feet structurally lower, to a depth of 6,352 feet. Formations penetrated, from top to bottom, are: (I a) valley fill, 120 feet; (I13) McRae (?) formation, 39 feet; (2a) Mesaverde formation, 686 feet; (2b) Mancos shale, 23o or 52o feet; (3) Dakota (?) sandstone, 335 or 45 feet; (4) Dockum redbeds, too feet; (5) San Andres formation, 65o feet; (6) Glorieta sandstone, 5o feet; (7) Yeso formation, 1,370 feet; (8) Abo redbeds, 690 feet; (9) Pennsylvanian strata, 1,740 feet; (1 o) Montoya group, 110 feet, including 10 feet of basal Cable Canyon sandstone; (1) El Paso group, 190 feet; (12) Bliss sandstone, 42 feet plus. Valley fill is tan to gray, medium- to coarse-grained gypsiferous sandstone containing rounded pebbles of gray limestone and light-brown shale. The McRae (?) formation is light-brown arenaceous shale interbedded with fine- to coarse-grained arkosic light-gray to tan sandstone, with fragments of volcanic rocks. The Mesaverde beds are light- to dark-gray, grayish-brown, and pale-brown fine- to coarse-grained micaceous sandstone interbedded with medium- to dark-gray and greenish-gray silty micaceous clay shale. Near the base of the formation are some thin seams of coal. The Yeso formation can be subdivided into 160 feet of the Joyita sandstone member, 220 feet of the Canas gypsum member, 500 or 710 feet of the Torres member, and 490 or 28o feet of the basal Meseta Blanca member.

Thomas J. Gartland, Maggie Brister No. t (formerly Drew Matthews No. 1; Sierra County, sec. 8, T. 12 S., R. 4 W.; table 6, fig 1, no. 3), was drilled near the west edge of the Rio Grande Valley about 6 miles west of Elephant Butte reservoir, to a depth of 8,585 feet. Formations penetrated, from top to bottom, are: (I) Quaternary (?) gravels, 58o feet; (z) Santa Fe group, 879 feet; (3) McRae (?) formation, 8o feet; (4) Mesaverde formation, 1,240 feet; (5) Mancos shale, 160 feet; (6) Dakota (?) sandstone, 220 feet; (7) San Andres formation, 735 feet; (8) Yeso formation, 1,53o feet, including 735 (?) feet of monzonite sill near base; (9) Abo redbeds, 1,390 feet; (I o) faulted Pennsylvanian, Precambrian, fault gouge, Devonian (?), 1,980 feet. Dips of 25-60 degrees are reported from this oil test, and many faults occur below the Yeso formation.

The Quaternary (?) gravels are coarse well-rounded fragments of volcanic rocks, with minor limestone and quartzite pebbles. The Santa Fe beds are brownish-gray to tan calcareous clayey gypsiferous siltstones and claystones, fine- to coarse-grained sandstones, and lenses of coarse angular to well-rounded volcanic gravels. McRae (?) beds are light-gray arkosic sandstones and purplish silty claystones. The Mesaverde formation consists of light- to medium-gray, fine- to medium-grained sandstone, containing plant fossils, fragments of pelecypods, thin coal seams, and interbeds of greenish silty claystone and light-gray to black, clayey to arenaceous shale. The Mancos is of medium-gray to black shale interbedded with light-gray very fine-grained sandstone. The Dakota (?) sandstone is light-gray to whitish fine-grained pyritiferous argillaceous sandstone, with some interbeds of gray to black shale. The San Andres formation consists of four lithologic subdivisions, in descending order: ( ) an upper 220 feet of brownish-gray to dark-gray fine-crystalline limestone, with arenaceous lenses and interbeds of brownish-gray calcareous siltstone and very fine-grained sandstone, as well as abundant calcite-filled vugs and calcite veinlets; (2) 22,o feet of interbedded dark-gray fine-crystalline arenaceous limestone, light-brown argillaceous siltstone, and white, pale-red, and dark-gray very fine-grained sandstone; (3) 75 feet of pale-red very fine- to fine-grained sandstone; (4) the basal 220 feet of permeable, medium- to dark-gray and light-brown, aphanitic to fine-crystalline arenaceous limestone, with minor thin beds of calcareous light-brown siltstone and white micaceous and pale-red sandstone. Above the monzonite sill the Yeso formation consists of an upper 205 feet of interbedded white micaceous sandstone, pale-red silty sandstone, dark-gray limestone, and light-brown calcareous siltstone; below the sill is 485 feet of intercalated gypsum, pale-red, pinkish, light-gray, and whitish fine-grained sandstone, dark reddish-brown silty shale, dark-gray pyritiferous limestone, and brownish-gray calcareous siltstone.

The monzonite intrusive (sill ?) is 735 feet thick and may be a series of sills with sandstone and siltstone beds in between. Ming-Shan Sun determined the mineral composition as: orthoclase, 48 percent; oligoclase, Ab 88, 43 percent; interstitial quartz, 5 percent; biotite, 3 percent; magnetite, 1 percent; with scattered tiny apatite crystals throughout. Basal beds of the Yeso formation below the monzonite are white very fine- to fine-grained friable sandstone, 105 feet thick. Abo redbeds are 1,390 feet thick, an excessive thickness for the formation, caused by steep dip of the beds reached at this depth. The upper 185 feet of the Abo redbeds is white to pale-red and purplish siliceous siltstones, reddish silty sandstones, and dark-red silty claystones; the lower 1,205 feet is interbedded dark-red, greenish-gray, and grayish-red siliceous siltstone, very fine-grained sandstone, and silty shale with scattered pellets of arenaceous limestone.

The lower 1,980 feet in the test well is Pennsylvanian limestones and dark-gray to black carbonaceous shales, which may be in part Devonian, and Precambrian muscovite red-feldspar granite. Fragments of the Precambrian rocks were found at depths of 7,300 and 8,500 feet; 245 feet of fault gouge was penetrated between depths of 7,805 and 8,050 feet, marked by much vein calcite, brecciated limestone, crystalline quartz, and veins and disseminated crystals of pyrite and chalcopyrite. Discontinuous sequence and gouge zones indicate numerous faults.

The Thomas J. Gartland, Garner No. 1 Federal (Sierra County, sec. 11, T. 12 S., R. 5 W.; not shown on map, fig 1) was drilled about 3 miles west of the Garland No. Brister, to a depth of 6,524 feet. The upper 700 feet is sands containing rounded fragments; cuttings from the rest of the rocks penetrated are angular fragments of Santa Fe sedimentary rocks and, in the lower part, volcanic sediments.

The Summit Exploration Co., Mims No. 1A(formerly J. H. Blackstone No. 1; Sierra County, sec. 2, T. 13 S., R. 4 W.; table 6, fig 1, no. 4), was drilled about 5 1/2 miles south-southeast of the Gartland No. 1 Brister, to a depth of 6,195 feet. Rock units penetrated, top to bottom, are: (1,986 feet of valley fill and Santa Fe (?) beds; (2) 824 feet of Mesaverde formation; (3) 380 feet of Mancos shale; (4) 358 feet of Dakota (?) sandstone; (5) 607 feet of San Andres formation; (6) 470 feet of Yeso formation; (7) 80 feet of monzonite; (8) 940 feet of Abo redbeds; (9) 550 feet of upper Pennsylvanian strata. The Cenozoic rocks include much rounded chert, volcanic fragments, and selenite crystals. The upper sandstones attributed to the Mesaverde formation are spotted by greenish grains of propylitized andesite (?) and may be part of the McRae formation. Again the thickness of the Dakota (?) sandstone, as interpreted by us, may be exaggerated by the inclusion of sandstone that might be placed in the basal Mancos shale. The San Andres and Yeso formations are similar lithologically except for a larger percentage of limestone in the San Andres formation and of gypsum in the Yeso formation. The Yeso formation is thinner than in any nearby sections, owing principally to lack of the basal "Meseta Blanca" sandstones and a relatively small amount of gypsum. The upper several hundred feet assigned to the Abo redbeds may be, however, basal Yeso sandstones; cuttings for this interval are inconclusive.

The Tularosa Basin Oil Co., Belmont No. 2 (Otero County, sec. 34 [?], T. 13 S., R. 7 E.; table 6, fig 1, no. 5), was drilled to a depth of 3,965 feet in the Tularosa Valley, about 10 miles northwest of Tularosa. Scout reports and a driller's log indicate 780 feet of valley fill, then the penetration of Yeso, Abo, Hueco, and Pennsylvanian strata. The test bottomed in lower Permian or upper Pennsylvanian rocks.

The McCall Drilling Co., Park Bowers No. 1 (Sierra County, sec. 19, T. 14 S., R. 2 W.; table 6, fig 1, no. 6), was drilled to a depth of 1,540 or 2,910 feet on the west side of the Jornada del Muerto, about 5 miles northwest of Cutter. The petroleum test was spudded in the Mesaverde formation, was still in Cretaceous sandstones and shales at 1,540 feet (top of Mancos ?), and, reportedly, bottomed in the Permian rocks.

The McCall Drilling Co., Park Bowers No. 2 (Sierra County, sec. 32, T. 14 S., R. 2 W.; table 6, fig 1, no. 7), was drilled to a depth of 2,900 feet on the west side of the Jornada del Muerto, about 3 miles west-northwest of Cutter. The test began in the Mesaverde formation and, reportedly, bottomed in the San Andres (?) formation.

The Barney Iorio, No. 1 Fee (Sierra County, sec. 25, T. 14 S., R. 5 W.), was drilled to a depth of 2,100 feet in the Rio Grande Valley, on the west side of the Caballo Mountains. Kelley and Silver (1952, p 221) reported 1,165 feet of pediment gravel and Santa Fe group overlying a basal 935 feet of the Thurman formation; hot mineral water was reported flowing from a depth of 1,550 feet.

The F. W. Carr, Gentry No. 1 State (Sierra County, sec. 32, T. 15 S., R. 3 W.; table 6, fig 1, no. 8), was drilled to a depth of 5,418 feet on the Putnam anticline, on the east edge of the Caballo Mountains. In nearby outcrops the Pennsylvanian beds dip at steep angles up to 82 degrees, and the cuttings indicate numerous faults, as well as steep dips. Rocks penetrated, top to bottom, are: (1) 1,375 feet of Pennsylvanian limestones and shales, containing chert, numerous fusulinids, brachiopods, and crinoid stem fragments; (2) 485 feet of the Montoya group, with a basal 20 feet of the Cable Canyon sandstone; (3) 630 feet of the El Paso group, with arenaceous dolomites near the base and, near the middle, fault gouge which includes powdered dolomite, coarse-crystalline calcite veins, disseminated galena, and brecciated chert; (4) 530 feet of mixed, brecciated, and powdered dolomite, limestone, and dark-gray calcareous shale, with numerous crystals of quartz, calcite, galena, pyrite, chalcopyrite, and some sphalerite; (5) 145 feet of Cable Canyon sandstone, obviously cut at low angle to bedding planes, so that dips must approach 82 degrees; (6) 675 feet of dolomites, probably of the El Paso group, perhaps in part Montoya; (7) 120 feet of medium-gray to black arenaceous shales and dark-gray Pennsylvanian limestones; (8) 1,145 feet of mixed Ordovician dolomite, Pennsylvanian limestones, sandstones, and shales, scattered galena, sphalerite, and gouge; (9) 296 feet of El Paso (?) dolomites; (10) 17 feet of mixed Pennsylvanian rocks and arenaceous El Paso dolomites.

The Western Drilling Co., Guame No. 2 Federal (Sierra County [formerly in Socorro County], sec. 21, T. 16 S., R. 2 E.; table 6, fig 1, no. 9), was drilled to a depth of 3,507 feet on the west side of the Jornada del Muerto, about 3 miles west and northwest from measured section H of the Hembrillo Canyon area. Cuttings are not available above the depth of 1,410 feet, but probable formations penetrated, top to bottom, are: (I) 200 (?) feet of alluvium; (2) 675 (?) feet of Mesaverde formation; (3) 455 (?) feet of Mancos shale; (4) 30 (?) feet of Dakota (?) sandstone; (5) 453 (?) feet of San Andres formation; (6) 30 feet of Glorieta sandstone; (7) 1,460 feet of Yeso formation, with whitish sandy clay near base; (8) 203 feet of Abo redbeds, with some interbedded whitish and greenish sandstones near the top. Thickness of the Yeso formation seems excessive as compared with the 892 feet measured west of Hembrillo Pass.

The Bruton Development Co., Guame No. x (Sierra County, sec. 21, T. 16 S., R. 2 E.; table 6, fig 1, no. I o), was drilled to a depth of 2,202 feet; the site is about 1,750 feet east of the Western Drilling Co., Guame No. 2 Federal. Tops of formations in the two wells indicate an apparent dip to the west of 9 degrees. Formations penetrated, top to bottom, are: (1) 180 feet of alluvium (?); (2) 469 feet of Mesaverde formation; (3) 455 feet of Mancos shale, with basal sandstone interbeds; (4) 31 feet of Dakota (?) sandstone; (5) 453 feet of San Andres formation; (6) 32 feet of Glorieta sandstone; (7) 602 feet of Yeso sandstones, gypsum, limestone, and calcic dolomite.

The Plymouth Oil Co., Evans No. 1 Federal (Otero

County, sec. 15, T. 20 S., R. 9 E.; table 6, fig 1, no. I 1), was drilled to a depth of 7,585 feet on the east side of the Tularosa Valley, about 8 miles west of the Sacramento Mountains. Dips of up to 3o degrees are reported from upper beds. Rocks encountered, top to bottom, are: (I) 690 feet of valley fill; (2) 490 feet of Yeso formation; (3) 202 feet of Abo redbeds; (4) 404 feet of hornblende biotite monzonite; (5) 814 feet of Abo redbeds and Hueco limestones, with thin monzonite sills; (6) 2,660 feet of shale and thick limestones, probably Virgilian to Missourian in age; (7) 910 feet of DesmoinesianDerryan strata; (8) 13o feet of Helms formation; (9) 34o feet of Rancheria formation; (10) 45 feet of Lake Valley formation; (11) 5 feet of Percha (?) black shale; (12) 120 feet of Fusselman dolomite; (13) 160 feet of Valmont dolomite; (14) 290 feet of pre-Valmont Montoya group; (15) 325 feet of El Paso group; bottomed in arenaceous lower third of the El Paso group.

The Sun Oil Co., T. J. Pearson No. 1 (Otero County, sec. 35, T. 20 S., R. Io E.), was drilled to a depth of 4,468 feet on the west edge of the southern Sacramento Mountains. Outcrops not far from the site have dips up to 35 degrees. The test was spudded in lower Hueco limestones, should have gone through the Powwow conglomerate at shallow depths, and went into Des Moines (Strawn) limestones at a depth of 3,03o feet, Mississippian rocks at 4,12o feet, Fusselman (?) dolomite at 4,25o feet, and Montoya (?) dolomite at 4,390 feet. The possible top of Missourian equivalents is at a depth of about 2,730 feet, suggesting that 2,500-2,700 feet of Virgilian strata was penetrated. The upper part of the Virgilian is ledge-forming limestones and thin shales, as seen cropping out along Grapevine and Culp Canyons northeast of the well site; the lower part is almost 500 feet of dark-gray silty shale overlying 1,700 feet of interbedded shales and dense limestones.

Three test holes were drilled southeast of San Augustin Pass on the west side of the Tularosa Valley, 4-6 miles east of the Organ Mountains. The Al Parker, Simmons No. IA Federal (Dona Ana County, sec. 35, T. 22 S., R. 5 E.; table 6, fig 1, no. 12), was drilled to a depth of 3,104 feet. Only a driller's log is available, but cuttings from a nearby well are of clay, friable tan sandstone, and pebbles of jasper, orange chert, pinkish rhyolite, pink and light-gray feldspars, and gray andesite. Probably only Cenozoic bolson and volcanic sediments were penetrated in this test well. The Al Parker, No. I State (Dona Ana County, sec. 15, T. 23 S., R. 5 E.; table 6, fig 1, no. 13), was drilled to a depth of 4,26o feet. The driller's log indicates mostly shale, with some sand beds and only thin limestones or limy beds; probably all are Cenozoic bolson deposits. The Viking Oil and Development Co., Cox No. 1 (Dona Ana County, sec. 26, T. 23 S., R. 5 E.; table 6, fig 1, no. i5), was drilled to a depth of 3,224 feet, probably all in Cenozoic bolson and volcanic sediments.

The Picacho Oil and Gas Syndicate, Armstrong No. (Dona Ana County, sec. 15, T. 23 S., R. 1 W.; table 6, fig 1, no. 14), was drilled to a depth of 3,196 feet, about 6 miles west of the Rio Grande Valley, at the south end of the Robledo Mountains fault block. Rocks penetrated, top to bottom, are: (I) 165 (?) feet of Santa Fe beds; (2) 2,175 feet of purple, greenish, medium-gray, pinkish, reddish, olive, and white latite to andesite crystal tuff and breccia-tuff, with lower red clays, tuffaceous sands, olive limy siltstones, and gypsum; (3) 135 feet unknown—cuttings not available; (4) 213 feet of upper Hueco limestones, reddish-brown siltstones, and shales; (5) 508 feet unknown—cuttings not available; reportedly bottomed in igneous rock. The Hueco formation crops out along Apache Canyon 3 1/2 miles northeast of the test-well site, is about 1,700 feet thick, with interbedded Abolike redbeds in upper part, and is overlain by Tertiary volcanic rocks and a redbed-gypsum sequence like that penetrated in the well.

The Snowden and Clary, No. 1 State (formerly Clary and Ruther; Dona Ana County, sec. 36, T. 23 S., R. 2 E.; table 6, fig 1, no. i6), was drilled to a depth of 2,585 feet on the east side of the Rio Grande Valley, about a mile south of Tortugas Mountain. Cuttings are available only from depths of 1,42o-1,865 feet; these are of Hueco limestones, with float of greenish micaceous sandstone and reddish-brown siltstone, which indicate that an Abo tongue was penetrated above 1,400 feet. The top 526 feet reportedly are sand, sand rock, and gravel; the well probably bottomed in upper Pennsylvanian strata.

The R. H. Ernest, Located Land Co. No. 1 (Otero County, sec. 20, T. 25 S., R. 7 E.) was drilled to depth of 3,941 feet near the northeast end of the Hueco Basin, about 9 miles north-northeast of Newman. Rocks penetrated, top to bottom, are: (I) 1,965 feet of valley fill, consisting of fine-grained tan calcareous sand and sandstone, pale-orange shale, scattered purple chert, black basaltic andesite, and mica; (2) 217 feet of limestone pebble-conglomerate, sand, and pale-orange shale; (3) 130 feet of basal Hueco limestones; (4) 73 feet of Powwow conglomerate; (5) 1,556 feet of Pennsylvanian strata from a depth of 2,385 feet to the bottom, including 15 feet of reddish shale (2,450-2,465 feet), shale and limestone with a ratio of 2:3, (2,465-2,764 feet), and interbeds of gypsum (2,764-2,860 feet), underlain by interbedded limestone and shale, mostly of probable Virgilian age. Test holes drilled in Texas several miles south of Newman reportedly bottomed in bolson deposits at depths of 4,010-4,920 feet.

Insoluble-Residue Analyses

Insoluble-residue analyses of 922 samples collected from pre-Pennsylvanian strata measured in the San Andres Mountains were made by E. W. Vanderpool and Maylon Baker, of the Midland Research Laboratory, for the purpose of comparing the results derived from this technique with those secured by field observation and petrologic and paleontologic studies. As might be expected, the results and interpretations, as set forth below, differ somewhat. Insoluble residues are lithologic features that in many cases are correlative across long distances but may cross time lines, just as any facies unit. The basal Paleozoic beds in the Cordilleran trough, for example, are the Prospect Mountain quartzite of Lower Cambrian age in southern Nevada and southwestern Utah, the Brigham quartzite of Middle Cambrian age in northwestern Utah, and the Flathead quartzite of younger Middle Cambrian age in Montana and western Wyoming (Deiss, 1938). These three siliceous sandstones are of similar lithology but of different ages. It should be no surprise, therefore, that the unit called the Bliss sandstone is of different ages in relatively nearby outcrops, or that fossils of basal Paleozoic sandstones are of Cambrian age in the Llano uplift region of Texas and of early Ordovician age in the Franklin Mountains.

A similar problem is involved in the correlation of the black shale and associated shaly marly limestone facies of the Woodford, Percha, Chattanooga, and New Albany formations. The complex relations between the Sly Gap, Contadero, Percha, "Three Forks," and Caballero formations in the San Andres Mountains provide an inkling of the complex and perplexing age and facies changes involved in comparing the above formations with the Canutillo formation of the Franklin Mountains, the Caballos formation of the Marathon region, the Woodford shale of west Texas, and the Morenci shale and Martin limestone of southeastern Arizona. For purposes of geologic field mapping and identification of well cuttings, these units should perhaps be labeled with a broad facies term, such as Percha or Woodford, and time designations should not be attempted except on fossil basis.

The top of the Bliss sandstone, as picked on the basis of insoluble residues, is at the top of glauconitic beds which are mostly more than 3o percent quartz sand. This places the contact with the El Paso group higher than the contact picked by us on the outcrop, as we assigned most of the arenaceous limestones to the basal beds of the El Paso group, and considered prominence rather than existence of glauconite as the basis for inclusion in the Bliss sandstone.

The contact of the Montoya group and the Fusselman dolomite, as determined from residues, is 40-60 feet below the formational boundary. Beds referred to the Woodford-Percha facies by means of residues are the Onate and Sly Gap formations in Ash Canyon and the Onate formation in Hembrillo and Rhodes Canyons. The top of the Mississippian, as determined from residues, is at the top of the Alamogordo member of the Lake Valley formation in Ash Canyon, and at the top of the Percha formation in Hembrillo and Rhodes Canyons. The cherty crinoid coquinas and shaly marly limestones of the middle and upper Lake Valley formation members contain insoluble residues similar to those of the basal Pennsylvanian beds; this is to be expected, as the basal Pennsylvanian clastics in the area were derived mostly from erosion of Mississippian rocks.

Insoluble-residue studies show that the beds we have referred to the Bliss sandstone contain a basal unit of sandy oolitic hematite, which makes up 30-65 percent of the lower 5-20 feet of the formation in Rhodes and Hembrillo Canyons. The remainder of the Bliss beds contains 55-75 percent glauconitic siliceous quartz sand with pebbly lenses. Lower beds in Rhodes Canyon contain is percent glauconitic arenaceous micaceous shale, whereas some of the lower rocks in Ash Canyon include as much as 35 percent of arenaceous micaceous greenish shale. Tiny fragments of schist and phyllite occur in the upper part of the Bliss sandstone in Ash Canyon.

The basal Gasconade zone of the El Paso group contains 10-65 percent siliceous glauconitic quartz sand, ranging from an average of 3o percent in Ash Canyon to 44 percent in Rhodes Canyon, with an overall average of 33 percent. Up to percent sandy shale (dolomoldic) occurs in the zone, although most of the beds are nonargillaceous. The first-endoceroid-zone beds contain up to 37 percent shaly silty quartz sand; the average, however, is only 15 percent for the three sections, with an average of 18 percent for Ash Canyon and 9 percent for Hembrillo Canyon. Sandy dolomoldic chert constitutes up to 48 percent of some of the beds and is a distinguishing characteristic by which the first endoceroid zone can be identified. As much as 18 percent of granular siliceous shale occurs within the cherty beds.

The first-piloceroid-zone beds contain 4-15 percent silt, 2-33 percent granular siliceous shale (average about 5 percent), and 1-8 percent sandy chert. The oolite zone contains 5-2o percent quartz sand, with minor amounts of siliceous shale and silty shale; none of the oolites were found silicified. Near the base of the Mcqueenoceras zone is a r o-foot interval that contains as much as 18 percent of sandy dolomoldic to smooth chert; most of the zone, however, contains only a few percent of quartz silt and sandy chert. Beds between the Mcqueenoceras and second-piloceroid zones contain an average of only 5 percent insolubles at Ash Canyon but 5-25 percent in Hembrillo Canyon, where they include about 4 percent quartz silt and **2-20** percent siliceous fossiliferous dolomoldic shale. The second piloceroid zone and beds up to the base of the Montoya group contain 5-15 percent quartz silt, sandy chert, and sandy siliceous shale, with several beds having as much as 35 percent of residues.

The basal unit of the Montoya group, the Cable Canyon sandstone, has an unexpectedly high percent of solubles according to Vanderpool's analyses, as siliceous pebbly quartz sand ranges only from 55 to 65 percent for full ro-foot samples. The sandstone is a distinct lithologic unit unlike any other between the top of the Bliss sandstone and the base of Pennsylvanian sandstones. Lower beds of the Upham dolomite show much less quartz sand in residues than seen in the outcrop, but this is probably due to the poor choice of samples sent to Vanderpool. Other than this basal sand, the Upham contains remarkably little insoluble residue, usually only **1-2** percent of drusy chert flakes. The base of the cherty Aleman dolomite is strikingly shown by insoluble residues, Vanderpool's contacts being not more than 5 feet from ours in all three canyons. Chert ranges up to 5o percent in some of the Aleman beds and varies from granular and partly sandy to smooth; these are the only beds with appreciable amounts of smooth chert in the measured Paleozoic sections below the Mississippian cherts of the Lake Valley formation. The Cutter dolomite contains considerable amounts of chert in some of its lower beds, with several horizons having as much as 35 percent sandy to granular dolomoldic chert. Medial and upper beds contain relatively few residues, 1-4 percent, except for several shaly beds that have as much as 25 percent sandy silty shale.

Residues of the Fusselman dolomite vary greatly in the two sections sampled. In Hembrillo Canyon the dolomite contains some granular chert and only traces of residues of smooth chert. At Ash Canyon the dolomite includes up to 45 percent of granular dolomoldic chert, although lower beds which should be equivalent to the Hembrillo Canyon outcrops contain only 7-25 percent chert.

The Onate formation includes 18-66 percent micaceous quartz silt and up to 52 percent silty micaceous shale. Beds referred to the Sly Gap formation at Ash Canyon contain 7o percent silty micaceous shale; in Hembrillo and Rhodes Canyons the shale is in addition fossiliferous and sandy, there is up to 12 percent quartz silt, and there are more solubles. Insoluble residues of the lower part of the Contadero formation are mostly micaceous shales, up to 7o percent, with as much as 6o percent of coarse silt to fine-grained quartz sand in the upper part. The Percha formation contains 25-75 percent of silty micaceous shale and as much as 38 percent of coarse silt to fine-grained quartz sand.

The Caballero formation in Ash Canyon contains 4o-65 percent sandy fossiliferous shale, as does the Andrecito member of the Lake Valley formation in that area. The Alamogordo member contains as much as 55 percent of granular to smooth chert; as in all the members of the Lake Valley formation, there are scattered tiny slender euhedral quartz crystals. Beds of the Nunn member typically contain 18-45 percent of fossiliferous shale, with 4-18 percent sandy granular chert. The Tierra Blanca member varies greatly in composition, with a range of 7-75 percent granular chert and 4-63 percent smooth fossiliferous crinoidal chert. The Arcente member in Ash Canyon contains 16-5o percent porous shale, up to 19 percent fossiliferous granular chert, and as much as 20 percent smooth chert with disseminated calcimolds. The Dona Ana member has only a few percent of granular to smooth chert, the chert occurring as scattered large nodules.

Basal Pennsylvanian beds contain much reworked chert from the Mississippian strata, high percentages of siliceous and pebbly quartz sands, much fossiliferous sandy granular chert, and micaceous shales. Insoluble residues range from 3o to 75 percent for most of the basal Pennsylvanian beds, with clastic fragments predominating over precipitated and replacement materials.

Petroleum Possibilities

Aside from the scientific contributions made in this report, a major purpose was to point out those stratigraphic features that would be favorable to the accumulation of petroleum and natural gas. Structural features that may affect the presence or absence of petroleum are brought out by areal mapping studies and have been discussed by Kelley and Silver (1952, pp 219-230).

Petroleum reservoirs usually are classified into two main types: ( ) structural traps, and (2) porosity traps. Structural traps are caused by deformation of the strata, either by folding or faulting. Porosity traps are chiefly due to processes of sedimentation, erosion, cementation, and secondary leaching. Sandstone reservoirs occur in lenses of sandstone within impermeable strata, lenses of sandstone of greater porosity than surrounding sandstones, and sandstone beds (or any other porous rock, such as porous dolomite) truncated by overlapping impervious strata. Limestone and dolomite reservoirs are in porous zones, beds, and reefmasses.

In southeastern New Mexico oil and gas is produced from the El Paso-Ellenburger group, the Simpson group sandstones, the Montoya group, the Fusselman dolomite, Devonian dolomites, Mississippian limestones, Pennsylvanian strata, the Bursum formation, the Hueco formation, the Abo dolomites, sandstones and dolomites of the Yeso formation, and the San Andres formation. Many of these producing zones are stratigraphic traps. In northwestern New Mexico oil and gas have been found in the Dakota sandstone, Pennsylvanian rocks, and the Mesaverde group. The rocks examined in the San Andres Mountains are similar in many respects to the beds that are prolific producers in southeastern and northwestern New Mexico.

Possible stratigraphic traps are suggested in the area where the relatively porous carbonate rocks of pre-Devonian age pinch out northward beneath the impervious shaly Devonian strata. Numerous permeable horizons and carbonaceous shales are contained in the thick Pennsylvanian and Lower Permian marine sequence; in the area between Rhodes and Hembrillo Canyons these formations contain numerous biohermal limestones, which are sources of oil in many other areas. Petroliferous limestones, as well as porous and permeable beds, are included in the San Andres and Yeso formations. Permeable sandstones occur in the Dakota (?) sandstone and in the Eagle Ford or Mancos formation, where they are associated closely with dark marine shales. The sedimentary rocks exposed in the range are not deformed to a prohibitive extent, nor are they metamorphosed except close to the Organ Mountains batholith.

Carbonaceous and bituminous dark-colored shales and carbonate rocks, possible source beds for petroleum, occur in Devonian, Pennsylvanian, Permian, and Cretaceous formations of the San Andres Mountains. Most of the Bliss sandstone beds are tightly cemented, but there are locally porous beds, especially among the coarser grained sandstones. The coquinoid limestones of the El Paso group, along with the local reefy beds, sandy lenses, and porous dolomitized zones, offer possible porosity traps for accumulation of oil and gas. The Montoya group dolomites and the Fusselman dolomite contain many porous zones, especially in the more coarsely crystalline crinoidal beds of the Upham dolomite, and secondary porosity is well developed where these dolomites are overlapped by the shaly Devonian rocks. Some of the coarser grained lenses of the Cable Canyon sandstone are permeable. The fossiliferous limestones of the Mississippian are possible porosity traps, especially where overlapped by Pennsylvanian siliceous sandstones and impervious shales.

The Pennsylvanian strata, Bursum formation, and Hueco formation are the most promising targets for oil and gas exploration. Large biohermal limestone masses occur in the Panther Seep formation from Sulphur Canyon southward to beyond Hembrillo Canyon, and thick biostromal limestones occur throughout the range in the Pennsylvanian and Wolfcampian formations. Alternations of porous permeable beds (calcarenites, calcirudites, coquinas, sandstones) and relatively impervious shaly beds offer numerous reservoir zones and confining "cap" rocks; all are associated with dark carbonaceous shales and with dark limestones that are in part fetid and petroliferous.

Limestones in the Yeso and San Andres formations are petroliferous, and many are porous and permeable. The sandstones in the Yeso formation are very fine grained, but many are porous. Sandstone beds in the Dakota (?) are relatively continuous and very porous and permeable; they occur beneath the dark-colored marine shales of the Mancos shale in basin areas adjoining the north part of the range, and are beneath the marine black shales of the Eagle Ford formation near the south part of the range. Sandstones in the Eagle Ford formation are mostly fine-grained subgraywackes, but some are very porous, and are in close association with carbonaceous shales. The fossiliferous sandy beds of the Lower Cretaceous thicken southward from Love ranch and, where preserved, are interbedded and overlain by considerable thicknesses of marine limestones and shales.

Cenozoic sediments are stream and lake deposits interbedded with volcanic rocks and volcanic sediments, types of sediments in which petroleum has rarely been found. They contain, however, numerous porous and permeable beds which could act as reservoirs; these permeable beds are interlayered with impervious strata that could serve as confining layers if oil and gas has migrated from pre-Cenozoic source beds. Most of the oil tests in southwestern New Mexico, however, have penetrated Cenozoic beds without finding more than faint shows of oil or gas.

Although source beds, reservoir horizons, and impervious trapping strata occur throughout the sedimentary sequence exposed in the San Andres Mountains and adjoining areas, one should not expect to find petroleum except in favorable structures, either those formed by gentle deformation of strata or those due to stratigraphic features. Either type of petroleum trap is difficult to locate in an area such as southwestern New Mexico, where possible clues to reservoirs are concealed by the thick sequences of Cenozoic volcanic rocks and bolson sediments. Careful geologic work supplemented, where needed, by geophysical investigations should precede drilling tests.

Glossary of lithologic Terms

Most technical geologic terms convey different shades of meaning to different geologists. Terms are defined herein as we have applied them in our study, in order to clarify our geologic jargon to both professional geologists and laymen.

ACICULAR—Shaped like a needle.

APHANITIC—Crystals under 0.2 mm in size; not detectable with naked eye, but may be seen with ordinary 10-power hand lens.

ARENACEOUS—Rock contains appreciable (but less than 5o percent) sand-sized grains of quartz.

ARGILLACEOUS—Rock contains appreciable (but less than *5o* percent) clay.

ARKOSIC—Rock contains 10-25 percent clastic feldspar grains.

BANDS (banded)—Laminae or thin beds that differ in color rather than in grain size.

BEDDING—Classification follows that of Maher and Lukert (1955, p 1662):
fissile—less than 1/16 inch
platy-1 /16-1/2 inch
very thin-bedded—1/2-2 inches
thin-bedded-2-4 inches
medium-bedded-4-, 2 inches
thick-bedded—12-36 inches
massive-bedded—more than 36 inches

BIOHERM—Moundlike, lenslike, domelike, or otherwise circumscribed mass built mainly by sedentary organisms and enclosed in normal rock of different lithologic character.

BIOSTROME—Laterally extensive bedded structures consisting of, and built mainly by, sedentary organisms.

BLOCKY—Applied to claystone or shale which splits into large rectangular or rhombic blocks; thinner bedding may or may not be apparent.

BOLSON DEPOSITS—Relatively unconsolidated deposits of sand, sandstone, clay, claystone, shale, gravel, conglomerate, siltstone, gypsum, etc., which were deposited in an arid to semiarid, closed to partly closed basin.

CALCARENITE—Limestones made up of clastic calcite grains and fragments of fossils, that are at least in part sorted; fragments average larger than silt size and would be called sandstone if the grains were predominantly quartz.

CALCIC—Relatively pure limestone, as contrasted with dolomitic limestones or impure limestones that contain argillaceous or arenaceous materials.

CALCILUTITE—Even-laminated to crosslaminated limestone composed of silt or clay-size, apparently detrital, calcite grains; results from lithification of calcium carbonate muds.

CALCIMOLDIC—Chert containing molds of calcite crystals that have been removed by leaching.

CALCIRUDITE—Rock resulting from lithification of detrital calcium carbonate materials predominantly larger than 4 mm in diameter.

CHERTY—Sparse to abundant nodules, lenses, stringers, and/or flakes of chert. Chert may be subdivided into chalcedonic, smooth, porcelaneous, fine-granular, coarse-granular, and chalky.

CLASTIC RATIO—Ratio of arenaceous and argillaceous clastic rocks to precipitated, and detritus of precipitated, rocks; ratio of arenaceous conglomerate, sandstone, shale, and siltstone to limestone, chert, gypsum, calcarenite, and calcilutite.

CLAYEY—Applied to shale beds which have indistinct bedding and approach claystone.

CLAYSTONE—Indurated clay without distinguishable bedding cleavage or fissility.

COQUINA—More or less cemented fossil-shell debris that has been transported some distance.

COQUINOID—Indurated fossil debris accumulated more or less in place.

CROSSBEDDED—Beds characterized by included minor beds that are oblique and inclined to the main stratification.

CROSSLAMINATION—Laminations confined to single beds and inclined to the general stratification. See *laminated.*

CRYSTALLINE—Classification of crystal sizes of crystalline sedimentary rocks follows that used for the crystalline igneous rocks:
coarse-crystalline—over 5 mm
medium-crystalline—1-5 mm
fine-crystalline-0.2-1 mm
aphanitic—under 0.2 mm; not detectable with naked eye
microcrystalline—Aphanitic, with crystals resolvable under ordinary 10-power hand lens; 0.05-0.2 mm cryptocrystalline—individual crystals detectable only with high-power petrographic microscope; under 0.01 mm

DENSE—Tightly cemented clastic rocks or crystalline rocks with very little pore space; used to indicate lack of porosity rather than aphanitic, microcrystalline, or lithographic texture.

DOLOMITIC—Crystalline carbonate rock containing appreciable (but less than 5o percent) dolomite, as estimated from action of dilute HCl.

DOLOMOLDIC—Chert containing molds of dolomite crystals that have been removed by leaching. May be indistinguishable from calcimoldic.

ENCRINITE—Crinoidal limestones or crinoidal coquinas composed primarily of sorted and washed crinoid fragments.

EQUIGRANULAR—Grains and/or crystals almost all of same size.

FACIES—Sedimentary facies, as defined by Moore (1949, p 8) are areally segregated parts of differing nature belonging to any genetically related body of sedimentary deposits.

FELDSPATHIC—Detrital rock containing an estimated 10 percent of feldspars.

FETID—When rock is broken, odor of sulfuretted hydrogen ("rotten egg" odor) is given off.

FLAGS—Thin even beds of rocks that easily separate along depositional planes; may be calcareous, argillaceous, or arenaceous.

FLAKY—Shale breaks into small paper-thin flakes.

FRIABLE—Loosely cemented rocks that crumble or break easily into individual grains.

GALLS—Curled, rounded, or elongated shavings resulting from drying and cracking of mud, which are later enclosed in sandy beds.

GRAIN SIZE—Wentworth classification used for elastic fragments:
boulder—over z56 mm (or 10 1/8 inches)
cobble-64-256 mm (or 2 1/2-10 1/2 inches)
pebble-4-64 mm (or 3/8-2 1/2 inches)
granule-2-4 mm (or 3/16-3/8 inch)
very coarse-grained—1-2 mm
coarse-grained—0.5-1 mm
medium-grained—0.25-0.5 mm
fine-grained—0.125-0.25 mm
very fine-grained—0.0625-0.125 mm
silt—0.004-o.0625 mm; quickly settles in slightly turbulent water
clay—under 0.004 mm; floats in slightly turbulent water

GRAYWACKE—Sandstone with matrix of clay and fine silt exceeding I 0 percent.

JASPER—Reddish, dense, cryptocrystalline, opaque variety of chert.

LAMINAE (laminated)—Very fine sedimentary planes and layers within thicker beds that are discrete units continuous over long lateral distances.

LIMY—Synonym for very calcareous; rock contains almost 5o percent calcite, chiefly as cementing material.

MARL—Intimate mixture of incoherent clay and carbonates, ranging from limy shale to very argillaceous limestone; may be relatively compact.

MICROCOQUINOID—Indurated fossil debris accumulated more or less in place, with bulk of fragments too small to be resolved with naked eye.

MICROGRAINED—Clastic rocks with grains too small to be resolved with naked eye; in most cases on borderline between very fine-grained sand and silt.

MICROLAMINATED—Laminae not clearly resolved without use of hand lens 0r microscope.

MICRO-OOLITE—Oolites or ooids not clearly detectable with naked eye; tiny spheroidal bodies with diameters under 0.05 mm.

PORPHYROBLASTS—Large crystals in matrix of smaller crystals or grains; a pseudoporphyritic texture, the large crystals having formed by partial replacement or recrystallization of the matrix.

PROPYLITIZED—Alteration, chiefly of rocks of andesitic composition, to rocks that appear drab green in hand specimen, and in which primary mafic minerals are replaced by chlorite, serpentine, calcite, sphene, and iron oxides.

QUARTZITE—Hard siliceous sandstone which, when broken, breaks across individual grains.

REDBEDS—Petrographic and genetic name applied to strata which are chiefly of reddish color—mostly sandstones, siltstones, and shales, although some limestones are reddish. Committee on stratigraphic nomenclature (Ashley et al., 1933, p 434) ruled that the term redbeds should be used for the lithologic part of a formational name, if applicable.

RUBBLY—Breaks into rough irregular fragments.

SAND-SHALE RATIO—Ratio of sandstone and conglomerate to siltstone and shale.

SANDY—Rock contains appreciable (but less than 50 percent) sand-sized grains of minerals, usually a mixture of quartz, calcite and others; contrasted with *arenaceous,* which is applied when elastic fragments are chiefly quartz.

SHALE PARTINGS—Paper-thin shale laminae between limestone or sandstone beds.

SHALY—Rock contains appreciable (but less than 50 percent) clay and very fine silt, with fissile bedding.

SILICEOUS—Rock with cement of, or intimate replacement by, silica.

SILTSTONE—Rock composed 0f more than 50 percent silt-sized elastic grains; not applied if grains are chiefly calcite.

SILTY—Rock contains appreciable (but less than 50 percent) silt-sized elastic grains, in most cases predominantly of quartz.

STRINGERS—Narrow irregular vein or filament of mineral obliquely traversing a sedimentary bed of different composition.

STROMATOLITE—Laminated but otherwise structureless body, generally of mound or conical shape, probably of algal origin but not biologically classifiable.

SUBGRAYWACKE—Sandstone with matrix of about 10 percent clay and fine silt.

TUFF—Lithified pyroclastic volcanic rock composed of fragments less than 4 mm in diameter; called volcanic ash when not lithified.

TUFFACEOUS—Rocks with appreciable (but less than 5o percent) fragments of volcanic ash.

TUFF-BRECCIA—Breccia of volcanic rocks with considerable amount of tuff matrix.

VALLEY FILL—Generalized term for relatively unconsolidated detrital sediments filling a preexisting valley.

PLATE 2

VIEWS OF OUTCROPS *IN* RHODES *AND ASH CANYONS*

A. Channel cut in cliff of the Bursum limest0ne on north side of Rhodes Canyon. Bursum and Panther Seep formations are below the distant cliff; Hueco formation crops out above cliff to top of mountain.

B. Section from Fusselman dolomite to basal Pennsylvanian on north side of Ash Canyon. Lower ledges are Fusselman dolomite; slope is on Devonian rocks; ledgy slope is lower Mississipian; cliff, notch, and ledge above are upper Mississippian strata; slope and ledges are basal Pennsylvanian outcrops.

C. Cherty beds of Aleman dolomite in Ash Canyon.

D. Unconformable contact between lower lighter-colored Cutter dolomite and overlying darker Fusselman dolomite in Ash Canyon.

PLATE 3

VIEWS OF OUTCROPS *IN* HEMBRILLO *CANYON*

A. Section from upper beds of Mont0ya group to middle Pennsylvanian strata on north side of canyon. Basal ledgy slope is Aleman dolomite, followed by slope of Cutter dolomite, cliff of Fusselman dolomite, slope of Devonian outcrops, cliff and ledge of Mississippian strata, slope of Derryan beds, and ledgy cliffs of Desmoinesian rocks.

B. Basal Pennsylvanian chert pebble-conglomerate filling channel cut down into Alamogordo member of the Lake Valley formation on north side of canyon.

C. Hills capped by biohermal reefs in Panther Seep formation, north of Upper Hembrillo Spring.

D. Section from Precambrian through Montoya group near mouth of canyon on north side. Basal slope is Precambrian metamorphic rocks; lower dark ledgy cliff is Bliss sandstone; ledgy slope and steep ledgy slope are El Paso group beds; solid dark cliff is Upham and lower Aleman dolomite; upper ledgy slope is upper Aleman and Cutter dolomite. White sands to east, in the distance, are in the Tularosa Valley.

PLATE 4

PHOTOMICROGRAPHS OF SEDIMENTARY ROCKS
(by Ming-Shan Sun)

A. Pennsylvanian coquina limestone (unit H 154), Hembrillo Canyon. Unsorted fossil fragments and fossils cemented by cryptocrystalline calcite. X

B. Pennsylvanian limy sandstone, Derryan age (unit R 96), Rhodes Canyon. Grains of angular quartz and calcite fossil fragments cemented by calcite and minor chalcedony. Grains have a film of ferruginous clayey quartz silt. x 15.

C. Fusselman dolomite (unit H 78), Hembrillo Canyon. Mosaic of subhedral to anhedral dolomite crystals, with scattered euhedral rhombs, ferruginous films, and pore spaces. X 1 5.

D. Upham dolomite, Montoya group (unit H 47), Hembrillo Canyon. Mosaic of subhedral to anhedral dolomite crystals, ferruginous rims, and ghosts of fossils; cut by coarse-crystalline quartz veinlet, which surrounds euhedral double dolomite rhombs outlined by heavy iron oxide rims. x x 5.

E. Oolitic dolomite, El Paso group (unit A 24), Ash Canyon. Mosaic of anhedral dolomite crystals, scattered angular quartz silt, films of iron oxides outlining recrystallized oolites, and scattered glauconite grains partly altered to limonite. X 15.

F. Bliss sandstone (unit H 8), Hembrillo Canyon. Relatively large angular quartz (white) grains, small glauconite (gray) grains and cement, and laminae rich in hematite (black) cement. x 15.

PLATE 5

PHOTOMICROGRAPHS OF *IGNEOUS AND* SEDIMENTARY ROCKS
(by Ming-Shan Sun)

A. Jornada olivine basalt. Euhedral olivine crystals, broken by cracks lined with iddingsite; laths of sodic labradorite in matrix of brownish-black palagonite. Crossed nicols. X 30.

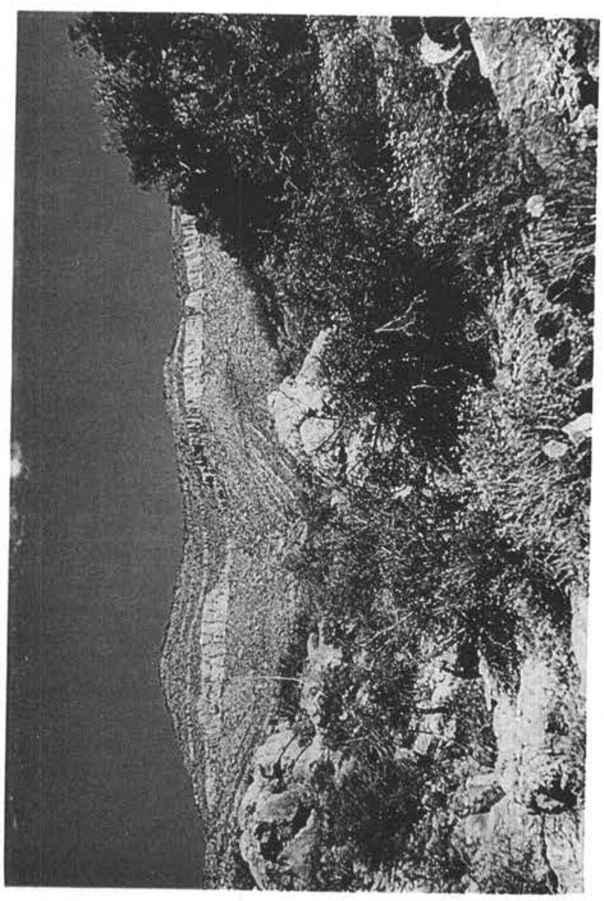
B. Tertiary hornblende andesite dike that cuts unit H 315 in Hembrillo Canyon. Trachytic matrix of andesine laths, scattered magnetite cubes, and phenocrysts (right) of zoned calcic andesine and hornblende; the latter mostly altered to magnetite, chlorite, and calcite. Crossed nicols. X 3o.

C. Siliceous light-brown siltstone, Abo redbeds (unit L89), Love ranch area. Quartz silt (white and gray), chalcedony (gray), calcite (dull gray), hematite (black), and scattered zircon grains. X 3o.

D. Dakota (?) sandstone (unit L 144), Love ranch area. Subrounded to rounded quartz grains, quartz cement, dust rims showing secondary growth of grains, and grains and cement of leucoxene. X 30.

E. Arkosic calcareous sandstone, Panther Seep formation (unit H 253), Hembrillo Canyon. Grains of plagioclase, orthoclase, twinned calcite, quartz, chlorite, aphanitic limestone, and fossil fragments, and grains of micrographic intergrowths of quartz and feldspar; cemented by cryptocrystalline cloudy calcite. Crossed nicols. X 15.

F. Precambrian granite, Rh0des Canyon. Crystals of microcline, quartz, orthoclase, sodic andesine, muscovite, apatite, and magnetite. Quartz also occurs as myrmekitic intergrowths in plagioclase (cloudy) and as tiny poikilitic crystals in potassium feldspars. Crossed nicols. X 15.



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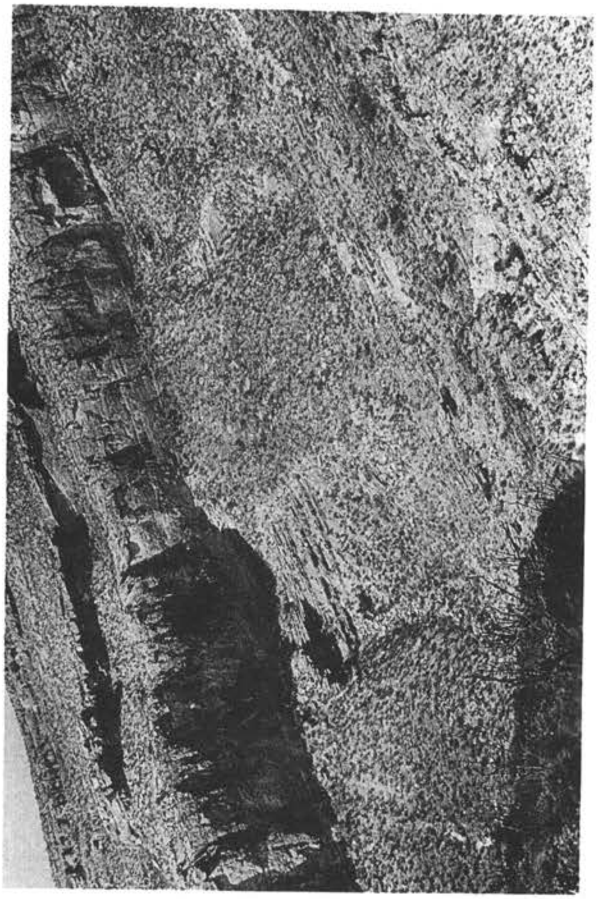

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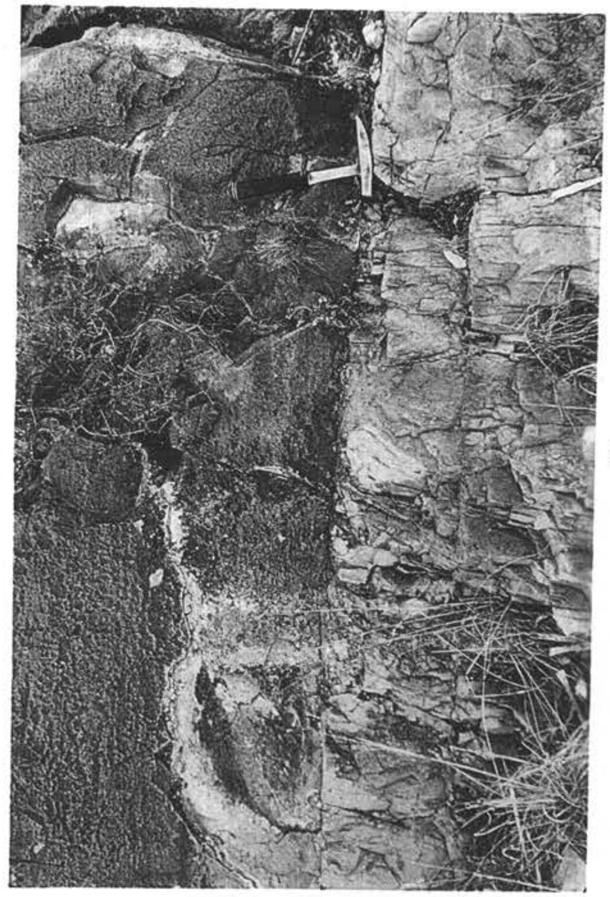

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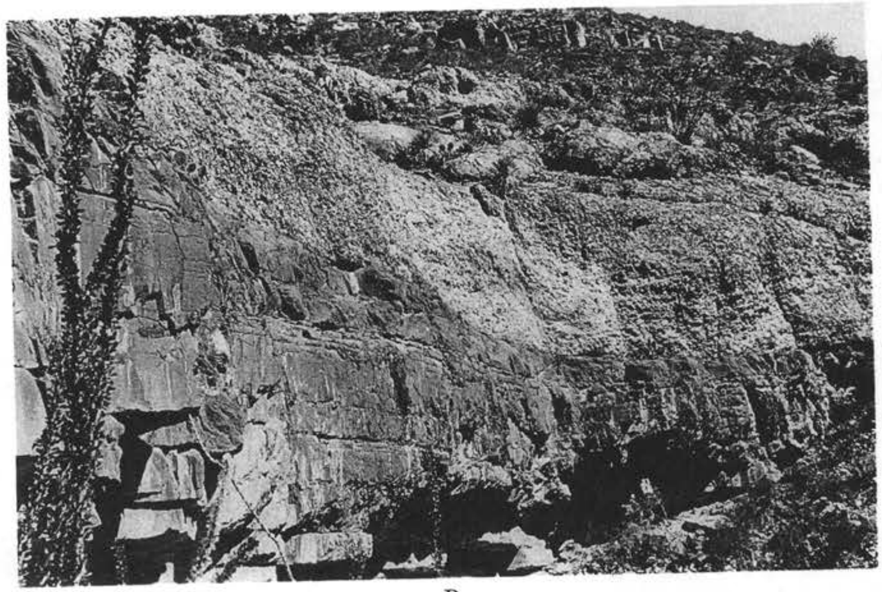
Plate 2. Views of outcrops in Rhodes and Ash Canyons.



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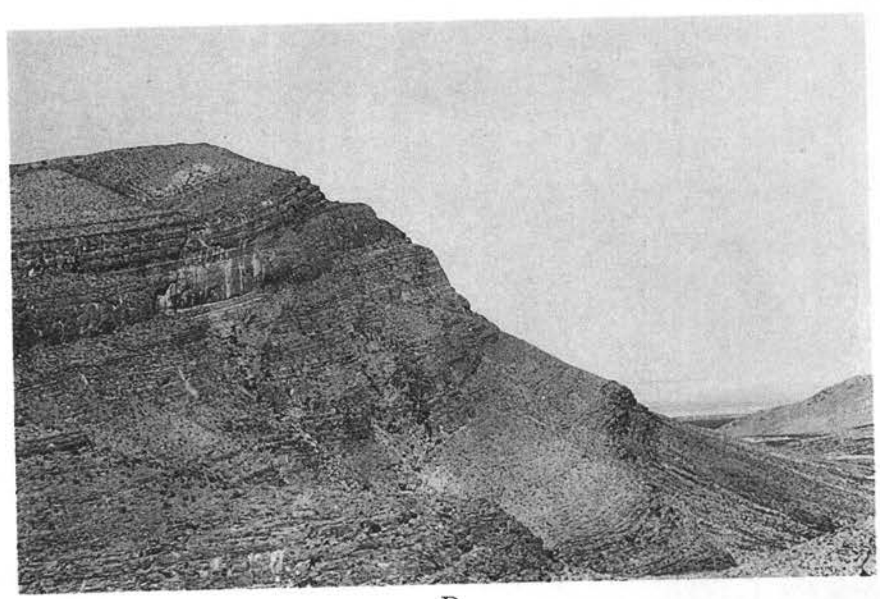

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Plate 3. Views of outcrops in Hembrillo Canyon.

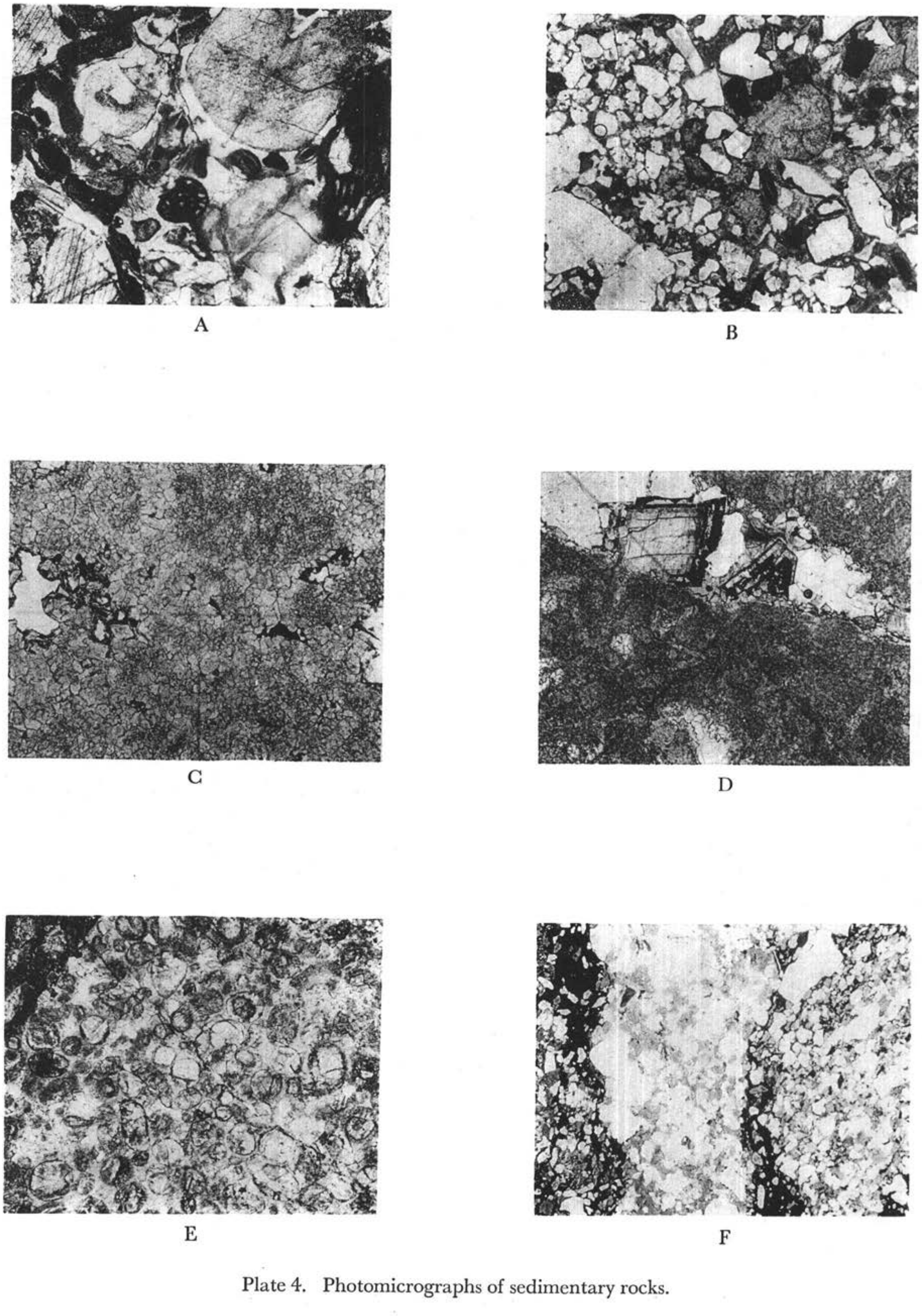
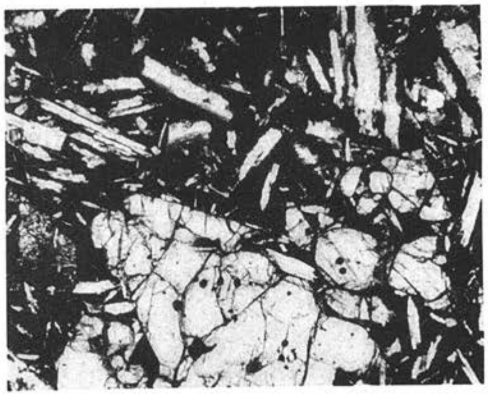


Plate 4. Photomicrographs of sedimentary rocks.



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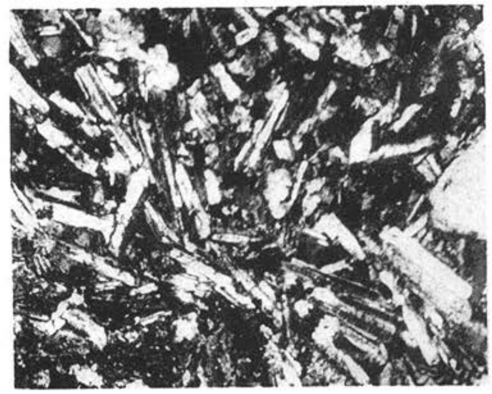

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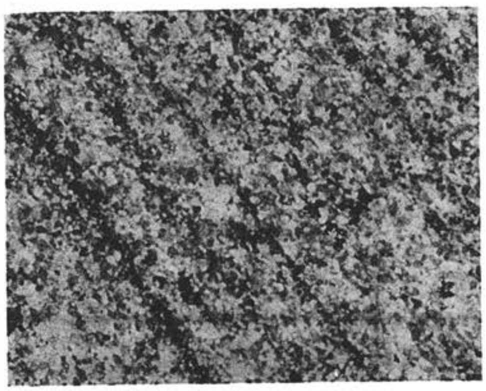

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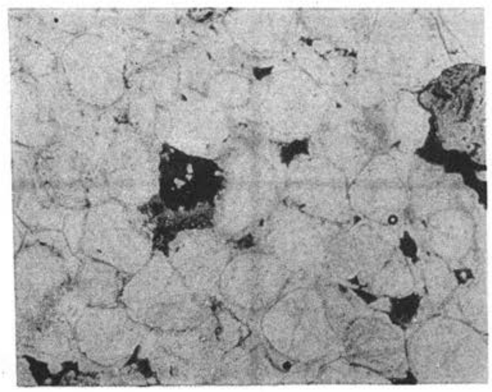

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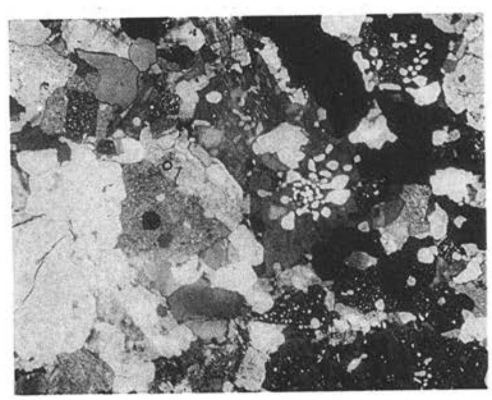

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Plate 5. Photomicrographs of igneous and sedimentary rocks.

Descriptions of Measured Sections

Descriptions of six sections are presented below as condensed from more detailed descriptions on file with the New Mexico Bureau of Mines and Mineral Resources, and are illustrated by the various columnar sections (figs 2-4, 8-14; pl 1). Lithologic units have been grouped as much as possible without losing adequate summation of the sedimentary rocks exposed in the mountain range. The unit numbers provide a ready cross reference between the columnar sections and the descriptions of the measured sections.

Seven characteristics of the rocks are listed, if pertinent: (1) rock name; (2) compositional adjective and mineral composition, i.e., cements, such as calcareous, siliceous, ferruginous, clayey, and detrital minerals, such as quartz, micas, calcite, feldspar, pyrite, rock fragments, chert; (3) color on fresh fracture, as well as banding and mottling, generalized to gray if not mentioned with range of light gray to medium gray; (4) grain size, shape, and roundness, or crystallinity; (5) bedding, as to thickness and mode; (6) special characteristics, such as chert nodules, mud cracks, concretions, crosslamination, fossils; (7) topographic expression, weathering color and surface, hardness and degree of consolidation.

SECTION C. DAKOTA (?) SANDSTONE AND DOCKUM FORMATION

Near L. D. Cain ranch, SE corner NE¼ sec. 11, T. 11 S., R. 3 E.

Unit no.	Description	Thickness (feet)
	Top of section on low hill amid pediment gravels; erosion surface cut on Dakota (?) sandstone	
	Dakota (?) sandstone	
C 11	Sandstone, siliceous, porous, whitish to pale-orange, fine- to medium-grained, crossbedded, thin-bedded; shaly lenses	10
C 10	Sandstone, siliceous, whitish purple-speckled, very fine-grained, lenticular, crosslaminated, medium-bedded; ledges	4
C 9	Sandstone, conglomeratic, calcareous, porous, white purple-tinted, coarse-grained; pebbles of quartz, chert, limestone	1
C 8	Sandstone, slightly calcareous, light-brown, fine-grained, platy; laminae with minor iron oxide, feldspar, chlorite	6
C 7	Sandstone, porous, light-gray, fine-grained, medium-bedded; ledges; surface speckled by silt-size magnetite-limonite	9
C 6	Sandstone, slightly calcareous, porous, light- to yellowish-gray, speckled by limonitic spots, fine- to medium-grained; quartz sand, friable to hard, cross-laminated to crossbedded; medium- to thick-bedded lenticular ledges	10
	Total thickness of remnant Dakota (?) sandstone	40
	Unconformity	
	Dockum formation	
C 5	Clay, calcareous, silty, yellowish, reddish, and greenish; limonitic stringers; unit ranges from ½ to 4 feet in thickness	2
C 4	Upper claystone, calcareous, silty, reddish with greenish bands; lower third is siltstone, micaceous, sandy, grayish-red	9
C 3	Siltstone, calcareous, micaceous, sandy, reddish-brown; silty feldspathic sandstone lenses; top 2 feet is grayish-red clay	11
C 2	Claystone, calcareous, silty, pale reddish-brown; laminae and lenses of light-gray and greenish-gray clay	3
C 1	Mostly covered soft pale-red silty shale and claystone; unconformable on San Andres formation	27
	Total thickness of Dockum formation	52

SECTION R. PALEOZOIC FORMATIONS IN RHODES CANYON AREA

San Andres formation measured west of Rhodes Pass, beginning at NE¼SW¼ sec. 29, T. 12 S., R. 2 E. Yeso formation measured on west side of Wood Ranch Valley and near Gyp Spring. Abo redbeds, Hueco formation, Bursum formation, Pennsylvanian rocks, Lake Valley formation, Devonian formations, Montoya group, El Paso group, and Bliss sandstone measured along Rhodes Canyon.

Unit no.	Description	Thickness (feet)
	Top of section on ridge crest; erosion surface cut on San Andres formation	
	San Andres formation	
R 421	Limestone, medium-gray, aphanitic; medium-bedded ledges capping ridge; gastropods, nautiloids; calcite-filled vugs	10
R 420	Limestone, light-gray, aphanitic to coarse-crystalline, medium-bedded; ledges; fossiliferous; calcite-filled vugs	52
R 419	Limestone, medium-gray, fine-crystalline, fetid, fossiliferous, medium-bedded; broken ledges; large coiled nautiloids	15
	Section traced to next ridge, 4,500 feet to west, NE¼-SE¼ sec. 30, T. 12 S., R. 2 E.	
R 418	Limestone, medium dark-gray, aphanitic, fetid, medium-bedded; ledges; fossiliferous nautiloids, brachiopods; caps ridge	10
R 417	Limestone, argillaceous, medium-gray, aphanitic, thin-bedded; rubbly ledges; medial zone of brownish, silicified fossils	55
R 416	Limestone, medium dark-gray, fine-crystalline, fossiliferous, medium-bedded; top is massive ledge; calcite-filled vugs	20
R 415	Limestone, light-gray, aphanitic, fossiliferous, fetid; numerous calcite-filled vugs; beds ½-2 feet thick; ledges	15
R 414	Limestone, medium-gray, aphanitic to fine-crystalline, fetid, medium-bedded; ledges; scattered fossils	28
R 413	Limestone, light-gray; aphanitic matrix cementing numerous fossil fragments; calcite-filled vugs; thick-bedded ledges	16

R 412	Limestone, medium-gray, weathers light-gray, aphanitic, medium-bedded; ledges; fossiliferous; calcite-filled vugs	26
R 411	Limestone, light-gray, aphanitic with coquinoid lenses, medium-bedded; ledges; top of dark-gray weathering ledges	9
R 410	Limestone, medium dark-gray, aphanitic to medium-crystalline, fetid; one massive bed; abundant *Dictyoclostus*	6
R 409	Limestone, slightly argillaceous, medium dark-gray, aphanitic, fetid, medium-bedded; shale partings, rubbly ledges	16
R 408	Limestone, medium dark-gray, fine-crystalline, fetid; massive ledges; *Bellerophon, Dictyoclostus, Euomphalus,* nautiloids	51
R 407	Limestone, silty, carbonaceous, medium- to dark-gray, aphanitic to fine-crystalline, platy to very thin-bedded; slope	3
R 406	Limestone, arenaceous laminae, medium dark-gray, aphanitic to medium-crystalline, thick-bedded; cliff	15
R 405	Limestone, dark-gray, porous, fine-crystalline, fetid; scattered quartz grains; thick-bedded ledges; calcite-filled vugs	5
R 404	Limestone, argillaceous, medium-gray, aphanitic; numerous fossil fragments; very thin-bedded slope; shale partings	5
R 403	Limestone, dark-gray, porous, fine-crystalline, fetid; scattered quartz grains; massive cliff; calcite-filled vugs	15
R 402	Limestone, argillaceous, dark-gray, fine-crystalline, fetid, thick-bedded	19
R 401	Limestone, dark-gray, porous, fine-crystalline, fetid; scattered quartz grains; massive cliff; calcite-filled vugs	16
R 400	Limestone, argillaceous, medium dark-gray, fetid, medium-crystalline; thick to massive-bedded cliff	25
R 399	Limestone, dark-gray, porous, fetid, fine-crystalline; scattered quartz grains; calcite-filled vugs; thick-bedded ledges	20
R 398	Limestone, medium dark-gray, aphanitic with coquinoid lenses; scattered quartz grains, calcite-filled vugs; massive ledges; base of dark-gray beds	25
R 397	Limestone, arenaceous, porous, medium-crystalline; thin-bedded ledges; lenses of arenaceous calcarenite and calcareous sandstone; quartz and calcite grains 0.2-0.3 mm, subrounded; weathers brownish, conspicuously darker and coarse textured	3½
R 396	Limestone, medium light-gray, fine- to medium-crystalline, porous; thin- to medium-bedded, rubbly ledges	16½
R 395	Limestone, dolomitic, porous, light-gray, fine-crystalline; medium-bedded ledges, weathers brownish; calcite-filled vugs	10
R 394	Limestone, dolomitic, porous, medium dark-gray, fetid, medium-crystalline; basal beds massive, upper thin-bedded	9
R 393	Limestone, light-gray, fine- to medium-crystalline, very thin-bedded; rubbly ledges	5
R 392	Limestone, medium dark-gray, aphanitic to medium-crystalline; thick-bedded ledges	11
R 391	Limestone, arenaceous, dolomitic lenses, medium dark-gray, fine-crystalline, fetid; crosslaminated by calcareous quartz silt; thin-bedded	19
R 390	Limestone, silty, light-gray, fine-crystalline; thin- to medium-bedded rubbly ledges	6
R 389	Limestone, light-gray, fine-crystalline, fetid, carbonaceous films; thin-bedded; calcite-filled vugs; breccia lenses	10
R 388	Limestone, dolomitic, brown to light-gray, fine-crystalline, fossiliferous; medium-bedded ledges	3½
	Partial thickness of upper limestone of San Andres formation	570½
	Glorieta sandstone member	
R 387	Sandstone, light-brown to moderate-yellow, silty to fine-grained; platy, lenticular, crosslaminated beds; friable; slope	12
R 386	Limestone, dolomitic, basal arenaceous, light-gray banded brown, fine-crystalline, fetid; thick-bedded ledges; coquina lenses	10½
R 385	Sandstone, calcareous, brown to yellow, fine-grained to silty; platy lenticular crosslaminated friable beds; slope	7-14
	Total thickness of Glorieta sandstone member	31½
	Total thickness of San Andres formation	602
	Section moved 5.8 miles northeast to SE¼SE¼ sec. 1, T. 12 S., R. 2 E., on west side of Wood Ranch Valley.	
	Yeso formation	
	Joyita sandstone member	
R 384	Sandstone, calcareous, silty, friable, pale reddish-brown mottled light-gray and greenish-gray, porous; very fine-grained subrounded to subangular quartz coated by calcareous hematitic silt; thin lenticular beds; slope	55-109
	Canas gypsum member	
R 383	Gypsum, massive to banded, light-gray, medium-crystalline, medium- to thick-bedded; rounded ledges in gullies	135
R 382	Interbedded gypsum and limestone, silty, medium-gray to brownish, fine-crystalline, thin-bedded; slopes and ledges	40
R 381	Interbedded: gypsum, arenaceous, silty; sandstone, silty, calcareous, light-red, fine-grained, friable; thin lenticular beds	35
R 380	Interbedded gypsum and limestone, silty, light-gray to brownish, fine-crystalline, thin-bedded; slopes and ledges	25
	Total thickness of Canas gypsum member	235
	Torres member	
R 379	Limestone, silty, medium light-gray, fine-crystalline; gypsum veinlets; thin-bedded; ledges	6
R 378	Gypsum, massive, light-gray mottled, medium-crys-	

	talline; sandstone and limestone laminae; medium-bedded; rounded ledges	3
R 377	Limestone, very silty, porous, gray to brownish banded; fine-crystalline, medium-bedded; lenses of calcareous siltstone	11
R 376	Limestone, silty, gray mottled brown, fine-crystalline, medium-bedded ledges; weathers with yellow to red tint	21
R 375	Siltstone, calcareous, hard, light-brown banded light gray; medium-bedded ledges	3
R 374	Sandstone, dark yellowish-orange to light-gray, silty to very fine-grained, friable; fissile to platy slope	4
R 373	Gypsum, light-gray mottled, medium-bedded, medium-crystalline; limestone laminae; medial 2-foot silty limestone ledge	20
R 372	Limestone, medium dark-gray, dense, fine-crystalline, very thin- to medium-bedded; ledges	7
R 371	Limestone, fine-crystalline, coarse-crystalline coquinoid lenses, fetid, porous; medium-bedded ledges; medial siltstone	20
R 370	Upper silty gypsiferous dark-gray thin-bedded limestone; lower mottled silty massive gypsum	5
R 369	Siltstone, calcareous, light-gray, platy to medium-bedded; upper 2-foot hard ledge; lower slope	10
R 368	Limestone, silty, medium dark-gray, fine-crystalline, platy to thin-bedded; ledges	5
R 367	Siltstone, calcareous, gypsiferous, medium light-gray, fissile; slope; partly covered	10
R 366	Limestone, silty, gray, fine-crystalline, medium-bedded; hard ledges; grades down into siltstone	13
R 365	Siltstone, calcareous, light-gray, porous, massive to medium-bedded; weathers light brown	8
R 364	Gypsum, light-gray mottled, fine-crystalline, medium-bedded; rounded slope; laminae of sandy siltstone	79
R 363	Siltstone, calcareous, gypsiferous, light-brown to light-gray, friable, porous, unbedded; slope	25
R 362	Limestone, silty, carbonaceous, dark-gray, aphanitic; basal 2-foot bed, rest thin-bedded; rubbly shale partings	10
R 361	Siltstone, calcareous, gypsiferous, light-gray to light-brown, very thin lenticular beds; slope	11
R 360	Gypsum, light-gray mottled, fine- to medium-crystalline; medium-bedded, rounded ledges; silty sandy laminae	14
R 359	Sandstone, calcareous, silty, grayish-orange, fine-grained, friable; platy to thin lenticular beds; slope	15
R 358	Gypsum, light-gray mottled, medium-crystalline, medium-bedded; slope; laminae of silty limestone and calcareous siltstone	23½
R 357	Limestone, silty, gypsiferous, porous, gray to dark-gray, medium-crystalline, thin-bedded; ledges and slopes	16½
R 356	Gypsum, silty, equigranular, light-gray mottled medium-gray, fine-crystalline, medium-bedded; slope	21
R 355	Siltstone, calcareous, light-brown, friable; slope; medial limestone, silty, fine-crystalline, porous; thin-bedded ledges	11
R 354	Gypsum, light-gray mottled, medium-crystalline, medium-bedded; laminae of limestone and silty sandstone	28
R 353	Limestone, silty, gypsiferous, fine-crystalline, fetid, porous; medium-bedded ledges; basal beds cap cuesta	24
R 352	Limestone, gypsiferous, light-gray, medium-crystalline, fossiliferous, porous, fetid; medium lenticular beds; rubbly ledges	11
R 351	Interbedded gypsum and silty gypsiferous limestone, thin-bedded; slopes and ledges	15
R 350	Gypsum, equigranular, light-gray mottled, fine-crystalline, medium-bedded; silty sandy laminae; slope	10
R 349	Limestone, silty, gypsiferous, aphanitic to fine-crystalline; thin-bedded ledges; many veinlets of gypsum	10
R 348	Limestone, silty, fine-crystalline, fetid, fossiliferous, thin lenticular beds; shale partings; top 5 feet is massive ledge	30
R 347	Siltstone, calcareous, gray to brownish, hard, fissile to medium-bedded; ledges and slopes; partly covered	20
R 346	Gypsum, equigranular to acicular, whitish, porous to dense, medium-bedded; rounded slopes; calcareous siltstone laminae	89½
R 345	Limestone, arenaceous, gypsiferous, light-gray, medium- to coarse-crystalline, fetid, porous, thin-bedded; cliff	11
R 344	Siltstone, calcareous, light-gray, weathers light brown, porous; thin lenticular beds; rounded ledges	20½
R 343	Gypsum, equigranular, light-gray mottled medium gray, fine-crystalline, medium-bedded; rounded ledges; sandy silty laminae	20
R 342	Siltstone, calcareous, light-gray to light-brown, soft to hard, unbedded to massive; capped by silty limestone	9
R 341	Gypsum, equigranular, mottled gray, fine-crystalline; laminae of silty sandstone; thin- to medium-bedded; rounded ledges	5
R 340	Siltstone, calcareous, light-red, soft, unbedded to fissile, clayey; slope	12
R 339	Gypsum, silty, equigranular, mottled gray, thin- to medium-bedded; rounded slope	13
R 338	Siltstone, calcareous, light-brown, thin-bedded to fissile; ledgy slope	5
R 337	Gypsum, silty, equigranular, light-gray mottled medium gray, fine-crystalline, thin- to medium-bedded; rounded ledges	19
R 336	Shale, calcareous, silty; intercalated light-gray and light-red laminae; fissile; slope	6
R 335	Gypsum, silty laminae, equigranular, light-gray banded medium-gray, fine-crystalline, medium-bedded; rounded ledges	5
R 334	Sandstone, calcareous, grayish-orange, silty to fine-	

	grained, friable, platy to thin-bedded; slope	13
R 333	Gypsum, equigranular, light-gray mottled, fine-crystalline; silty sandstone laminae; thin- to medium-bedded; rounded ledges	42
R 332	Siltstone, calcareous, sandy, light-gray, porous, unbedded to fissile; partly covered slopes and ledges	21
R 331	Limestone, arenaceous, gypsiferous, dark-gray, medium-crystalline, fetid; medium- to thick-bedded ledges	22
R 330	Siltstone, calcareous, sandy, gray, soft, fissile; medial 5-foot sandstone, silty, light-brown, thin-bedded; slope	10
R 329	Gypsum, light-gray, medium-crystalline, equigranular; rounded ledge with lower slope	12
R 328	Sandstone, calcareous, silty, light-red, fine-grained, friable, very thin lenticular beds; partly covered slope	20
R 327	Gypsum, white to light-gray, medium-crystalline to acicular, porous to dense, medium-bedded; slope	10
R 326	Sandstone, partly covered, silty, calcareous, grayish-orange, fine-grained, friable; thin lenticular beds; slope	15
R 325	Gypsum, light-gray to white, acicular, porous to dense, minor admixed silt; rounded slope	5
R 324	Limestone, arenaceous, silty, porous, light-gray, fine-crystalline, medium-bedded; ledges capping low cuesta	3½
R 323	Sandstone, partly covered, silty, calcareous, grayish-orange, fine-grained, friable, thin-bedded; slope	11½
R 322	Limestone, arenaceous, porous, fine-crystalline; medium-bedded ledges grade laterally into calcareous sandy siltstone	2
R 321	Gypsum, white to light-gray, medium-crystalline, acicular, porous to dense, minor silt; rounded slope	13
	Total thickness of Torres member	935

Section moved 2.8 miles to southwest to center of SW¼ sec. 15, T. 12 S., R. 2 E., ½ mile south of Gyp Spring.

Meseta Blanca member

R 320	Sandstone, calcareous, silty, grayish-orange, fine-grained, friable; platy to thin lenticular beds; slope	20
R 319	Sandstone, silty, gypsiferous, argillaceous, light-red and light-gray, porous, fine-grained, friable, fissile; slope	60
R 318	Interbedded: siltstone, calcareous, pinkish; sandstone, light-red, silty, fissile; mostly covered slope	78
R 317	Sandstone, silty, argillaceous, friable, light-red to orange-pink, fine-grained; medium lenticular laminated beds; lenses of light-gray sandstone and of hard calcareous moderate-pink siltstone; slope	100
R 316	Partly covered, intercalated, friable sandy siltstone and silty sandstone, reddish-orange, partly calcareous; slope	90
R 315	Siltstone, sandy, grayish-olive, platy to very thin-bedded; broken ledges	6
	Total thickness of Meseta Blanca member	354
	Total thickness of Yeso formation	1579

Section moved 4.9 miles south-southeast to center of west line SW¼ sec. 12, T. 13 S., R. 2 E., on ridge top south of Rhodes Spring.

Abo redbeds

R 314	Siltstone, brown to reddish-brown, hard, crosslaminated, medium- to thick-bedded; caps dip slope	15
R 313	Siltstone, micaceous, grayish-red, hard, crosslaminated; beds lenticular, medium-bedded; ledge	20
R 312	Interbedded: siltstone, micaceous, grayish-red, crosslaminated; shale, calcareous, silty, grayish-red; ledges and slopes	12
R 311	Mostly covered shale, calcareous, silty, grayish-red, fissile to unbedded; slope; medial 1-foot siltstone	22
R 310	Siltstone, micaceous, grayish-red, crosslaminated, hard; lenticular medium-bedded ledges	12½
R 309	Interbedded: siltstone, calcareous, grayish-red, hard, thin-bedded; shale, silty, dark reddish-brown, blocky	14½
R 308	Shale, silty, dark reddish-brown, blocky; several ledges of siltstone, siliceous, grayish-red, hard, crosslaminated	44
R 307	Siltstone, calcareous, grayish-red, hard, crosslaminated; thin-bedded ledges; medial 10 feet is silty calcareous shale	55
R 306	Shale, partly covered, calcareous, silty, grayish-red mottled greenish, fissile to unbedded; slope	18
R 305	Siltstone, siliceous, grayish-red, hard, crosslaminated; medium- to thick-bedded ledges	23½
R 304	Mostly covered shale, calcareous, silty, grayish-red, fissile to clayey; slope	58½
R 303	Siltstone, conglomeratic, calcareous, hard, grayish-red mottled pale green; angular pebbles of chert and limestone; ledge	1
R 302	Shale, calcareous, silty, grayish-red, fissile; slope; medial 18-inch siltstone ledge, pale reddish-brown, hard	9
R 301	Siltstone, calcareous, micaceous, pale reddish-brown, crosslaminated, thick-bedded; cliff with medial shaly notch	16
R 300	Shale, calcareous, silty, grayish-red, scattered mottling of grayish green, fissile to clayey; slope	34
R 299	Partly covered shale, silty, calcareous, dark reddish-brown; nodules of dusky-red calcareous siltstone; slope	29
R 298	Siltstone, calcareous, grayish-red, hard, thick-bedded, crosslaminated; cliff; scattered limestone pebbles	19½
R 297	Siltstone, calcareous, micaceous, grayish-red; hard thick lenticular beds; ledge or cliff; calcite-filled vugs	9
R 296	Shale, silty, grayish-red to dark reddish-brown, clayey to fissile; scattered calcareous pellets; slope	24

R 295	Siltstone, conglomeratic, calcareous, grayish-red to pale-green; lenticular medium-bedded ledges; subrounded limestone, quartz, and chert pebbles	1½
R 294	Limestone, very silty, micaceous, grayish-red to pale-green, aphanitic; nodular bed; intercalated calcareous siltstone	1
R 293	Shale, partly covered, calcareous, silty, grayish-red to dark reddish-brown; few nodules of calcareous siltstone	31
R 292	Interbedded calcareous: shale, silty, dark reddish-brown; siltstone, micaceous, hard, grayish-red; medium-bedded ledges	20
R 291	Shale, calcareous, silty, grayish-red; nodules of silty aphanitic grayish-red limestone up to 10 inches long	25
R 290	Shale, partly covered, calcareous, silty, dark reddish-brown, fissile; slope; scattered small limestone concretions	24
R 289	Siltstone, calcareous, micaceous, grayish-red; fissile to single ledge	1
R 288	Shale, calcareous, silty, grayish-red; nodules and lenses of silty grayish-red aphanitic limestone	15
R 287	Shale, calcareous, silty, grayish-red to dark reddish-brown; scattered nodules of calcareous siltstone; slope	135
R 286	Shale, calcareous, silty, grayish-red to dark reddish-brown; scattered calcareous concretions; fissile; slope	50
R 285	Shale, calcareous, silty, dark reddish-brown mottled light olive-gray; scattered calcareous siltstone nodules; slope	37
R 284	Siltstone, calcareous, light brownish-gray to pale reddish-purple; very thin-bedded nodular rubbly ledges	3
R 283	Shale, calcareous, silty, dusky-red grading down into light olive gray, fissile to blocky; slope	3½
R 282	Shale, calcareous, silty, light olive-gray, hard, blocky; capped by 6-inch ledge of limestone, silty, gray, aphanitic	6½
R 281	Shale, calcareous, silty, dark reddish-brown mottled light olive gray, fissile, slope; scattered siltstone nodules	30
R 280	Siltstone, calcareous, dark reddish-brown to light olive-gray; thin lenticular beds; shale partings	7
R 279	Shale, calcareous, silty, mottled light olive gray and dark reddish-brown; clayey to blocky	8
	Total thickness of Abo redbeds	835
	Hueco formation	
R 278	Interbedded: shale, calcareous, silty, fissile; limestone, silty, shaly, dark-gray, fine-crystalline, fossiliferous, thin-bedded	4
R 277	Limestone, argillaceous, dark-gray; lenses of arenaceous calcarenite and of pelecypod-brachiopod coquina; medium-bedded	6
R 276	Limestone, argillaceous, dark-gray, hard; grades up into interbeds with shale, calcareous, dusky-yellow	5
R 275	Siltstone, calcareous, olive-gray to grayish-red; lenses of calcarenite near top; basal 6-inch limestone, nodular	10
R 274	Shale, silty, grayish-red; upper beds light olive gray; nodules of argillaceous limestone; fissile; slope	22½
R 273	Shale, silty, grayish-red to brownish-gray; limestone nodules; basal 18 inches calcilutite ledge; top 6 inches is nodular limestone	7½
R 272	Basal argillaceous aphanitic yellowish-weathering limestone ledge; upper hard calcareous grayish-red thin-bedded siltstone	5
R 271	Interbedded limestone and shale: limestone, argillaceous, medium- to light-gray, aphanitic, nodular to medium-bedded; shale, calcareous, dusky-yellow to dark-gray, fissile to clayey; ledges and slopes	30
R 270	Calcarenite, arenaceous, grayish-brown, medium-grained; of calcite, quartz, and limonitic silt; hard lenticular bed; ledge	1½
R 269	Limestone, argillaceous, grayish-brown, medium-crystalline; massive ledges grading down into silty calcareous shale	12
R 268	Calcarenite, dusky-yellow to dark-gray, fine- to medium-grained, grains subrounded, fossiliferous, medium-bedded; ledges	2½
R 267	Shale, yellowish, fissile to clayey; slope; 2 ledges of limestone, argillaceous, yellowish to dark-gray, fossiliferous	22
R 266	Limestone, dark-gray, aphanitic; thin- to thick-bedded ledges; fossiliferous; top beds with nodules of chert; silty light-brown calcarenite lenses; *Pseudoschwagerina rhodesi, Schwagerina* aff. *S. andresensis*	12
	Section moved 9,000 feet north-northwest to center SE¼ sec. 35, T. 12 S., R. 2 E., about ¼ mile northeast of Red House Spring.	
R 265	Shale, calcareous, dark-gray, fissile; lenses and medial ledge of calcarenite, dark-gray, algal, fine-grained	15
R 264	Interbedded: shale, calcareous, mottled purplish; slopes; limestone, argillaceous, aphanitic; thin- to medium-bedded ledges	25½
R 263	Shale, partly covered, calcareous, light-gray, fissile to clayey; slope	16
R 262	Calcarenite, micaceous, silty, grayish-red, fine-grained, crosslaminated; massive ledge; basal shaly fossiliferous limestone	3½
R 261	Shale, calcareous, light-gray laminated pale reddish brown, fissile; slope; laminae of light-brown aphanitic limestone	6
R 260	Calcarenite, coarse-grained, coquinoid; medium-bedded ledges; medial reddish shale; basal coarse-crystalline limestone	8
R 259	Interbedded silty, calcareous: shale, greenish-gray; subgraywacke, micaceous, dark grayish-green, very fine-grained	10
R 258	Shale, silty, calcareous, greenish-gray, fissile; slope; intercalated thin limestone beds, argillaceous, weather greenish	3½
R 257	Calcarenite, arenaceous, medium- to coarse-grained; subangular calcite, quartz, chert; limestone and chert pebble conglomeratic lenses	2½

R 256	Shale, silty, calcareous, greenish-gray, fissile; slope; limestone interbed, aphanitic, fossiliferous, weathering greenish	5½
R 255	Limestone, cherty, dark-gray, fine-crystalline, medium- to thick-bedded ledges; *Schwagerina* aff. *S. andresensis*	18
R 254	Shale, calcareous, gray, reddish-brown, dusky-yellow; calcareous nodules; fissile to blocky; slope	14½
R 253	Shale, calcareous, light- to greenish-gray; slope; grades up into limestone, silty, aphanitic, nodular; thin-bedded ledges	14½
R 252	Upper sandstone, calcareous, micaceous, greenish, fine-grained, crosslaminated; calcarenite lenses; lower sandy calcareous micaceous greenish shale	8
R 251	Shale, calcareous, greenish-gray, fissile; carbonaceous films; slope; lower shaly limestone laminae; upper foot sandy	7
R 250	Limestone, medium dark-gray, aphanitic, medium-bedded; ledges; upper foot conglomeratic, coquinoid, nodular	5½
R 249	Shale, calcareous, greenish-gray, blocky; limestone concretions; weathers yellowish to greenish; slope	8½
R 248	Limestone, silty, brownish-gray, fine-crystalline; medium-bedded ledges; silty calcarenite lenses, micaceous, feldspathic	3
R 247	Limestone, dark-gray, aphanitic; many fossil fragments; thin- to medium-bedded ledges; top 3 feet is calcareous shale	11½
R 246	Shale, light-gray to reddish, fissile; slope; nodules and lenses of argillaceous fossiliferous limestone	6½
R 245	Limestone, dark-gray, aphanitic; medium-bedded ledges; basal 30 inches is light-gray calcareous clayey shale	9
R 244	Upper limestone, argillaceous, gray to dark-gray, aphanitic, fossiliferous; thin nodular beds; lower yellowish calcareous shale	6
R 243	Limestone, dark-gray, aphanitic; silty fossiliferous lenses; thin- to thick-bedded rubbly ledges; weathering brownish	14
R 242	Shale, calcareous, light-gray, clayey; medial 30 inches calcilutite, dark-gray, fossiliferous, chert flakes; sandy laminae	6
R 241	Limestone, coquinoid, oolitic, olive-gray; thick-bedded ledges; top 6 inches is crosslaminated friable calcarenite	7
R 240	Limestone, top argillaceous, aphanitic, thin nodular beds; ledges; lenses of algal and limestone pebble-conglomerate	4½
R 239	Shale, calcareous, yellowish to reddish, fissile; slope; medial 3½ feet is limestone, silty, aphanitic, fossiliferous, nodular	7½
R 238	Calcarenite, arenaceous, silty, micaceous, purplish to gray, very fine-grained, fossiliferous, thin-bedded; calcareous sandstone lenses	6
R 237	Shale and claystone, purplish to greenish, fissile to blocky; slope; upper beds silty with sandy laminae	18
R 236	Upper calcarenite, silty, purplish, fine-grained; algae and fossil fragments; nodular ledge; lower greenish calcareous shale	2
R 235	Shale, calcareous, light-gray, clayey to fissile; slope; capped by 1-foot limestone of large colonial corals	4
R 234	Limestone, algal calcarenite, light-gray, fine- to very coarse-grained; lenses of limestone pebble-conglomerate with a few light-brown silicified nodules; to east, in a channel fill, limestone boulder-conglomerate is 2-40 feet thick	1
	Total thickness of Hueco formation	417½

Unconformity

Bursum formation

R 233	Limestone, aphanitic, thick-bedded, ledges; lenses of algal coquinoid calcarenite, medium- to very coarse-grained	10
R 232	Limestone, medium light-gray to dark-gray, fine- to coarse-crystalline, somewhat porous; wavy indistinct bedding, 2-4 feet apart; vertical cliff; numerous small fossils and fragments; algal lenses; recrystallized zones	55

Section moved 3,100 feet east-southeast to center W½SE¼ sec. 1, T. 13 S., R. 2 E., ¾ mile northeast of Rhodes Spring.

R 231	Interbedded silty: shale, calcareous, reddish, greenish, gray; limestone, olive, purplish, brownish, aphanitic, medium-bedded	14
R 230	Shale, calcareous, lower gray, upper red-purple and greenish, fissile; scattered pelecypods; limestone lenses	36
R 229	Limestone, dark-gray, laminated, fine-crystalline, thin- to thick-bedded; ledges; many tiny fossil fragments and algae	15
R 228	Interbedded: shale, calcareous, silty, fissile; limestone, silty, medium-gray, aphanitic, thin-bedded; ledges	25½
R 227	Shale, partly covered, calcareous, silty, medium-gray, fissile; slope; weathers light gray	24½
R 226	Limestone, silty, medium-gray, aphanitic; scattered fossil fragments; nodular thin to medium beds; ledgy slope	18
R 225	Upper limestone, argillaceous, aphanitic, very thin-bedded rubbly ledges; lower shale, calcareous, micaceous; nodular slope	14
R 224	Interbedded: calcarenite, arenaceous, silty, micaceous, fine-grained, medium-bedded; shale, very calcareous, silty, micaceous, calcilutite lenses	23
R 223	Interbedded: shale, calcareous, silty, fossiliferous, fissile; sandstone, calcareous, micaceous, fine-grained, thin-bedded	5
R 222	Sandstone, calcareous, light-brown, fine- to coarse-grained, thin-bedded; broken ledges; lenses of shale, sandy, calcareous	5
R 221	Calcarenite, fine- to medium-grained; very thin-bedded laminated ledges; top foot is limestone pebble-conglomerate	7

R 220	Limestone pebble-conglomerate; lenticular massive beds; subrounded to angular pebbles, ½-5 inches long, of limestone, minor chert and sandstone, in matrix of fossiliferous calcareous sandstone and arenaceous feldspathic calcarenite; ledges	15
	Total thickness of Bursum formation	267
	Local unconformity	
	Panther Seep formation (uppermost Pennsylvanian)	
R 219	Interbedded dark-gray: calcilutite, argillaceous, laminated; medium lenticular beds; ledges; shale, calcareous, silty, fissile	11
R 218	Limestone, dolomitic, silty, gray to light-brown, fine-crystalline, thin- to medium-bedded; ledges	4½
R 217	Interbedded: limestone, light-gray, aphanitic, fossiliferous; massive to nodular ledges; shale, gray, calcareous, fissile	32½
R 216	Limestone, medium light-gray, aphanitic, fossiliferous; ranges from thin nodular beds to massive-bedded	41½
R 215	Shale, grayish-black, fissile; slope; capped by sandstone, calcareous, micaceous, very fine-grained, very thin-bedded	4½
R 214	Upper limestone, grayish-black, fine-crystalline; medium-bedded ledges; lower siltstone, limy, laminated, fossiliferous	8½
R 213	Shale, grayish-black, fissile; slope; capped by 18-inch limestone, carbonaceous, grayish-black, aphanitic, thin-bedded	10
R 212	Limestone, arenaceous, dark-gray, fine-crystalline; medium-bedded ledges; basal 18 inches shale, calcareous, silty, dark-gray	6
R 211	Sandstone, calcareous, micaceous, olive-gray, porous, fine- to medium-grained, crosslaminated, thin- to medium-bedded	19½
R 210	Subgraywacke, calcareous, silty, greenish-gray, fine-grained, thin- to medium-bedded; rubbly ledges; shale lenses	10
R 209	Interbedded silty: shale, carbonaceous, fissile; subgraywacke, calcareous, greenish-gray, fine-grained; slopes and ledges	70
R 208	Shale, partly calcareous, grayish-black, fissile; thin limestone lenses; pelecypods; 3-foot calcareous siltstone near base	35
R 207	Upper limestone, silty, carbonaceous, dark-gray, fine-crystalline; thin-bedded ledges; lower shale, calcareous, silty; slope	10
R 206	Upper limestone, arenaceous, silty, tan, fine-crystalline, crosslaminated; 42-inch ledge; lower shale, calcareous, greenish	8½
R 205	Sandstone, calcareous, silty, greenish, very fine-grained, platy to thin-bedded; medial 8 feet shale, sandy, calcareous	14½
R 204	Interbedded: shale, calcareous, greenish; slopes; limestone, argillaceous, dark-gray, aphanitic, medium-bedded; ledges	7
R 203	Upper 6 feet limestone, argillaceous, algal, fine-crystalline; massive ledge; lower shale, partly covered, calcareous	17
R 202	Limestone, silty to argillaceous, gray to brownish, fine- to medium-crystalline, laminated, massive-bedded, ledges	11
R 201	Shale, calcareous, silty; plant imprints; slope; capped by 3-foot sandstone, calcareous, micaceous, olive, fine-grained	39
R 200	Calcarenite, silty, conglomeratic, dark-gray, coarse-grained, fossiliferous, friable, crosslaminated, thick-bedded; ledges	9
R 199	Limestone, medium light-gray, aphanitic, scattered fossil fragments, medium- to thick-bedded; ledges	6
R 198	Shale, calcareous, silty, olive-gray; upper interbeds of subgraywacke, silty, micaceous, greenish, very fine-grained	14
R 197	Interbedded: limestone, silty, argillaceous, aphanitic, nodular; shale, calcareous, silty; siltstone, limy, yellowish-orange	11
R 196	Interbedded micaceous, greenish: subgraywacke, silty, fine-grained; shale, calcareous; top 23 feet mostly covered	36
R 195	Sandstone, calcareous, micaceous, olive, fine-grained, thin-bedded; top 30 inches calcarenite, arenaceous, fossiliferous	9
R 194	Upper third shale, calcareous, mostly covered; lower limestone, dark-gray, fine-crystalline, fossiliferous, thin-bedded ledges	13
R 193	Limestone, medium light-gray, aphanitic, fossiliferous, medium- to thick-bedded; ledges; *Triticites;* medial nodular beds	16½
R 192	Limestone, aphanitic to fine-crystalline, fossiliferous; upper laminated; thick- to thin-bedded ledges; upper 18 inches is shale	18½
R 191	Limestone, light- to dark-gray, aphanitic; numerous fossil fragments; thick-bedded ledges; oolitic and glauconitic lenses	10
R 190	Shale, calcareous, micaceous, silty, light olive-gray, fissile, fossiliferous; slope	9
R 189	Interbedded silty, micaceous: shale, grayish-red; sandstone, calcareous, glauconitic, olive-gray, fine-grained	8
R 188	Shale, partly covered, calcareous, micaceous, silty, olive, fissile; many brachiopods near base; upper calcarenite lenses	38
R 187	Limestone, coquinoid, calcarenite lenses, medium-gray, aphanitic, silty matrix, thick-bedded; ledges; medial 2 feet shale	15
R 186	Interbedded silty: shale, calcareous, micaceous, fissile, limestone nodules; calcilutite, carbonaceous, dark-gray, nodular	20½
R 185	Shale, lower mostly covered, slightly calcareous, silty, micaceous, gray, fissile; slope; scattered 1-inch limestone nodules	29½
R 184	Limestone, dark-gray, fine-crystalline, fossiliferous; abundant *Triticites* aff. *T. cullomensis;* massive-bedded, brown ledges	8

R 183	Shale, calcareous, dark- to light-gray; slope; basal and medial 15-inch limestone ledges, silty, aphanitic; coquinoid lenses	8½
R 182	Sandstone, limy, micaceous, friable to hard, silty to very fine-grained, greenish to brown, thin-bedded; ledgy slope	32½
R 181	Limestone, carbonaceous, dark-gray to brownish, fine-crystalline; *Triticites* aff. *T. cullomensis;* medial 1-foot shale	6
R 180	Shale, very silty, calcareous, greenish, fissile; slope; top 2 feet limestone, argillaceous, aphanitic, thin nodular beds	10
R 179	Limestone, light-gray, aphanitic; coquinoid lenses; thick-bedded ledge; *Triticites;* basal 1-foot is shale, calcareous, silty	5
R 178	Shale, calcareous, silty, light-brown; capped by 1-foot calcarenite, fine- to very coarse-grained, coquinoid; *Triticites*	5
R 177	Sandstone, calcareous, micaceous, olive, friable, porous, fine- to coarse-grained, thick-bedded; top 3 feet is shale, micaceous	14
R 176	Shale, silty, calcareous, micaceous, olive to dark-gray, fissile; slope; lenses of shaly siltstone	30½
R 175	Limestone, dark-gray, fetid, aphanitic to coarse-crystalline; abundant fusulinids, *Dunbarinella ervinensis, Triticites* cf. *T. plummeri, Schubertella* aff. *S. kingi;* brachiopods, bryozoa, crinoid columnals, echinoid spines; thick to massive-bedded brownish ledges	17½
R 174	Upper shale, grayish-black, clayey, numerous *Aviculopecten;* lower limestone, argillaceous, yellowish, aphanitic, coquinoid	2½
R 173	Shale, mostly covered, slightly calcareous, silty, light olive-gray, fissile; slope	21½
	Section moved 6,800 feet southeast to center SE¼ sec. 14, T. 13 S., R. 3 E., high up on northwest side of Bosque Canyon, above Potter ranch headquarters.	
R 172	Limestone, medium light-gray, aphanitic to coarse-crystalline; fossil fragments and coquinoid lenses, thick- to massive-bedded; cliff; *Triticites rhodesi, T.* cf. *beedi, Dunbarinella ervinensis;* weathers hard rough-pitted and pointed surface	35
R 171	Shale, partly covered, carbonaceous, grayish-black, fissile; slope; calcilutite lenses, argillaceous, blackish, laminated	162½
R 170	Limestone, medium-gray, fine-crystalline, laminated; *Triticites;* massive-bedded cliff; upper 6½ feet is medium-bedded ledges	38½
R 169	Limestone, dark-gray, fine-crystalline; *Triticites;* wavy medium-bedded cliff; top 3 feet is argillaceous, nodular, slope	31½
R 168	Shale, silty, carbonaceous, grayish-black, fissile; slope; basal 1-foot is limestone, argillaceous, dark-gray, fossiliferous	87½
R 167	Interbedded calcareous, micaceous, light olive-gray: shale, sandy, fissile; sandstone, fine-grained, thin- to medium-bedded	29
R 166	Sandstone, calcareous, micaceous, whitish, coarse-grained, feldspathic lenses, crosslaminated; lenticular thick beds; ledges	13
R 165	Limestone, silty, yellowish-brown, aphanitic to fine-crystalline; *Triticites;* lower beds sandy; upper dark-gray shale lenses	15
R 164	Upper limestone, arenaceous, flat pebble-conglomerate lenses; lower third sandstone, calcareous, porous, olive, fine-grained	8½
R 163	Limestone, slightly silty, medium-gray, aphanitic, scattered fossil fragments, thin-bedded; rubbly tan ledges	9½
R 162	Sandstone, calcareous, micaceous, porous, olive, fine-grained, thick-bedded; lower 2 feet limestone, arenaceous, coquinoid	7
R 161	Shale, partly covered, silty, micaceous, calcareous, olive, fissile; slope; lenses of sandy calcareous greenish siltstone	102
R 160	Limestone, sandy to argillaceous, fine- to medium-crystalline; recrystallized microcoquina; *Triticites* cf. *T. cullomensis;* medium lenticular beds	5
R 159	Shale, silty, micaceous, calcareous, olive-gray, fissile; greenish siltstone and very fine-grained sandstone lenses; slope	55
R 158	Interbedded calcareous, micaceous, olive-gray: shale, silty, fissile; siltstone; top 3 feet sandstone, silty, crosslaminated	55
R 157	Shale, calcareous, silty, olive-gray, fissile; slope; numerous large disc-shaped concretions; sandy siltstone lenses	20
	Total thickness of Panther Seep formation	1,458
	Local unconformity	
	Missouri series (lower upper Pennsylvanian)	
R 156	Limestone, argillaceous, dark-gray, aphanitic, thin- to medium-bedded; iron-stained ledges; near top is 2 feet limy shale	10
R 155	Interbedded: limestone, argillaceous, dark-gray, laminated; oolitic lenses, thin-bedded; shale, calcareous, silty, fissile	19
R 154	Limestone, medium-gray, fine-crystalline, algal; oolitic lenses; thin- to medium-bedded; brownish rubbly ledges	11
R 153	Mostly covered slope of intercalated calcareous shale and shaly limestone; medial 2 feet argillaceous dark-gray limestone	21
R 152	Limestone, micro-oolitic, aphanitic matrix, spherical to ellipsoidal oolites; lenticular thin beds, rubbly ledges	4
R 151	Interbedded partly covered, fossiliferous: limestone, argillaceous, dark-gray, thin-bedded; shale, calcareous, fissile	35
R 150	Limestone, argillaceous, dark-gray, aphanitic; wavy thin to medium bedding; rubbly ledges; fossiliferous; a few chert nodules	25
R 149	Limestone, medium dark-gray, aphanitic to fine-crystalline, thick- to thin-bedded; upper ledges, lower slope	11
R 148	Limestone, fine- to coarse-crystalline, lenses of recrys-	

	tallized coquina, thick- to massive-bedded; cliff	24
R 147	Andesite sill, olive-gray, aphanitic to fine-crystalline; much secondary calcite; lenticular	1½
R 146	Upper third limestone, fine-crystalline, very thin-bedded, rubbly ledges; lower shale, mostly covered, calcareous, nodular	10½
R 145	Limestone, light-gray, fine-crystalline; few small chert nodules; medium-bedded ledges; medial 4 feet is calcareous shale	16
R 144	Shale, partly covered, calcareous, light-gray, clayey; nodules of argillaceous dark-gray limestone; slope	9
	Total thickness of Missouri series (less 1½ foot sill)	195½

Local unconformity

Des Moines series (upper middle Pennsylvanian)

R 143	Intercalated medium dark-gray: limestone, argillaceous, aphanitic; thin nodular to medium-bedded; limestone, fine-crystalline, massive	22½
R 142	Shale, calcareous, light-gray, clayey; numerous nodules and lenses of dark-gray argillaceous aphanitic limestone	3½

Section moved 8,100 feet east-northeast to top of Amole Ridge, SE¼SE¼ sec. 7, T. 13 S., R. 4 E., on north side of Rhodes Canyon above "Granite" Gap.

R 141	Limestone, medium dark-gray, aphanitic; scattered crinoid columnals; bedding indistinct, massive; vertical cliff	30
R 140	Mostly covered slope; scattered ledges of shaly nodular limestone	10
R 139	Limestone, medium dark-gray, aphanitic; scattered crinoid columnals; massive; 2 ledges with medial 1-foot notch	15
R 138	Limestone, shaly, coquinoid, medium light-gray, thin-bedded; lenses of light-gray calcareous shale; ledgy slope	7
R 137	Sill, greenish-gray hornblende andesite	3
R 136	Limestone, coquinoid, friable, fine-crystalline; lenses of calcarenite; thick lenticular beds; rounded ledges; *Fusulina*	10
R 135	Partly covered slope; ledges of nodular shaly limestone and calcareous shale	12
R 134	Limestone, coquinoid, friable, aphanitic to medium-crystalline; thin lenticular beds; thin ledges; *Fusulina;* base covered	13
R 133	Limestone, cherty, medium-crystalline, very thin-bedded; rubbly ledges; chert as nodules and lenses, 10-30 percent	8
R 132	Calcarenite, conglomeratic, coarse-grained; grains subangular, of limestone, fossils, chert, and clay galls; thick lenticular beds; rounded ledge	7
R 131	Limestone, cherty like R 133, medium-bedded; ledges, with medial 3 feet shale; *Eoschubertella* and *Fusulina* cf. *F. girtyi*	28
R 130	Mostly covered slope; scattered thin ledges of shaly nodular limestone and of friable fossiliferous calcarenite	19
R 129	Limestone, medium-crystalline, medium-bedded; hard ledges; basal 2 feet is shale intruded by andesite sill	8
R 128	Limestone, cherty, medium-crystalline; lenses of coquina; medium-bedded ledges; basal 5 feet is mostly covered	10
R 127	Limestone, basal 10 feet cherty, medium-crystalline, thick-bedded to massive; cliff; numerous recrystallized fossils	30
R 126	Andesite sill in top 2 feet; basal limestone, cherty, medium-crystalline, thin-bedded; thin ledges; fossiliferous	5
R 125	Limestone, medium-crystalline, porous; medium-bedded ledges; recrystallized coquinoid calcarenite; *Fusulina,* brachiopods, bryozoa, algae, crinoids	28
R 124	Andesite sill in top 2 feet; lower part mostly covered, with a few thin ledges of cherty limestone	10
R 123	Limestone, cherty, medium-crystalline, thick-bedded; ledgy cliffs; chert in nodules, stringers, and lenses	63
R 122	Limestone, cherty, aphanitic to medium-crystalline; medium-bedded ledges; *Wedekindellina;* top is 2-foot andesite sill	29
R 121	Limestone, cherty, fossiliferous, aphanitic to medium-crystalline, thick-bedded; ledges; *Fusulina, Wedekindellina euthysepta*	60
R 120	Limestone, medium- to coarse-crystalline, medium-bedded; ledges; medial 10 feet is cherty, fossiliferous	20
R 119	Limestone, cherty, medium-gray, aphanitic, thick-bedded; massive ledges; *Wedekindellina* aff. *W. dunbari*	23
R 118	Limestone, cherty, fine- to coarse-crystalline, crinoidal, medium-bedded; ledgy slope; *Wedekindellina;* brownish chert nodules	27
R 117	Limestone, cherty, aphanitic, massive beds; ledgy cliff; *Wedekindellina elfina, Eoschubertella, Fusulina euryteines*	55
R 116	Mostly covered slope; scattered outcrops of friable coquinoid limestone and calcareous nodular shale	15
R 115	Limestone, cherty, fossiliferous, medium-crystalline, thick-bedded; single ledge; *Fusulina;* calcarenite lenses; algal	7
R 114	Mostly covered slope; scattered outcrops of nodular calcareous shale and friable coquinoid limestone	16
R 113	Limestone, cherty, calcarenite lenses, fine- to coarse-crystalline, fossiliferous; thick-bedded cliff; *Fusulina*	22
R 112	Calcarenite, arenaceous, mottled light brown, medium- to coarse-grained, thin- to thick-bedded; ledges	15
	Total thickness of Des Moines series (minus 9 feet of sills)	322

Local unconformity

Derry series (lower middle Pennsylvanian)

R 111	Limestone, mottled light brown, aphanitic, fossiliferous, medium-bedded; broken ledges	6
R 110	Sandstone, calcareous, granule to medium-grained;	

	angular quartz, minor mica, calcite; medium-bedded ledges; crosslaminated	10
R 109	Siltstone, very calcareous, grayish-black, hard, thin- to medium-bedded; broken ledges	14
R 108	Limestone, fine-crystalline; lenses of calcarenite, thin-bedded, thin ledges; top 10 feet is mostly covered slope	17
R 107	Sandstone, calcareous, silty, gray to reddish-brown, medium-grained with pebble lenses; medium-bedded ledges	9½
R 106	Sandstone, calcareous, friable, weathering dusky brown, fine-grained, sparse granules, crosslaminated, thin-bedded; shale lenses	18½
R 105	Shale, silty, dark-gray; medial 5-foot sandstone, calcareous, silty, micaceous, brownish-gray, fine-grained; slope	17
R 104	Calcarenite, friable, light-gray, medium-grained; thin-bedded ledge; underlain by silty dark-gray shale	5
R 103	Limestone, medium-crystalline, fossiliferous; calcarenite lenses, shale partings; thin-bedded, ledgy slope	10
R 102	Limestone, silty, arenaceous, dark-gray, fine-crystalline, medium-bedded; ledges; grades into hard siltstone	8
R 101	Limestone, silty, arenaceous, dark-gray, aphanitic, fossiliferous; medium-bedded ledges, calcarenite lenses; *Millerella, Profusulinella copiosa, Pseudostaffella*	15
R 100	Calcarenite, arenaceous, friable, dark-gray, medium-grained, crossbedded, very thin-bedded; ledgy slope	5
R 99	Limestone, fine-crystalline, thin-bedded; broken ledges; scattered chert; lenses of coarse-grained calcarenite	8
R 98	Sandstone, light-gray, calcareous to siliceous, coarse-grained, crosslaminated, thick lenticular beds; thick ledges	17
R 97	Partly covered shale, calcareous, sandy; basal 2 feet is hard siltstone, siliceous, greenish-black, very thin-bedded	14
R 96	Quartzite, calcareous, greenish-gray, fine- to coarse-grained, fossiliferous; thin-bedded ledges; *Millerella*	2
R 95	Shale, calcareous, slope; medial 5 feet is limestone, cherty, fine-crystalline, fossiliferous, thick-bedded; ledges	14
R 94	Limestone, arenaceous, medium-crystalline, fossiliferous, thin-bedded; broken ledges; lenses of siliceous siltstone	5½
R 93	Siltstone, siliceous, grayish-black, medium-bedded; single hard ledge	2½
R 92	Quartzite, calcareous, brownish-gray, poorly-sorted; fine to very coarse subangular grains; resistant ledge	1½
R 91	Subgraywacke, calcareous, micaceous, grayish-green with reddish-brown bands; very fine to medium subangular grains, chiefly quartz with minor feldspar, chert, mica and lithic fragments, cemented by ferruginous silt; thin-bedded; rubbly ledges	10½
R 90	Pebble-conglomerate, sandy, calcareous; subangular quartz in matrix of greenish silt; medium-bedded, crossbedded rubbly ledges	9
R 89	Shale, carbonaceous, slightly silty, dark-gray, fissile; slope	1½
R 88	Chert-conglomerate; granules to boulders of chert, predominantly whitish, in matrix of medium-grained subangular quartz sand cemented by siliceous silt; lenticular beds ½-6 feet thick; hard rounded ledges	9½
	Total thickness of Derry series	230

Section moved 4,900 feet northeast to SW¼NW¼ sec. 9, T. 13 S., R. 4 E., along side canyon on north side and near mouth of Rhodes Canyon

Unconformity

Lake Valley formation

Tierra Blanca member

R 87	Limestone, cherty, light-gray, aphanitic to fine-crystalline; scattered crinoid stems; one bed; abundant large nodules of light-gray aphanitic chert; ledge	3½
	Total thickness of Tierra Blanca member	3½

Nunn member

R 86	Limestone, argillaceous, medium-gray, soft; beds ½-6 inches; abundant crinoid stem fragments; slope	5½
R 85	Limestone, dark-gray, argillaceous in part, aphanitic to microcrystalline; abundant fragments of crinoid stems and bryozoa; beds ½-6 inches; weathers shaly; slope	18
R 84	Limestone, crinoidal, medium-gray; beds ½-6 inches; weathers shaly at top; abundant small (1.0-2.5 mm) flattened fragments of crinoid stems; slope	5
	Total thickness of Nunn member	28½

Alamogordo member

R 83	Limestone, dark-gray, aphanitic to microcrystalline; scattered (0.5 mm) crinoid stem fragments; bedding indistinct; abundant 6-inch concentrically banded oblate nodules, and lenses (6″ × 5′) of black chert; top of cliff	20
R 82	Limestone, dark-gray, aphanitic to microcrystalline; one bed; abundant small euhedral quartz crystals	1½
	Total thickness of Alamogordo member	21½

Andrecito member

R 81	Limestone, arenaceous, dark-gray, crinoidal; beds ½-4 feet, lower 4 feet crosslaminated; base of cliff	8½
	Total thickness of Lake Valley formation	62

Unconformity

Percha formation

R 80	Shale, calcareous, silty, olive-gray; some lenses of micaceous, calcareous, olive-gray siltstone; slope; poorly exposed	48½
R 79	Shale, calcareous, micaceous, grayish-olive, fissile; a few lenses of gray to brownish hard siltstone; slope	25
R 78	Sandstone, siliceous, tan, fine- to coarse-grained, len-	

Unit	Description	Feet
	ticular; lower ½ foot is calcareous silty shale; phosphatic nodules and fossils	1½
	Total thickness of Percha formation	75
	Contadero formation	
R 77	Limestone, silty, dark-gray, aphanitic; nodular to thin-bedded; fossiliferous, crinoidal; irregular ledge	3½
R 76	Shale, calcareous, olive-gray; interbedded with thin lenticular beds of calcareous medium-gray siltstone; slope	26½
R 75	Shale, dark-gray to pale-olive; in three beds separated by two thin beds of dark brownish-gray calcareous siltstone	3½
R 74	Siltstone, calcareous, dark reddish-brown; angular ledges; medial dark-gray fissile shale	2
R 73	Shale, dark-gray, weathers very light-gray, fissile	1
R 72	Shale, pale olive-gray, calcareous, silty	7
R 71	Shale, tan, weathers purplish, silty, calcareous, micaceous	1½
	Total thickness of Contadero formation	45
	Sly Gap formation	
R 70	Siltstone, calcareous, yellowish to gray; bedding nodular, thin; interbedded with olive-gray, silty, calcareous shale	5½
R 69	Shale, calcareous, yellowish-gray; scattered nodules and thin beds of gray siltstone. Units R 69-66 form conspicuous yellowish to light-gray weathering slope in contrast to darker weathering beds above and below	2
R 68	Siltstone, calcareous, gray, nodular; thin beds of yellowish shale with abundant silty dark-gray limestone nodules; slope	11
R 67	Limestone, medium-gray, aphanitic, very silty, nodular; grayish-yellow shale partings; few thin yellowish hard calcareous siltstone beds	2½
R 66	Shale, silty, grayish-yellow; with very abundant irregular nodules of medium-gray aphanitic, silty limestone	2½
R 65	Shale, slightly calcareous, dark-gray, crinoidal	2
R 64	Siltstone, calcareous, mottled medium- and dark-gray, weathers light-brown; ledge	1
R 63	Shale, calcareous, pale-olive, highly fossiliferous	2
R 62	Shale, micaceous, silty, black, dark olive-gray and grayish red-purple, fissile; in part calcareous; top 6-inch dark olive-gray calcareous siltstone bed is prominent ledge	2½
	Total thickness of Sly Gap formation	31
	Onate formation	
R 61	Siltstone, dolomitic, dark-gray, weathers grayish-brown, hard, fucoidal; prominent thin ledge	1
R 60	Siltstone, calcareous, dark-gray, nodular, fossiliferous; slope	2
R 59	Shale, calcareous, silty, pale-olive; abundant small nodules of aphanitic gray pyritiferous limestone, and lenticular beds of light-gray calcareous hard siltstone; slope	5
R 58	Siltstone, dolomitic, dark olive-gray; irregular ledge	1½
R 57	Shale, dolomitic, dark olive-gray; two thin medial olive siltstone beds	2½
R 56	Siltstone, dolomitic, dark-olive; bedding indistinct; slope	1
R 55	Interbedded dolomitic: siltstone, yellowish, hard; shale, olive, clayey, thin-bedded; ledges and slopes	5
R 54	Siltstone, dolomitic, dark yellowish-orange to gray; some very fine-grained quartz sand; slope	3
R 53	Siltstone, dolomitic, gray, weathers tan; abundant bryozoa; hard, prominent ledge	2
	Section moved 2,700 feet southwest to center of SW¼SE¼ sec. T. 13 S., R. 4 E., on north side of Rhodes Canyon, about 500 feet above the road.	
R 52	Interbedded thin nodular limestones and silty shales; poorly exposed	9
	Total thickness of Onate formation	32
	Unconformity	
	Montoya group	
	Cutter dolomite	
R 51	Dolomite, calcareous, dark-gray, weathers very light-gray, aphanitic; ledge	4½
R 50	Dolomite, calcareous, light-gray, aphanitic; poorly exposed; slope	7
R 49	Dolomite, calcareous, gray, aphanitic; beds 2-12 inches; white chert bed at base; slope	15½
R 48	Dolomite, calcareous, light-gray, aphanitic, medium-bedded; abundant gray irregular chert nodules	17
R 47	Dolomite, slightly calcareous, light-gray, aphanitic; 1-foot beds; scattered round dark-gray chert nodules	6½
R 46	Dolomite, slightly calcareous, cherty, gray, aphanitic, medium-bedded; thin dark-gray chert lenses and nodules	6½
	Total thickness of Cutter dolomite	57
	Aleman dolomite	
R 45	Dolomite, cherty, gray, aphanitic; thin-bedded; chert, mottled gray, as continuous thin lenses in lower half, as abundant irregular nodules in upper half	17
R 44	Dolomite, cherty, gray, aphanitic, thin-bedded; chert as thin lenses, up to 3 feet long, parallel to bedding	7½
R 43	Dolomite, cherty, gray, aphanitic to microcrystalline, thick-bedded; chert, light-gray, as thin discontinuous irregular lenses, and small nodules; base of steep slope	5½
R 42	Dolomite, cherty, dark-gray, aphanitic to microcrystalline, massive; chert, light-gray in thin irregular lenses and small nodules; top of cliff	22½
R 41	Dolomite, cherty, dark-gray, aphanitic to microcrystalline, thin-bedded; chert, black to light-gray, in	

	thin discontinuous lenses and abundant oblate to round nodules	13½
R 40	Dolomite, gray, aphanitic to microcrystalline, thick-bedded; small siliceous limonitic nodules at top	9
R 39	Dolomite, crinoidal, gray, aphanitic to medium-crystalline; lower thin beds, upper 4-foot bed	5½
R 38	Dolomite, crinoidal, light-gray, aphanitic to medium-crystalline, thin- to thick-bedded; sparse, light-gray chert nodules; abundant silicified fossils along bedding planes	5½
	Total thickness of Aleman dolomite	86

Upham dolomite

R 37	Dolomite, crinoidal, medium- to light-gray, aphanitic to medium-crystalline; massive scattered chert nodules at base	24
R 36	Dolomite, crinoidal, cherty, gray, aphanitic to medium-crystalline, massive; thin discontinuous lenses and concentrically banded, oblate and spherical nodules of dark-gray chert	17
R 35	Dolomite, crinoidal, medium- to light-gray, aphanitic to coarse-crystalline, massive	49½
R 34	Dolomite, crinoidal, arenaceous, dark-gray, aphanitic to medium-crystalline, massive	7½
R 33	Dolomite, calcareous, arenaceous, medium- to dark-gray, very fine- to coarse-crystalline, massive; a few small tan chert nodules; quartz, very fine-grained to pebbly	13
R 32	Sandstone, dolomitic, gray, very fine- to very coarse-grained, angular to well-rounded grains; massive; grades into arenaceous dolomite	4
	Total thickness of Upham dolomite	115

Cable Canyon sandstone

R 31	Sandstone, dolomitic, conglomeratic, light-gray, weathers moderate-brown; very fine-grained to pebbly, angular to well-rounded grains; minor smoky, brown, and bluish quartz, and light-gray, black, and tan chert fragments; base of cliff	2½
	Total thickness of Montoya group	260½

Section moved 2,600 feet northeast to SE¼NE¼SE¼ sec. 8, T. 13 S., R. 4 E., along side canyon on north side and near mouth of Rhodes Canyon.

Unconformity

El Paso group

R 30	Dolomite, gray, aphanitic to fine-crystalline; thin- to thick-bedded; upper 5 feet is cliff; lower slope	12
R 29	Dolomite, light-gray, aphanitic to very fine-crystalline; bedding 1-4 inches, nodular; slope	2½
R 28	Dolomite, light- to dark-gray, bedding indistinct; poorly exposed; slope	23
R 27	Dolomite, gray in upper 25 feet, light olive-gray below, micro- to fine-crystalline; 5-foot oolitic zone begins 15 feet below top; thin- to medium-bedded; slope	35
R 26	Covered; along strike, dolomite as below	12
R 25	Dolomite, dark-gray, fine-crystalline; beds 1-12 inches thick; 3-foot bed at top; 28-inch bed at base; ledges and slopes	16
R 24	Dolomite, basal light- to yellowish-gray, gray above; fine-crystalline, massive; cliff or steep slope	27
R 23	Dolomite, gray, fine- to medium-crystalline; 1-8 inch beds	14
R 22	Limestone, dark-gray, aphanitic to fine-crystalline, medium-bedded; rounded ledges; grades laterally into angular brown-weathering dolomite ledges	6
R 21	Dolomite, gray, fine- to medium-crystalline, thick-bedded; ledge	4½
R 20	Limestone, dark-gray with whitish mottling near base, aphanitic to fine-crystalline, thin- to medium-bedded; ½-2 inch beds light-gray shale and nodular limestone; fucoidal; slope	25½
R 19	Limestone, dark-gray, aphanitic to microcrystalline, thick-bedded, laminated; slopes and ledges	19
R 18	Dolomite, gray, fine- to medium-crystalline, thick-bedded; ledges	4
R 17	Limestone, light-gray, aphanitic; beds 1-4 inches thick	2
R 16	Dolomite, calcareous, gray, fine-crystalline; beds 1-24 inches thick; slopes and thin ledges	20
R 15	Dolomite, light-gray, micro- to fine-crystalline; beds average 5 inches thick; slopes and thin ledges	25
R 14	Dolomite, calcareous, arenaceous, light-gray, fine- to medium-crystalline; beds 1-5 inches	11
R 13	Dolomite, arenaceous, light olive-gray, micro- to fine-crystalline; quartz very fine-grained; beds 1-10 inches; slope	7½
R 12	Dolomite, arenaceous, grayish-brown, microcrystalline; massive basal ledge; poorly exposed 1-4 inch beds above; quartz sand; crosslaminations	4½
R 11	Dolomite, arenaceous, moderate-red to light grayish-brown, fine- to medium-crystalline; quartz fine-grained to pebbly; medium-bedded; irregular slopes and ledges	7
R 10	Dolomite, arenaceous, pale reddish-brown to yellowish mottled gray; fine- to medium-crystalline; quartz very fine-grained; medium-bedded; minor glauconite; irregular slopes and ledges	15
R 9	Dolomite, arenaceous, moderate-red to moderate-brown, fine- to medium-crystalline; quartz, very fine-grained to pebbly, angular; medium-bedded; cross-laminated; minor muscovite and glauconite; irregular rounded cliff	14
	Total thickness of El Paso group	306½

Bliss sandstone

R 8	Sandstone, calcareous, glauconitic, grayish-green; silty to medium-grained, angular to subangular; globular glauconite; medium- to thick-bedded; cross-laminated; rounded ledge	5
R 7	Sandstone, dolomitic, glauconitic, mottled grayish-green and moderate yellow-green; medium- to	

Unit no.	Description	Thickness (feet)
	coarse-grained, angular to subrounded; crosslaminated; irregular ledges and slopes	2½
R 6	Sandstone, calcareous, glauconitic, mottled moderate-red and dark grayish-green; medium-grained, angular to subrounded; beds 1-6 inches, crosslaminated; upper 3-foot ledge, rest slope	15
R 5	Sandstone, dolomitic, glauconitic, light olive-gray to grayish-olive; silty to medium-grained, angular; minor mica, rock and fossil fragments; ledge	6½
R 4	Limestone, arenaceous, grayish-brown; small gastropods	½
R 3	Sandstone, calcareous, glauconitic, grayish-olive to dark reddish-brown; silty to coarse-grained, angular to well-rounded; crosslaminated; minor glauconite, pyrite, and chert; ledges and slopes	7
R 2	Sandstone, calcareous, glauconitic, mottled moderate-red and dark grayish-green; silty to very coarse-grained; angular; beds 1-2 feet; partings of siliceous hematite; rounded ledge	4½
R 1	Hematite, oolitic, arenaceous, dusky-red mottled greenish-black; oolites 0.75-5.0 mm; quartz, silt to pebble size, angular to well-rounded; thin- to thick-bedded; minor chlorite	5
	Total thickness of Bliss sandstone	46
	Unconformity	
	Precambrian rocks	
	Granite, pink; with inclusions of dark-green schist, and cut by thin pegmatite dikes.	

SECTION H. PALEOZOIC FORMATIONS IN HEMBRILLO CANYON AREA

San Andres, Yeso, Abo, and Hueco formations measured west of Hembrillo Pass, beginning at center of south line SW¼SE¼ sec. 25, T. 16 S., R. 2 E. Pennsylvanian rocks, Lake Valley formation, Devonian formations, Fusselman dolomite, Montoya group, El Paso group, and Bliss sandstone measured along Hembrillo Canyon.

Unit no.	Description	Thickness (feet)
	Top of section is mountain top; erosion surface cut on San Andres formation, about 1½ miles west of south from Little Tank	
	San Andres formation	
H 359	Limestone, medium dark-gray, fine- to medium-crystalline, fetid; massive-bedded cliff capping dip-slope ridge	40
H 358	Limestone, gray, aphanitic to fine-crystalline, fetid, thick-bedded; irregular ledgy cliff; fossiliferous	90
H 357	Limestone, light-gray, aphanitic to fine-crystalline, fetid; silty lenses; thin- to medium-bedded; ledges	25
H 356	Limestone, silty, dolomitic, light-gray, aphanitic, fetid, thin-bedded; ledges; oolitic; fossiliferous calcarenite lenses	2
H 355	Sandstone, calcareous, silty, yellowish, fine-grained, crosslaminated, thin-bedded, friable, porous; slope; Glorieta (?) sandstone	41
	Total thickness of remnant of San Andres formation	198
	Yeso formation	
H 354	Sandstone, calcareous, silty, reddish-orange, fine-grained, porous, friable, crosslaminated, thin-bedded; ledgy slope	52
H 353	Limestone, silty, dark-gray, aphanitic to fine-crystalline; upper medium-bedded ledges; lower thin-bedded, fossiliferous	50
H 352	Limestone, gray to olive, fine-crystalline, porous, fetid; lower medium-bedded ledgy cliff; upper thin-bedded slope	40
H 351	Limestone, medium dark-gray, aphanitic to medium-crystalline, fetid, fossiliferous, thin- to thick-bedded; ledges	50
H 350	Limestone, light-gray, aphanitic to fine-crystalline, fetid, fossiliferous, thick-bedded; ledges; chert nodules near top	12½
H 349	Limestone, medium dark-gray, fine- to medium-crystalline, fetid, porous, scattered fossils, thin-bedded; ledgy slope	22½
H 348	Limestone, silty, medium dark-gray, fine- to medium-crystalline, fetid, porous, fossiliferous; medium-bedded ledges	32
H 347	Sandstone, silty, calcareous, yellowish-orange, very fine-grained, porous, friable, crosslaminated, thin-bedded; slope	7
H 346	Limestone, gray, aphanitic, coquinoid lenses, medium-bedded; ledges; 18-inch yellowish, calcareous sandstone in upper third	26
H 345	Limestone, carbonaceous, medium dark-gray, aphanitic, medium-bedded; shale partings, ledges; weathers medium light-gray	14½
H 344	Sandstone, calcareous, silty, yellowish-orange, very fine-grained, thin-bedded; upper 18 inches silty brownish limestone	11½
H 343	Limestone, light-gray, fine-crystalline, thin-bedded; basal breccia of angular limestone cobbles in calcareous siltstone	7
H 342	Sandstone, calcareous, reddish, brownish, and grayish, fine-grained, very thin-bedded; ledgy slope	31
H 341	Calcilutite, very silty, olive-gray, aphanitic, porous(!) fetid, thin- to thick-bedded; lenticular ledges; siltstone lenses	18
H 340	Limestone, silty, medium dark-gray, aphanitic, fetid, thin- to medium-bedded; ledges; upper 2-foot is calcareous yellow sandstone	11½
H 339	Upper sandstone, calcareous, brownish, very fine-grained, very thin-bedded; ledgy slope; lower calcareous sandy claystone	5½
H 338	Sandstone, calcareous, gypsiferous, silty, light-red to light-brown, very fine-grained, friable, crossbedded, thin-bedded	54½
H 337	Upper gypsum, whitish, dense to fine-crystalline, medium-bedded; lower sandstone, calcareous, silty, gypsiferous, pinkish	4½
H 336	Gypsum, whitish, dense to fine-crystalline, medium-bedded, slope; laminae of gypsiferous limestone; basal silty lenses	17½

H 335	Upper sandstone, calcareous, silty, gypsiferous, pinkish, friable; lower gypsum, whitish, dense, with laminae of limestone	24½
H 334	Limestone, silty, light-gray, aphanitic, thin-bedded; slope	10
H 333	Interbedded: limestone, argillaceous, dark-gray, aphanitic, fetid, medium nodular beds; claystone, calcareous, light-gray	15
H 332	Limestone, medium dark-gray, aphanitic to fine-crystalline, fetid, medium-bedded; ledges	25
H 331	Gypsum, gray, aphanitic, thin- to medium-bedded, slope; lenses of brownish silt and fine-grained sand	20
H 330	Limestone, medium dark-gray, aphanitic to fine-crystalline, fetid, porous, fossiliferous, medium-bedded; ledges	87½
H 329	Gypsum, whitish, aphanitic, medium-bedded; slope; capped by 3½-foot limestone, very silty, soft, greenish, rounded ledge	17½
H 328	Gypsum, whitish, fine-crystalline, thick-bedded, slope; upper 1-foot limestone, silty, arenaceous, dark-gray, aphanitic	10
H 327	Gypsum, partly-covered, fine crystalline to banded, thin-bedded; lenses of silt and friable reddish sandstone	110
H 326	Gypsum, silty, mottled, banded, medium-crystalline, medium-bedded; top fourth is limestone, porous, fetid, light-gray	30
H 325	Mostly covered calcareous silty pinkish sandstone; basal 5 feet is limestone, silty, arenaceous, dark-gray, aphanitic; ledges	20
H 324	Interbedded: sandstone, calcareous, silty, pinkish to tan, friable; limestone, silty, arenaceous, dark-gray, aphanitic	15
	Section moved 4,600 feet north to SE¼SW¼ sec. 19, T. 16 S., R. 3 E., ½ mile south of east from Little Tank.	
H 323	Mostly covered sandstone, calcareous, silty, friable, pinkish to light tan, very fine-grained; gypsum laminae; slope	40
	Total thickness of Yeso formation	892
	Abo redbeds	
H 322	Sandstone, silty, calcareous, tan, weathers pinkish, very fine-grained, medium-bedded; resistant ledge capping dip slope	4
H 321	Upper siltstone, sandy, calcareous, arkosic lenses, reddish; lower sandstone, silty, calcareous, tan, medium-bedded, ledges	13
H 320	Shale, partly covered, calcareous, silty, grayish-red, fissile to clayey; sandy laminae; slope	7
H 319	Siltstone, sandy, calcareous, pink to tan, medium-bedded, hard ledges; medial 2-foot grayish-red shale	12½
H 318	Interbedded: siltstone, sandy, calcareous, grayish-red, thin-bedded ledges; shale, calcareous, silty, grayish-red, slope	15
H 317	Shale, partly covered, silty, calcareous, grayish-red, fissile to clayey; sandy laminae; slope	13½
H 316	Interbedded calcareous, grayish-red: siltstone, sandy, crosslaminated, thin-bedded ledges; shale, silty, fissile, slope	16
H 315	Shale, calcareous, silty, grayish-red, fissile to clayey; sandy laminae; slope; cut by greenish andesite dike	18
H 314	Shale, silty, calcareous, grayish-red, fissile; sandy lenses; slope; capped by siltstone, hard, sandy, calcareous	6
H 313	Siltstone, conglomeratic, sandy, calcareous, grayish-red, medium-bedded; ledges; tabular pebbles of siltstone and limestone	5
H 312	Shale, calcareous, silty, grayish-red, fissile, sandy laminae; medial 18-inch siltstone, sandy, calcareous, grayish-red	25
H 311	Siltstone, sandy, calcareous, arkosic lense, grayish-red, thin- to medium-bedded, crosslaminated; ledges	55
H 310	Upper third shale, calcareous, silty, grayish-red, fissile; lower siltstone, sandy, calcareous, grayish-red, medium-bedded	30
H 309	Shale, silty, calcareous, grayish-red, fissile, sandy lenses; slope; medial 2-foot siltstone, sandy, medium-bedded ledges	18
H 308	Siltstone, sandy, calcareous, grayish-red; thin- to medium-bedded ledges; basal 5-foot is shale, silty, grayish-red	17
H 307	Upper siltstone, sandy, feldspathic, grayish-red; thick-bedded ledges; lower shale, silty, calcareous, reddish; slope	10
H 306	Siltstone, limy, sandy, grayish-red, arkosic laminae, crosslaminated; thick- to thin-bedded ledges; medial 5-foot shale	30
H 305	Siltstone, limy, sandy, arkosic laminae; upper grayish-red, lower olive-gray; medium-bedded, ledges	15
H 304	Shale, calcareous, silty, grayish-red, fissile; slope; near base 2-foot siltstone, limy, siliceous, greenish, ledges	25
H 303	Sandstone, silty, arkosic, pale-red, very fine-grained, crosslaminated, medium-bedded; hard ledges	5
H 302	Shale, calcareous, silty, grayish-red, fissile, sandy laminae; medial 2-foot siltstone, limy, siliceous, gray, medium-bedded	58½
H 301	Shale, calcareous, silty, grayish-red, fissile; slope; capped by 5½-foot sandstone, silty, arkosic, pale-red, massive ledge	51½
H 300	Upper 5-foot siltstone, limy, sandy, olive-gray, medium-bedded, ledge; lower shale, calcareous, silty, grayish-red	14
H 299	Shale, silty, calcareous, grayish-red, clayey; upper 5-foot is siltstone, calcareous, sandy, arkosic, grayish-red, thick ledge	31
H 298	Upper sandstone, very silty, arkosic, pinkish, crosslaminated, thick-bedded ledges; lower shale, silty, calcareous, reddish	23½
H 297	Siltstone, sandy, calcareous, feldspathic, reddish to olive; medium-bedded ledges; medial shale, calcareous, silty, reddish	7½

H 296	Shale, calcareous, silty, reddish, fissile; slope; basal 30-inch siltstone, sandy, calcareous, feldspathic, reddish	14
H 295	Shale, calcareous, silty, reddish, fissile; basal 30-inch ledge of sandstone, calcareous, silty, reddish, crosslaminated	29
H 294	Interbedded calcareous, reddish: shale, silty, fissile; siltstone, sandy, crosslaminated, thin-bedded	11
H 293	Shale, calcareous, grayish-red, silty and sandy lenses clayey to fissile; partly covered slope	27½
H 292	Limestone pebble-conglomerate, gray tinted greenish and reddish; matrix is calcareous ferruginous quartz silt; lenticular ledges	5½
	Total thickness of Abo redbeds	613

Local unconformity

Hueco formation

H 291	Interbedded: shale, calcareous, purplish; limestone, argillaceous, siliceous, fine-crystalline, fossiliferous, thin-bedded	11
H 290	Limestone, argillaceous, siliceous, fine-crystalline, fossiliferous, thin-bedded; ledges weather dark yellowish-brown	26

Section moved 2.2 miles north to NW¼SE¼ sec. 7, T. 16 S., R. 3 E., about 1¼ miles northwest of Hembrillo Pass.

H 289	Interbedded partly covered: limestone, argillaceous, thin-bedded; weathers yellowish; shale, calcareous, gray to reddish	17
H 288	Calcarenite, arenaceous, weathers brownish, medium-grained, crosslaminated; calcareous coarse-grained quartz sandstone lenses	4
H 287	Shale, calcareous, gray, pinkish beds near base; capped by 2-foot limestone, argillaceous, tan, thin nodular beds	47
H 286	Shale, calcareous, greenish, fissile, slope; grades up into 2-foot limestone, argillaceous, dark-gray, fossiliferous	22
H 285	Shale, calcareous, pale-red, clayey; upper 2-foot is limestone, argillaceous, nodular lenticular beds that weather tan	10
H 284	Interbedded: limestone, silty, light-gray; pelecypod coquina lenses; shale, calcareous, gray; numerous limestone nodules	10
H 283	Limestone, silty, light-gray; lenses of flat limestone pebble-conglomerate with many pelecypods; ledges	4

Section moved 1.5 miles south-southeast to NW corner, SE¼NE¼ sec. 20, T. 16 S., R 3 E., about ½ mile southeast of Hembrillo Pass.

H 282	Limestone, argillaceous, silty, dark-gray, aphanitic; medium-bedded ledges, weather pale yellowish-brown	8
H 281	Shale, limy, clayey; numerous limestone lenses; basal 10 feet is limestone, argillaceous, fine-crystalline, thin-bedded, ledges	32
H 280	Shale, limy, clayey; many limestone nodules; near top and base are 2-foot limestones, argillaceous, aphanitic, fossiliferous	17
H 279	Interbedded calcareous thin-bedded: shale, silty, fissile; siltstone, shaly; medial and basal sandy siltstone ledges	33
H 278	Shale, calcareous; many limestone nodules, lenses; near base is calcarenite, silty, greenish, fossiliferous, medium-grained	30
H 277	Upper sandstone, calcareous, silty, micaceous, olive, crosslaminated, thin-bedded, ledges; lower shale, limy, fissile, slope	7
H 276	Limestone, argillaceous, cherty, medium-gray, aphanitic, coquinoid lenses, thin- to medium-bedded; ledges	8
H 275	Shale, limy, fissile, slope; medial 2-foot limestone, silty, argillaceous, dark-gray, medium-bedded, ledge	4
H 274	Sandstone, silty, calcareous, micaceous, light-olive gray, very fine-grained, crosslaminated, thin-bedded; ledges	6
H 273	Shale, calcareous, upper sandy, medium light-gray, fissile; slope; lenses of brownish sandstone	15
H 272	Limestone, aphanitic to medium-crystalline; *Schwagerina andresensis;* massive; prominent cliff; chert nodules near top	14½
	Total thickness of Hueco formation	325½

Bursum formation or *uppermost Virgil series*

H 271	Interbedded: limestone, argillaceous, aphanitic, thin- to medium-bedded, fossiliferous, ledges; shale, calcareous, nodular	45½
H 270	Upper limestone, fine-crystalline, fossiliferous, medium-bedded, prominent ledge; lower shale, calcareous, fissile, slope	18
H 269	Sandstone, conglomeratic lenses, calcareous, light-gray, porous, medium- to coarse-grained; crosslaminated, lenticular, medium-bedded; prominent brownish-weathering ledge; subangular pebbles of quartz, chert, and limestone (equivalent to R 220)	13
	Total thickness of Bursum formation or upper Virgil beds	76½

Unconformity

Panther Seep formation (Uppermost Pennsylvanian)

H 268	Shale, calcareous, light-gray, fissile; basal 2-foot sandstone, calcareous, micaceous, silty, greenish, medium-bedded, ledge	26
H 267	Shale, calcareous, medium-gray, fissile, partly covered slope; medial and upper sandy lenses	41
H 266	Upper sandstone, pebbly, calcareous, porous, greenish, coarse-grained; medium-bedded ledge; lower shale, calcareous, fissile	6

Section moved 2,400 feet northwest to center of west line SE¼ sec. 17, T. 16 S., R 3 E., at crest of Hembrillo Pass.

H 265	Shale, calcareous, sandy, fissile, slope; top foot is limestone, argillaceous, dark-gray, dense, ledge	29
H 264	Shale, calcareous, silty, platy; limestone lenses; slope;	

	top 3 feet is limestone, dark-gray, fine-crystalline; thick ledge	15
H 263	Shale, calcareous, platy, sandy laminae; basal 2½ feet is sandstone, calcareous, silty, micaceous, brownish, very fine-grained	10
H 262	Interbedded: shale, calcareous, fissile, slopes; calcilutite, silty, argillaceous, dark-gray, laminated, thin-bedded, ledges	38
H 261	Calcilutite, argillaceous, blackish, laminated; medium-bedded ledges; basal 3 feet is shale, calcareous, dark-gray, carbonaceous	12
H 260	Interbedded dark-gray: shale, calcareous, fissile; calcilutite, argillaceous, aphanitic, laminated, very thin-bedded	20
H 259	Intercalated calcareous: shale, dark-gray, fissile; sandstone, silty, micaceous, greenish, medium-grained, thin-bedded	2
H 258	Shale, calcareous, dark-gray, limestone nodules; basal 2 feet is calcilutite, argillaceous, dark-gray, laminated, one bed	10
H 257	Interbedded dark-gray: shale, calcareous, fissile, slopes; calcilutite, silty, argillaceous, laminated, thin-bedded ledges	18
H 256	Subgraywacke, calcareous, silty, micaceous, olive, fine- to medium-grained; lenticular crosslaminated beds, 3-18 inches thick	1
H 255	Shale, calcareous, fissile; lower 2-foot siltstone, calcareous, micaceous; angular limestone and sandstone pebble lenses	9
H 254	Interbedded calcareous: shale, silty, fissile; sandstone, micaceous, grayish-olive, fine- to medium-grained, medium-bedded	20
H 253	Sandstone, arkosic, calcareous, micaceous, olive, coarse-grained, crosslaminated; massive bed; lower shale interbeds, silty	10
H 252	Shale, calcareous, silty; slope; top foot is limestone, aphanitic, with medial 3-inch lense of dark-gray chert; ledge	4
H 251	Limestone, dark-gray, aphanitic, coquinoid lenses, medium-bedded; basal foot is sandstone, calcareous, silty, brownish	6
H 250	Shale, calcareous, fissile; slope; medial 3 feet is limestone, dark-gray, aphanitic, thin- to medium-bedded, ledges	7
H 249	Interbedded, calcareous, gray: shale, clayey; sandstone, fine-grained, very thin-bedded; top 30 inches is sandstone ledge	21½
H 248	Interbedded calcareous: shale, clayey; sandstone, friable, fine-grained; upper calcilutite, silty, dark-gray, laminated	6½
H 247	Shale, calcareous, fissile; thin lenses of silty sandstone; slope; basal foot is siltstone, limy, light-gray, hard ledge	6
H 246	Shale, calcareous, fissile; lenses of silty brownish limestone, and silty dense laminated calcilutite, thin- to medium-bedded	24
H 245	Limestone, aphanitic, medium-bedded; persistent ledge; basal 18 inches is shale, calcareous, greenish; silty sandstone lenses	5
H 244	Upper shale, calcareous, pinkish; limestone nodules; lower limestone, fine-crystalline; weathers brownish; persistent ledge	3
H 243	Shale, calcareous, weathers pinkish; lenses of silty sandstone; several medial 6-inch limestone ledges, silty, fossiliferous	51½
H 242	Interbedded: limestone, argillaceous, greenish, aphanitic, lenticular; shale, calcareous, clayey, with limestone nodules and lenses	10
H 241	Shale, calcareous, fissile to platy, slope; lenses of calcilutite, silty, dark-gray, laminated, ledges	10½
H 240	Shale, calcareous, light-gray, fissile, slope; near top is a 1-foot sandstone, silty, calcareous, fine-grained, lenticular	10
H 239	Interbedded, calcareous, greenish: shale, clayey, weathers purplish, slopes; siltstone, sandy lenses, thin lenticular beds	16
H 238	Upper silty calcilutite; medial crosslaminated, coarse-grained fossiliferous calcarenite; basal calcareous whitish shale	2½
H 237	Interbedded: limestone, fine-crystalline, fossiliferous, medium-bedded; calcarenite, arenaceous, coarse-grained, crosslaminated	11
H 236	Shale, calcareous, silty, fissile; slope; upper 6 inches is limestone, lenticular, of fossil fragments in fine-crystalline matrix	4
H 235	Limestone, dark-gray, aphanitic, medium-bedded; limonitic concretions; basal 6-inch is calcilutite, argillaceous, brownish	3
H 234	Shale, calcareous, greenish, pinkish, fissile; slope; many sandstone lenses, limy, silty, micaceous, greenish, fine-grained	36½
H 233	Interbedded: limestone, argillaceous, aphanitic, weathers yellowish, algal; shale, calcareous, light-gray, clayey	27
H 232	Upper limestone, argillaceous, greenish, fine-crystalline, thin-bedded; lower shale, calcareous, greenish, limestone nodules	18
H 231	Interbedded: limestone, aphanitic, medium-bedded, fossiliferous; shale, calcareous, micaceous, light-gray, reddish, greenish	17
H 230	Shale, sandy, calcareous, reddish; upper 4 feet is sandstone, calcareous, with conglomeratic lenses of flat chert & limestone pebbles	25
H 229	Sandstone, calcareous, micaceous, reddish to greenish, fine-grained; feldspathic lenses; basal third is shale, limy, olive	25
H 228	Interbedded calcareous, greenish: shale with limestone nodules; sandstone, silty, micaceous, thin-bedded; siltstone, sandy	14
H 227	Shale, calcareous, olive; limestone nodules; slope; thin interbeds of sandstone, calcareous, silty, micaceous, olive, platy	47
H 226	Shale, limy, olive-gray; limestone nodules; slope; laminae and platy lenses of siltstone, calcareous,	

sandy, greenish 19

H 225
Interbedded: shale, limy, olive, slope; calcilutite, silty, aphanitic, laminated, platy; calcilutite fills channels 20½

H 224
Shale, limy, olive-gray; lenses an dnodules of limestone; carbonaceous films; clayey to fissile; partly-covered slope 34½

H 223
Limestone, partly silty, aphanitic to fine-crystalline, fossiliferous, algal, medium-bedded; thin shale lenses; ledges 13½

H 222
Calcarenite, silty, weathers olive, fine- to medium-grained, fossiliferous, medium-bedded; shale laminae and lenses 11½

H 221
Shale, calcareous, greenish, fissile; lenses of silty calcarenite; upper 2 feet is siltstone, limy, olive, cross-laminated 15

H 220
Limestone, silty, gray, weathers dark yellowish-brown, aphanitic to fine crystalline; calcareous silt laminae; massive ledge 7½

H 219
Calcarenite, coquinoid, dark-gray, laminated orange, fine- to medium-grained, crosslaminated, medium-bedded; shale interbeds 32½

H 218
Shale, calcareous, light-gray, fissile, slope; lenses up to 1 inch thick and nodules of dark-gray silty limestone 35

H 217
Shale, calcareous, olive, partly sandy and micaceous; laminae of tan very fine-grained calcareous sandstone 20

H 216
Shale, calcareous, olive; sandstone interbeds, limy, silty, micaceous, brownish, very fine-grained, lenticular ledges 90

Section moved 1.3 miles north to SE¼NE¼ sec. 8, T. 16 S., R 3 E., about a mile northwest of Upper Hembrillo Spring.

H 215
Limestone, aphanitic to medium-crystalline; coarse coquina lenses; massive vertical cliff; fossiliferous, *Triticites* 50

H 214
Limestone, aphanitic to fine-crystalline; undulating bedding planes, medium-bedded; scattered fossil fragments 6½

H 213
Sandstone, calcareous, micaceous, yellowish to brownish, fine-grained, thin- to medium-bedded, crosslaminated; ledges 38½

H 212
Mostly covered; ledges of calcareous greenish sandstone and sandy shale; top 2 feet is calcarenite, silty, brownish 60

H 211
Shale, calcareous, sandy, medium light-gray, fissile to clayey; slope 20

H 210
Shale, sandy, silty, micaceous, greenish, fissile; lenses of sandstone, calcareous, micaceous, olive-gray, fine-grained 115

H 209
Sandstone, calcareous, micaceous, olive, medium-bedded; ledges; lower shale lenses, sandy, dark-gray, fissile 10

H 208
Shale, calcareous, carbonaceous, dark-gray, fissile to blocky; slope; a few calcarenite beds, argillaceous, olive-gray 15

H 207
Interbedded blackish, carbonaceous: shale, fissile; calcilutite, argillaceous, microlaminated; 2 massive ledges of silty limestone 24

H 206
Limestone, microcoquinoid, micro-oolitic, aphanitic matrix, very thin-bedded; rubbly ledges, calcarenite lenses 6

H 205
Calcilutite, very silty, dark-gray, microlaminated; micro-oolite lenses; pyrite crystals; carbonaceous shale lenses 15

H 204
Shale, carbonaceous, blackish, fissile; lenses of calcilutite, argillaceous, dark-gray, microlaminated, thin-bedded 25

H 203
Shale, calcareous, fissile, slope; lower limestone interbeds, gray, fine-crystalline, fossiliferous, medium-bedded 15

H 202
Upper limestone, fine-crystalline, fossiliferous, *Lissochonetes,* medium-bedded, ledges; lower shale, calcareous, dark-gray 26

H 201
Shale, carbonaceous, blackish, fissile; slope; top foot is limestone, dark-gray, aphanitic, algal, ledge 29

H 200
Interbedded: limestone, argillaceous, dark-gray, aphanitic; medium-bedded ledges; shale, calcareous, silty, clayey; slopes 25

H 199
Upper calcilutite, coquinoid, argillaceous, microlaminated, thin-bedded, ledges; lower shale, limy, light-gray, clayey 4

H 198
Shale, calcareous and silty to carbonaceous, light- to dark-gray, fissile to clayey; slope 43½

H 197
Limestone, argillaceous, dark-gray, aphanitic; thick bedded ledges; top third is microcoquinoid, oolitic, fossiliferous 7½

H 196
Limestone, siliceous, silty, aphanitic to medium-crystalline; massive cliff; top fourth is of ledges with shale interbeds 20

H 195
Shale, calcareous, fissile; silty calcarenite lenses; basal foot is coquinoid limestone, fine-crystalline; thin nodular beds 10

H 194
Shale, carbonaceous, blackish; disc-shaped concretions; upper foot is calcilutite, carbonaceous, argillaceous, laminated 32

H 193
Shale, sandy, carbonaceous, blackish to greenish; top foot is calcilutite, carbonaceous, silty, dark-gray, laminated; *Triticites* 33

H 192
Interbedded: shale, greenish-gray, sandy; calcareous concretions; fissile; sandstone, silty, calcareous, dark greenish-gray, fine-grained, platy; near base is a foot of calcilutite, argillaceous, dark-gray, aphanitic, laminated, thin-bedded 20

H 191
Shale, sandy, greenish-gray; many concretions; sandstone laminae. Twenty feet west, lenses of boulder-conglomerate pinch-out and grade into sandstone lenses near base of shale; boulders up to 3 feet, chiefly limestone, some sandstone 25

H 190
Interbedded greenish: shale, sandy, fissile; sandstone, silty, calcareous, fine-grained, platy; slopes and ledges 5

H 189
Sandstone, limy, olive, hard, porous, medium- to

	coarse-grained, thick-bedded; ledges; some glauconite, white feldspar	7
H 188	Shale, sandy, calcareous, greenish, fissile; slope; scattered concretions; sandstone laminae and thin lenses	73
H 187	Sandstone, limy, olive, hard to friable, porous, medium- to coarse-grained, crosslaminated; beds 1-2 feet thick, lenticular; conglomerate lenses. Grains angular, chiefly quartz, minor calcite, mica, ferruginous silt galls, white feldspar, glauconite	17
H 186	Shale, sandy, greenish-gray, fissile; lenses and laminae of sandstone, silty, calcareous, tan, very fine-grained	38
H 185	Shale, calcareous, sandy, greenish; lenses of sandstone, silty, calcareous, tan; of limestone, shaly, brownish, aphanitic	33
	Total thickness of Panther Seep formation	1825

Unconformity

Section moved across fault, 4,500 feet east-southeast to center SW¼ sec. 10, T. 16 S., R. 3 E., on south side of Hembrillo Canyon about ¾ mile northeast of Upper Hembrillo Spring.

Missouri series (lower upper Pennsylvanian)

H 184	Calcarenite, fine-grained, oolitic; mottled by brownish silt; laminated, medium-bedded, outcropping ledges	4
H 183	Upper shale, calcareous, clayey; lower limestone, dark-gray, aphanitic, thin- to medium-bedded, ledges	5
H 182	Shale, calcareous, olive, fissile; upper 2 feet is limestone, argillaceous, aphanitic; thin nodular beds, rubbly ledges	7
H 181	Interbedded: limestone, silty, dark-gray, aphanitic, medium-bedded; calcarenite lenses; shale, calcareous, light-gray	12
H 180	Limestone, silty, argillaceous, dark-gray, fine-crystalline; microcalcarenite lenses, oolitic; medium-bedded, ledges	13½
H 179	Shale, slightly calcareous, light olive-gray, clayey to fissile; slope; partly covered at base	34½
H 178	Limestone, cherty, fine-crystalline; *Wedekindellina;* medium- to massive-bedded; alternating ledges and notches	45
H 177	Limestone, cherty, fine-crystalline; scattered fossils; medium- to massive-bedded; prominent cliff	40
H 176	Shale, calcareous, dark- to greenish-gray; basal 3 feet is limestone, light-gray, fine-crystalline; ledge	19
H 175	Limestone, argillaceous, blackish, aphanitic, thin-bedded; rubbly ledges; lenses of crinoid coquina	31
H 174	Interbedded: limestone, argillaceous, light- to dark-gray, aphanitic, very thin-bedded; shale, calcareous, clayey to fissile	25
H 173	Shale, limy, nodular, fossiliferous; many limestone lenses; upper foot is calcarenite, silty, fetid, crinoidal, brownish	9
H 172	Shale, calcareous, dark-gray; many limestone nodules; coquina lenses; top 18 inches is calcarenite, silty, fossiliferous; *Triticites*	16
H 171	Interbedded: shale, calcareous, nodular to fissile; limestone, argillaceous, dark-gray, aphanitic, thin-bedded	10
	Total thickness of Missouri series	271

Local unconformity

Des Moines series (upper middle Pennsylvanian)

H 170	Limestone, dark-gray, medium-crystalline, thin- to medium-bedded; ledges; scattered chert nodules; fossiliferous	6½
H 169	Limestone, silty, fine-crystalline, thin- to massive-bedded; coquinoid and silty calcarenite lenses; *Fusulina* aff. *F. leei*	118½
H 168	Limestone, coquinoid, light-gray, medium-crystalline; *Fusulina* aff. *F. Leei, Wedekindellina;* thin lenticular beds	6
H 167	Limestone, dark-gray, fine-crystalline; coarse-crystalline coquinoid lenses; thick-bedded, ledges	4

Section moved 3,000 feet north-northeast to NW corner NE¼ sec. 10, T. 16 S., R. 3 E., on north wall of Hembrillo Canyon above Ritch windmill.

H 166	Limestone, coquinoid, light-gray, fine- to coarse-crystalline, massive-bedded; weathers rough; cliff caps mesa	20
H 165	Limestone, dark-gray, medium-crystalline, massive-bedded; ledges; scattered large chert nodules	13
H 164	Interbedded light-gray, nodular: limestone, argillaceous, aphanitic, fossiliferous, *Fusulina,* very thin-bedded; shale, limy	10
H 163	Limestone, coquinoid, light-gray, fine- to coarse-crystalline, massive; vertical cliff; fossil fragments recrystallized	22
H 162	Limestone, coquinoid; chert nodules and lenses; fine- to coarse-crystalline, thick-bedded; ledges	20
H 161	Limestone, coquinoid, light-gray, fine- to coarse-crystalline, thick-bedded; vertical cliff; along strike grades into nodular limestone; medium- to thick-bedded; ledges	20
H 160	Limestone, cherty, shaly, fine-crystalline; scattered fossils; fissile to thin-bedded; partly covered ledgy slopes	61
H 159	Limestone, cherty, silty, dark-gray, aphanitic to fine-crystalline, fossiliferous, medium- to thick-bedded; cliff; fusulinids abundant, *Fusulina* aff. *F. euryteines, Wedekindellina euthysepta;* 10% chert nodules, dark-gray, weather brownish	9
H 158	Limestone, cherty, silty, dark-gray, aphanitic, thin- to medium-bedded; rubbly ledges; chert 5%	28
H 157	Limestone, cherty, dark-gray, aphanitic; upper fourth is light-gray, mottled, coquinoid, fine- to coarse-crystalline; medium- to massive-bedded, cliff; *Fusulina* aff. *F. euryteines, Wedekindellina, Eoschubertella*	27
H 156	Limestone, cherty, silty to shaly, aphanitic, medium-bedded; ledges and slopes; *Fusulina* aff. *F. leei*	10

H 155	Limestone, cherty, shaly, fine-crystalline, some coquina lenses, *Fusulina* aff. *F. leei;* thin- to medium-bedded	34
H 154	Limestone, cherty to coquinoid, aphanitic to coarse-crystalline, medium- to massive-bedded; ledgy cliff	36
H 153	Limestone, coquinoid, light-gray, fine- to medium-crystalline, friable, medium-bedded; ledgy slope	40
H 152	Upper third is limestone, cherty, fine-crystalline, medium-bedded, ledges; lower shale, calcareous, dark-gray, limestone lenses	10
H 151	Limestone, upper massive bed; medial coquinoid medium-bedded ledgy slope; lower cherty medium-bedded ledges	20
H 150	Limestone, coquinoid, light-gray, partly friable; matrix of silty fine-crystalline calcilutite; fossils and fossil fragments average 1-2 mm but up to 50 mm; *Fusulina;* beds lenticular, medium-bedded; ledgy slope	12
H 149	Limestone, slightly silty, fine-crystalline, coquina lenses, thin- to medium-bedded; ledges; upper and lower cherty beds	23
H 148	Limestone, cherty, fine- to medium-crystalline, medium- to thick-bedded; ledges; *Fusulina;* sill in upper third	45
	Total thickness of Des Moines series (minus 2 foot sill)	593

Disconformity

Derry series (lower middle Pennsylvanian)

H 147	Limestone, silty, carbonaceous, blackish, fine-crystalline, medium-bedded; shaly lenses; ledgy slope; *Fusulinella*	10
H 146	Calcarenite, light-gray, fine- to coarse-grained; thin lenticular beds, friable; thin rounded ledges	13
H 145	Limestone, silty, carbonaceous, blackish, fine-crystalline, medium-bedded; ledges; coated by brown calcite	12
H 144	Limestone, very silty, dark-gray, fine-crystalline, very thin-bedded; ledgy slope; blackish shale lenses	21
H 143	Upper third is limestone, argillaceous, blackish, fine-crystalline, medium-bedded; ledges; *Fusulinella?;* lower sill	26½
H 142	Limestone, very silty, blackish, fine-crystalline, medium-bedded; rubbly ledges; medial andesite sill	10½
H 141	Limestone, argillaceous, blackish, fine-crystalline, medium-bedded; silty crosslaminations; *Profusulinella?, Marginifera*	12
H 140	Limestone, bluish-gray, medium-crystalline, fossiliferous; medium-bedded; ledges; hornblende andesite sills	8
H 139	Limestone, argillaceous, carbonaceous, blackish, fine-crystalline, platy to medium-bedded; ledges; *Marginifera, Mesolobus*	27

Section moved 3,650 feet north to SW¼NE¼ sec. 3, T. 16 S., R. 3 E., on west wall of north tributary canyon of Hembrillo Canyon, about ¾ mile east of north of Ritch windmill.

H 138	Shale, grayish-black, fissile; limestone nodules and lenses; top foot is limestone, silty, aphanitic, ledge	10
H 137	Shale, calcareous, blackish, fissile to clayey; lenses and nodules of limestone, silty, fossiliferous, dark-gray	33½
H 136	Limestone, argillaceous, dark-gray, aphanitic, thin-bedded; ledges; top foot is limestone pebble-conglomerate	5
H 135	Shale, calcareous, fissile to clayey; limestone nodules; medial 2-foot limestone is silty, dark gray, thin bedded	14½
H 134	Limestone, silty, carbonaceous, fetid, dark-gray, aphanitic, medium-bedded; cliff; upper chert nodules	28
H 133	Limestone, silty, dark-gray, fossiliferous, aphanitic, thin- to medium-bedded; ledgy slope; siltstone lenses	10
H 132	Interbedded silty: shale, calcareous to carbonaceous, fissile; limestone, dark-gray, medium-crystalline to aphanitic	10
H 131	Quartz granule-sandstone, conglomeratic, calcareous, dark greenish-gray, crosslaminated; lenticular rounded ledge	4
H 130	Shale, carbonaceous, grayish-black, fissile to clayey, slope; weathers mottled pale-red and tan	25
H 129	Upper limestone, dark-gray, aphanitic; thin- to medium-bedded ledges; lower shale, calcareous, silty, greenish; slope	10
H 128	Shale, calcareous, silty, greenish, fissile; slope; top 2 feet is limestone, fine-crystalline, fossiliferous; single ledge	12½
H 127	Shale, calcareous, fissile; slope; top 18 inches is quartz pebble-conglomerate, calcareous, light-gray, crosslaminated, irregular ledge	7½
H 126	Upper limestone, dark-gray, aphanitic, thin-bedded; lower quartz pebble-conglomerate and granule sandstone, crosslaminated	19½
H 125	Calcarenite, gray to tan, fine- to coarse-grained, thick-bedded, crosslaminated; ledgy cliff; upper shale lenses	18½
H 124	Conglomerate, light gray to tan; chert cobbles and boulders in matrix of siliceous ferruginous quartz pebble-conglomerate and sandstone cemented by ferruginous silt; beds very lenticular, thick- to massive-bedded; rounded rubbly ledges	22
	Total thickness of Derry series (minus 25½ feet of sills)	344½

Angular unconformity

Section moved 2,100 feet southeast to NW¼SW¼ sec. 2, T. 16 S., R. 3 E., on north wall of Hembrillo Canyon about ¾ mile northeast of Ritch windmill.

Lake Valley formation

Tierra Blanca member

H 123	Limestone, silty, cherty, light-gray, microcrystalline; scattered crinoid stem fragments; beds 2-8 inches; abundant whitish chert nodules; tiny euhedral quartz crystals; cliff	25
	Total thickness of Tierra Blanca member	25

Nunn member

H 122	Shale, hard, calcareous, light-gray; lenses of light-gray chert near top; slope	3
H 121	Encrinite, light-gray, nodular, slope	1
H 120	Covered, probably limestone as below; slope	1
H 119	Limestone, light-gray, medium-bedded; shale partings	5
H 118	Limestone, arenaceous, dark-gray, aphanitic to microcrystalline, medium-bedded; quartz abundant as small euhedral crystals, silt, and very fine sand; slope	5
	Total thickness of Nunn member	15

Alamogordo member

H 117	Limestone, dark-gray, aphanitic; chert like H 113; top of cliff	10½
H 116	Limestone, silty, dark-gray, aphanitic; thin lenticular beds	½
H 115	Limestone, dark-gray, aphanitic; bedding indistinct; black chert nodules as in unit H 113 scattered throughout	9½
H 114	Limestone, aphanitic; thin nodular beds	1
H 113	Limestone, gray, microcrystalline, stylolitic; medium- to thick-bedded; scattered black chert nodules, concentrically banded, oblate and lenticular	11
H 112	Limestone, crinoidal, dark-gray, aphanitic, thick-bedded	3½
	Total thickness of Alamogordo member	36

Andrecito member

H 111	Limestone, crinoidal, medium- to dark-gray, aphanitic; lower thin beds, 2-foot bed above; lower foot arenaceous; base of cliff	3
H 110	Sandstone, calcareous, tan, silty to very fine-grained; lenticular	3
	Total thickness of Andrecito member	6
	Total thickness of Lake Valley formation	82

Unconformity

Section moved 1,000 feet east-northeast to center of NW¼SW¼ sec. 2, T. 16 S., R. 4 E., on north side of Hembrillo Canyon.

Percha formation

H 109	Shale, calcareous, silty, gray; nodules of dark-gray silty limestone in lower 2 feet; slope	5
H 108	Limestone, silty, dark-gray, nodular, crinoidal, fossiliferous; irregular ledge	1
H 107	Shale, light-olive, silty, calcareous; thin beds separated by 1-inch nodular siltstone beds; slope	8
H 106	Siltstone, calcareous, gray, nodular with shale partings, fossiliferous; slope	5
H 105	Shale, light-olive, calcareous, silty; 6-inch bed of nodular silty dark-gray limestone at base and 3 feet above base; abundant small nodules of gray siltstone scattered throughout; slope	7
H 104	Shale, light-gray to olive, silty, micaceous, dolomitic, fissile; a few thin lenticular beds of dark-gray siltstone in lower 8 feet with siltstone nodules in upper 8 feet; slope	26
H 103	Shale, medium- to dark-gray, micaceous, dolomitic	1½
H 102	Shale, light-gray, micaceous, silty, calcareous, soft, fissile; thin interbeds of dark-gray silty crinoidal limestone; irregular slope	4½
H 101	Covered, shale like H 102 along strike	2
H 100	Limestone, argillaceous, arenaceous, dark-gray; beds thin, lenticular; grades laterally into sandstone; irregular ledge	3
H 99	Shale, black, siliceous, fissile, slope	4
	Total thickness of Percha formation	67

Contadero formation

H 98	Siltstone, light-gray to grayish-orange, calcareous, micaceous, soft; weathers shaly; slope	4
H 97	Sandstone, light-brown, nodular; rounded ledge	2½
H 96	Shale, light-gray, soft, fissile, dolomitic	3
H 95	Interbedded: light-gray silty fissile dolomitic shale; dark-gray dolomitic micaceous siltstone; slope	20½
H 94	Shale, dolomitic, light-gray, soft, fissile; slope	1
H 93	Siltstone, brownish-gray, micaceous, laminated; weathers shaly; thin ledge-forming micaceous light-brown-weathering crosslaminated, very fine-grained sandstone 1 foot above base; thin purplish-gray shale 8 feet above base; fossiliferous; irregular slope	15

Section moved 2,800 feet west of south, across the canyon to NW¼NW¼ sec. 11, T. 16 S., R. 4 E., on south side of Hembrillo Canyon.

H 92	Shale, dark-gray, silty, micaceous, calcareous, hard, platy; slope	5
	Total thickness of Contadero formation	51

Sly Gap Formation

H 91	Siltstone, calcareous, slightly micaceous, light-gray; slope	5
H 90	Siltstone, calcareous, micaceous, light-gray; thin interbeds of nodular gray silty aphanitic limestone; slope	10
H 89	Limestone, dark-gray, silty, nodular, aphanitic; interbedded with gray calcareous micaceous shaly weathering nodular siltstones; slope	15
H 88	Siltstone, limy, gray, fossiliferous; ledge	½
H 87	Limestone, silty, gray, aphanitic, nodular; irregular ledge	5½

H 86
Shale, dolomitic, light-olive to dark-gray; scattered nodules of silty gray limestone; slope 29

H 85
Shale, dolomitic, micaceous, silty, black, fissile; lenses of silty aphanitic olive limestone; slope 5

Total thickness of Sly Gap formation 70

Onate formation

H 84
Sandstone, calcareous, light-brown, very fine-grained, crosslaminated; ledge 1

H 83
Interbedded: shale, calcareous, nodular, olive; siltstone, gray, calcareous, hard; irregular slope 10

H 82
Siltstone, dolomitic, medium-gray to grayish-orange, medium-bedded; slope 4

H 81
Siltstone, dolomitic, dark-gray, very thin-bedded; shaly thin lenses of black fissile shale; slope 8

Total thickness of Onate formation 23

Unconformity

Fusselman dolomite

H 80
Dolomite, dark-gray, micro- to very fine-crystalline; massive; top of Fusselman cliff 10

H 79
Dolomite, calcareous, gray, fine-crystalline, massive; dark-brown weathering silicified dolomite zones, 2-4 inches thick; scattered small nodules of black chert in upper 7 feet 12

H 78
Dolomite, calcareous, light- to medium-gray, aphanitic to fine-crystalline; one massive bed; a few thin lenticular chert beds near top 24

H 77
Dolomite, calcareous, light- to very light-gray, aphanitic to fine-crystalline; two beds 7

H 76
Dolomite, calcareous, vuggy, gray, aphanitic to microcrystalline, massive; basal beds contain abundant quartz-filled vugs; base of Fusselman cliff 8

Total thickness of Fusselman dolomite 61

Unconformity

Montoya group

Cutter dolomite

H 75
Dolomite, gray, aphanitic, thin- to massive-bedded; zone of light-gray round to oblate chert nodules 1 foot below top of unit; top of slope 22

H 74
Dolomite, light-gray, aphanitic, thin- to medium-bedded 4

H 73
Dolomite, vuggy, gray, aphanitic, medium- to massive-bedded; scattered vugs containing quartz and dolomite crystals 6

H 72
Dolomite, vuggy, gray, aphanitic to microcrystalline, medium- to massive-bedded; vugs filled with quartz and dolomite crystals 15½

H 71
Dolomite, light-gray, aphanitic to microcrystalline; beds 8-14 inches thick 3½

H 70
Dolomite, medium- to light-gray, microcrystalline; 5 inch beds; scattered nodules of black chert 10

H 69
Dolomite, dark-gray, aphanitic to microcrystalline; beds 1-24 inches thick, nodular in part; 4-5 inch silicified dolomite bed 6 feet below top; nodules of black chert in upper 5 feet 15

H 68
Dolomite, light-gray, aphanitic to microcrystalline; beds 1-12 inches thick; scattered smooth dark-gray chert nodules in upper 5 feet 25

H 67
Covered; along strike dolomite like H 66 12

Section moved 1,000 feet south of east to NW¼NE¼ NW¼ sec. 11, T. 16 S., R. 4 E., on south side of Hembrillo Canyon.

H 66
Dolomite, argillaceous, soft, mottled light-gray and very pale-orange; shaly; abundant pelecypods 12

H 65
Dolomite, medium- to dark-gray, aphanitic; beds 5-12 inches thick; a few nodules of gray chert 11

H 64
Dolomite, dark-gray, aphanitic to microcrystalline; beds 4-12 inches thick 10½

H 63
Dolomite, light-gray, fine-crystalline; one bed 4½

H 62
Dolomite, gray, microcrystalline; bedding indistinct; scattered nodules of light-gray chert 5

H 61
Dolomite, dark-gray, aphanitic to microcrystalline; bedding indistinct 10

H 60
Dolomite, gray, aphanitic to fine-crystalline; bedding indistinct 5

H 59
Dolomite, cherty, gray, aphanitic to microcrystalline; bedding indistinct; some large nodules and irregular beds of light-gray chert in basal 6 feet, small nodules of yellowish chert above 11

Total thickness of Cutter dolomite 182

Aleman dolomite

H 58
Dolomite, cherty, medium- to very light-gray, aphanitic to microcrystalline; abundant very irregular, large nodules and lenses of light-gray chert 6

H 57
Dolomite, light-gray, aphanitic; base of slope 3½

H 56
Dolomite, dark-gray, aphanitic to microcrystalline; one bed; top of upper Montoya cliff 5

H 55
Dolomite, medium-gray, aphanitic; one bed 4½

H 54
Dolomite, vuggy, light-gray, fine- to medium-crystalline, massive-bedded; vugs filled with dolomite and quartz crystals 6

H 53
Dolomite, cherty, dark-gray, aphanitic to fine-crystalline; bedding indistinct; abundant small nodules and lenses of gray to black chert; base of upper Montoya cliff 34

H 52
Dolomite, cherty, dark-gray, aphanitic to fine-crystalline; bedding indistinct; abundant round nodules and thin lenses of black chert; cliff and steep slope 30

H 51
Dolomite, cherty, gray, micro- to fine-crystalline; bedding indistinct; abundant irregular nodules of black chert; steep slope 5

H 50
Dolomite, cherty, dark-gray, aphanitic to fine-crystalline; beds 1-2 feet thick; abundant black chert as nodules and thin irregular lenses; steep slope 28½

Unit	Description	Thickness (feet)
H 49	Dolomite, cherty, medium- to dark-gray, micro- to fine-crystalline; beds 6-24 inches thick; chert, medium- to dark-gray as abundant nodules and lenses; thin bed of dark chert at base; lower 5 feet cliff; steep slope above	15½
	Total thickness of Aleman dolomite	138
	Upham dolomite	
H 48	Dolomite, crinoidal, medium- to light-gray, fine-crystalline, massive-bedded; scattered chert nodules	11
H 47	Dolomite, crinoidal, dark-gray, fine-crystalline	35
H 46	Dolomite, crinoidal, gray, fine-crystalline, massive-bedded	5
H 45	Dolomite, crinoidal, dark-gray, fine-crystalline, massive-bedded	10
H 44	Dolomite, arenaceous, dark-gray, fine-crystalline, massive-bedded; quartz, coarse-grained	10
H 43	Dolomite, crinoidal, arenaceous, gray, micro- to fine-crystalline; quartz, silty to pebbly, subrounded; 6-inch bed at base, massive-bedded above	6½
	Total thickness of Upham dolomite	77½
	Cable Canyon sandstone	
H 42	Sandstone, dolomitic, conglomeratic, gray; silty to pebbly, angular to rounded; laminated; weathers shaly; forms notch	2½
	Total thickness of Montoya group	400
	Unconformity	
	Section moved 2,700 feet east-northwest to W½SE¼ SE¼ sec. 2, T. 16 S., R. 4 E., on north wall of Hembrillo Canyon.	
	El Paso group	
H 41	Dolomite, light- to medium-gray; aphanitic to fine-crystalline; beds 3-36 inches thick with partings of light-gray shale; very small light-gray chert nodules abundant in some beds	17½
H 40	Dolomite, dark-gray, fine-crystalline, thick-bedded; base of cliff	3½
H 39	Dolomite, light-gray, microcrystalline; one bed; ledge	2
H 38	Dolomite, dark-gray, fine-crystalline, thick-bedded; a few small light-gray chert nodules; ledges and slopes	13
H 37	Dolomite, gray, micro- to fine-crystalline, medium-bedded; abundant nodules and thin discontinuous lenses of light-gray to black chert; top of cliff	25
H 36	Dolomite, light- to medium-gray, micro- to fine-crystalline; beds average 6 inches thick	35
H 35	Dolomite, light- to very light-gray, micro- to fine-crystalline; beds average 6 inches thick	10
H 34	Dolomite, medium- to light-gray, micro- to fine-crystalline; beds ½-30 inches thick	35
H 33	Dolomite, medium- to light-gray, micro- to fine-crystalline; beds ½-6 inches thick; minor pyrite	20
H 32	Dolomite, medium- to light-gray; beds 1-12 inches thick	40
H 31	Dolomite, gray, micro- to fine-crystalline, medium-bedded; base of cliff	31
H 30	Dolomite, light- to medium-gray, fine- to medium-crystalline; bedding indistinct; steep slope	14
H 29	Dolomite, cherty, light- to medium-gray; beds 2-5 inches thick; discontinuous lenses and nodules of medium- to dark-gray chert	18
H 28	Dolomite, oolitic, light- to dark-gray, aphanitic to fine-crystalline; beds indistinct or discontinuous; oolites less than 1.0 mm diameter	22
H 27	Dolomite, arenaceous, medium- to dark-gray, fine-crystalline; beds 1-6 inches thick, nodular in part; quartz is fine-grained, subrounded to well-rounded and frosted	26
H 26	Dolomite, medium-gray, micro- to fine-crystalline; beds 2-10 inches thick	19
H 25	Dolomite, light-gray, fine-crystalline; beds 2-5 inches thick; base of discontinuous cliff	15
H 24	Dolomite, gray, fine-crystalline; beds 2-12 inches thick; slopes and ledges	35
H 23	Dolomite, light-gray, micro- to fine-crystalline; beds indistinct and discontinuous, 1-2 inches thick; cliff	40
H 22	Dolomite, medium- to light-gray, micro- to fine-crystalline; massive; discontinuous cliff	20
H 21	Dolomite, light- to very light-gray, micro- to fine-crystalline, crinoidal; massive; trace of pyrite; steep slope	10
H 20	Dolomite, light-gray, fine-crystalline; beds 2-24 inches thick; steep slope	29½
H 19	Limestone, light- to dark-gray, aphanitic to medium-crystalline; upper thin-bedded, lower medium-bedded	20½
H 18	Limestone, light- to dark-gray, fine- to medium-crystalline; beds average 6 inches thick, fucoidal	13½
H 17	Limestone, dolomitic, arenaceous, light-gray, aphanitic to medium-crystalline; very fine-grained, angular to subrounded and frosted quartz; upper thin-bedded, massive below; fucoidal; traces of glauconite and mica	11½
H 16	Limestone, arenaceous, light-gray, fine-crystalline; crosslaminated with thin partings of shaly glauconitic sandstone; base of steep slope	7
H 15	Limestone, arenaceous, light-gray, fine- to medium-crystalline; bedding irregular; abundant fine-grained quartz, minor glauconite and micaceous hematite; top of cliff	3
H 14	Limestone, very arenaceous, micaceous, light- to light olive-gray, aphanitic; massive-bedded with faint crosslaminations; small amounts of micaceous hematite and glauconite; cliff	12½
H 13	Limestone, arenaceous, glauconitic, greenish-gray, fine-crystalline; one bed; ledge	3½
H 12	Sandstone, limy, glauconitic, greenish-gray, fine-grained; one bed; steep slope	4½

H 11	Limestone, dolomitic, arenaceous, glauconitic, light blue-gray to light-gray; quartz is silty to coarse-grained; bedding indistinct; minor glauconite and mica; irregular cliff	13
H 10	Limestone, silty, arenaceous, glauconitic, micaceous; banded dark yellowish-green and dusky-red; fine-crystalline; one bed; rounded ledge	7
H 9	Limestone, arenaceous, glauconitic, moderate-yellow, fine-crystalline; one bed; quartz is very fine- to fine-grained and angular; trace of mica; ledge	3½
	Total thickness of El Paso group	580
	Bliss sandstone	
H 8	Sandstone, conglomeratic, calcareous, ferruginous, glauconitic, dark yellowish-green and dusky-red; silty to pebbly, grains angular to rounded; beds 1-12 inches thick; minor siliceous and micaceous hematite, pink crystalline calcite, and white dolomite; highly glauconitic at top; irregular steep slope	15
H 7	Sandstone, conglomeratic, siliceous, calcareous, glauconitic, ferruginous, pale- to dark yellowish-green and dusky-red; silty to pebbly, grains angular to rounded; crosslaminated; thin lenses of siliceous hematite and scattered oolites of hematite; rock and fossil fragments, pyrite and mica; irregular steep slope	10½
H 6	Sandstone, conglomeratic, siliceous, glauconitic, dusky yellowish-green; quartz is silty to pebbly,-angular to subrounded; 6 inches of siliceous hematite at top; steep slope	4
H 5	Sandstone, glauconitic, hematitic, dark-gray; silty to very coarse-grained, angular to well rounded; hematitic oolites; crosslaminated	1½
H 4	Hematite, siliceous, blackish-red, with very thin pebbly, siliceous lenses of crosslaminated dark-gray sandstone; irregular slope	4
H 3	Sandstone, conglomeratic, siliceous, dark-gray, weathers light-gray; quartz is very coarse-grained to pebbly, angular; crosslaminated; ledge	1
H 2	Hematite, oolitic, arenaceous, blackish-red; oolites average 0.5 mm; quartz is fine- to coarse-grained, angular to subrounded; some thin crosslaminated lenses of siliceous pebbly dark-gray sandstone; steep slope	7
H 1	Sandstone, siliceous, glauconitic, mottled light-brown and light olive-gray; silty to very coarse-grained, grains angular to subrounded; one bed; weathers shaly at top; scattered large oolites of hematite with quartz centers; ledge	3
	Total thickness of Bliss sandstone	46
	Unconformity	
	Precambrian rocks	
	Light-gray quartzite, intruded by light-pink felsite which also intruded quartz feldspar schist.	

SECTION HV. LOWER PART OF PANTHER SEEP FORMATION AND UPPER PART OF MISSOURI SERIES IN HEMBRILLO CANYON

Section measured on northeast side of fault, a mile north of Upper Hembrillo Spring, beginning at NE corner NW¼ sec. 9, T. 16 S., R. 3 E. Description of this section is given to illustrate the lateral lithologic changes from correlative intervals of section H. Section H was measured only one-half to one mile to the southwest.

Unit no.	Description	Thickness (feet)
	Lower part of Panther Seep formation (upper Pennsylvanian)	
HV 27	Calcilutite, argillaceous, dark-gray, laminated; shale lenses; thin-bedded, ledges; top faulted (H 205)	3
HV 26	Interbedded dark-gray: shale, calcareous, fissile; calcilutite, argillaceous, laminated, very thin-bedded; slopes and ledges	12
HV 25	Limestone, micro-oolitic, aphanitic matrix; medium-bedded ledge; limestone pebble-conglomerate lenses at top (basal H 205)	2
HV 24	Shale, calcareous, dark-greenish, fissile; lenses of limestone and calcilutite, fossiliferous, dark-gray, ledges (H 203-204)	53
HV 23	Limestone, aphanitic, fossiliferous; medium- to thick-bedded ledges; microcoquina and calcilutite lenses (upper H 202)	7
HV 22	Shale, calcareous, greenish-gray, fissile to blocky; limestone lenses and nodules, slope (H 201-200)	46
HV 21	Limestone, argillaceous, fine-crystalline, medium-bedded; ledges; scattered fossil fragments (H 199-200)	15
HV 20	Shale, calcareous to carbonaceous, dark-gray, fissile; limy nodules; *Marginifera* cf. *M. wabashensis* (H 198)	37
HV 19	Limestone, upper microcoquinoid, lower argilla,-ceous, slightly arenaceous, dark-gray; medium-bedded ledges (H 196-197)	10
HV 18	Shale, calcareous, fissile; several beds of argillaceous limestone and carbonaceous laminated calcilutite (H 194-195)	28
HV 17	Shale, calcareous, sandy laminae, olive-gray, fissile; slope	10
HV 16	Limestone, silty; lenses of fine-grained silty calcarenite; medium-bedded ledges; *Triticites;* medial limy silty shale (upper H 193)	11
HV 15	Upper sandy calcareous greenish shale; lower sandstone, calcareous, olive, medium-grained, porous, thin- to thick-bedded	10
HV 14	Shale, slightly calcareous, sandy, micaceous, greenish to yellowish; sandstone laminae and ledge; slope	26
HV 13	Interbedded calcareous dark greenish-gray; shale, sandy, fissile; sandstone, weathers brownish, fine-grained, crosslaminated	40
HV 12	Shale, blackish to greenish, fissile, slope; nodules and lenses of argillaceous limestone	12
HV 11	Shale, greenish to blackish, fissile; sandstone lenses, calcareous, silty, brownish, very fine-grained, fossiliferous	8
HV 10	Shale, blackish to greenish, fissile; slope; lenses of argillaceous limestone with phosphatic pelecypods	10

Section moved 2,600 feet southeast across Hembrillo Canyon, to northeast corner SW¼SW¼ sec. 10, T. 16 S., R. 3 E., about ¾ mile northeast of Upper Hembrillo Spring

HV 9	Sandstone, calcareous, micaceous, medium-grained; scattered glauconite and white feldspar; hard thick-bedded ledges (H 189)	23½
HV 8	Upper sandy silty greenish shale; lower calcareous, micaceous, brownish, medium-grained sandstone	8
HV 7	Shale, sandy, silty, dark-greenish, fissile; many laminae and lenses of micaceous sandy siltstone; slope	17½
HV 6	Sandstone, limy, micaceous, olive, medium-grained, crosslaminated, thick-bedded; massive rounded ledges (H 187)	13½
HV 5	Shale, silty, sandy, greenish, fissile; lenses and laminae of silty sandstone and sandy siltstone, calcareous (H 185-186)	76½
	Partial thickness of Panther Seep formation	479
	Unconformity	
	Missouri series (lower upper Pennsylvanian)	
HV 4	Interbedded: calcilutite, silty, laminated, tan, thin-bedded; shale, calcareous, dark-gray, fissile (H 184)	12
HV 3	Shale, calcareous; slightly carbonaceous, medium dark-gray, fissile; slope	35
HV 2	Limestone, argillaceous, dark-gray, aphanitic; calcilutite lenses; thin-bedded, ledges; shale lenses, calcareous, clayey	25
HV 1	Shale, calcareous, light greenish-gray, fissile to clayey; scattered limestone nodules; slope; base is fault	40
	Partial thickness of Missouri series	112

SECTION A. PALEOZOIC FORMATIONS IN ASH CANYON AREA

Panther Seep formation measured on west side of upper Ash Canyon, beginning in the center of NE¼SW¼ sec. 20, T. 19 S., R. 4 E. Lower Pennsylvanian rocks, Mississippian formations, Devonian formations, Fusselman dolomite, Montoya group, El Paso group, and Bliss sandstone measured along Ash Canyon.

Unit no.	Description	Thickness (feet)
	Top of section on ridge crest; erosion surface cut on lower limestones of Hueco formation	
	Hueco formation (basal beds)	
A 219	Limestone, light-gray, aphanitic, coquinoid lenses, thick- to massive-bedded; ledgy cliff, *Schwagerina andresensis*	68½
	Partial thickness of Hueco formation	68½
	Local unconformity	
	Panther Seep formation (uppermost Pennsylvanian)	
A 218	Upper sandstone, brownish, fine- to medium-grained, hard, thin-bedded; lower siltstone, sandy, thin-bedded	20
A 217	Shale, greenish-gray, silty near top, hard, platy to blocky; slope	50
A 216	Intercalated partly covered: shale, calcareous, silty; siltstone, calcareous, dark-gray; grades laterally into calcilutite, silty, dark-gray, laminated; lenses of sandstone, greenish to brownish, fine-grained; slopes and ledges	102
A 215	Intercalated argillaceous, silty; limestone, blackish, aphanitic; calcilutite, gray, laminated; platy to thick-bedded	36½
A 214	Sandstone, limy, micaceous, medium-grained; cross-bedded, thick lenticular beds; basal limestone pebble-conglomerate	14½
A 213	Intercalated silty, argillaceous: limestone, blackish, aphanitic; calcilutite, laminated tan; platy to thick-bedded	65
A 212	Gypsum, light-gray, medium-crystalline; massive to laminated by siltstone and limestone; slope	79
A 211	Interbedded blackish, carbonaceous: limestone, argillaceous; shale; medial foot is sandstone, limy, micaceous, fine-grained	57
A 210	Intercalated limy, light-gray: shale, sandy, fissile; sandstone, micaceous, fine-grained, crosslaminated, thin-bedded	6
A 209	Interbedded silty, dark-gray: shale, calcareous; calcilutite, argillaceous, laminated, upper 4½ feet is limestone, massive	49
A 208	Interbedded limy: shale, sandy; sandstone, micaceous, fine-grained, crosslaminated, thin- to medium-bedded	15
A 207	Limestone, argillaceous, dark-gray, calcilutite lenses; basal and upper 2-foot sandstones, limy, micaceous, fine-grained	29
A 206	Limestone, argillaceous, carbonaceous, dark-gray, fetid, medium-bedded; calcilutite and limy siltstone lenses	117
A 205	Calcilutite, silty, dark-gray, laminated tan, medium-bedded; upper interbeds of shale, silty, calcareous, fissile	39
A 204	Gypsum, light-gray, granular, medium-crystalline, massive beds; slope; silty calcilutite lenses	25
A 203	Upper calcilutite, argillaceous, dark-gray laminated; shale lenses; lower limestone, argillaceous, dark-gray, aphanitic	26
A 202	Interbedded: shale, calcareous; calcilutite, silty, dark-gray, laminated; lenses of limy siltstone and silty calcarenite	93
A 201	Sandstone, feldspathic, calcareous, medium-grained, crosslaminated; pebbly lenses; lenticular beds, prominent ledge	17
A 200	Calcilutite, silty, dark-gray, laminated; shale interbeds, calcareous, silty; limy siltstone and silty sandstone lenses	36
A 199	Sandstone, calcareous, micaceous, gray weathers tan, very fine-grained; silt laminae; crosslaminated; single hard ledge	2

A 198
Upper limestone, argillaceous, dark-gray, aphanitic; laminated calcilutite lenses; lower shale, calcareous, fissile 22

A 197
Interbedded silty, dark-gray: calcilutite, argillaceous, laminated, medium-bedded; shale, calcareous, fissile 14

A 196
Limestone, argillaceous, dark-gray, aphanitic to fine-crystalline, medium-bedded; calcilutite lenses near top 15

A 195
Shale, silty, calcareous, gray, fissile; slope; upper lens of silty calcilutite and calcareous siltstone 11

A 194
Sandstone, feldspathic, calcareous, light-gray weathers brown, coarse-grained, porous; thin- to massive-bedded ledges 15½

A 193
Upper limestone, argillaceous, dark-gray, aphanitic; medial shale, silty; basal sandstone, limy, silty, olive-gray 9½

A 192
Interbedded silty, dark-gray: shale, calcareous, fissile; calcilutite, laminated, fossiliferous, medium-bedded 28

A 191
Sandstone, limy, silty, micaceous, gray to olive, fine- to medium-grained; lenticular medium-bedded ledge 3½

A 190
Shale, calcareous, blackish, fissile; nodules and lenses of limestone, carbonaceous, argillaceous, dark-gray, aphanitic 48½

A 189
Interbedded blackish: shale, calcareous, fissile; limestone, carbonaceous, argillaceous, aphanitic; calcilutite lenses 15

A 188
Shale, calcareous, blackish, fissile to nodular; many calcareous nodules; medial foot is limestone, carbonaceous, shaly 35

A 187
Interbedded: calcareous fissile shale; calcilutite, argillaceous, laminated, dark-gray, hard, thin- to medium-bedded 30

A 186
Interbedded silty: calcarenite, micaceous, very fine-grained, laminated; shale, calcareous, fissile to blocky 16

A 185
Interbedded: shale, calcareous, fissile to clayey; limestone, shaly, dark-gray, aphanitic; calcilutite lenses 32½

A 184
Interbedded: shale, calcareous, greenish, fissile; calcilutite, silty, argillaceous, dark-gray, laminated; hard ledges 15

A 183
Interbedded limy, silty: sandstone, very fine-grained, crosslaminated; shale, greenish, fissile 6½

A 182
Upper calcarenite, silty, dark to olive-gray, oolitic, very fine-grained, fossiliferous; lower shale, calcareous 7

A 181
Interbedded silty, light-gray: shale, fissile; sandstone, calcareous, micaceous, very fine-grained, platy; weathers tan 32

A 180
Shale, greenish, fissile, sandstone laminae; upper foot is limestone, very argillaceous, fine-crystalline, algal 16

A 179
Upper sandstone, calcareous, micaceous, silty, very fine-grained, platy; lower shale, carbonaceous, dark-gray, laminated 5

A 178
Upper limestone, argillaceous, dark-gray, aphanitic, weathers tan to orange; lower shale, carbonaceous, dark-gray, fissile 4

A 177
Interbedded: shale, sandy, greenish, fissile; sandstone, arkosic, calcareous, light-gray, fine-grained, crosslaminated 82½

A 176
Interbedded silty, greenish: shale, calcareous, fissile; calcilutite/calcareous siltstone, laminated, very thin-bedded 16½

A 175
Interbedded: shale, sandy, greenish, fissile; sandstone, arkosic, calcareous, light-gray, fine-grained, crosslaminated 45

A 174
Interbedded: shale, dark-gray, blocky; calcilutite, silty, gray to brownish, laminated, thin-bedded 37

A 173
Interbedded: shale, silty, olive, laminated; sandstone, arkosic, calcareous, micaceous, fine-grained, fissile to thin-bedded 35

A 172
Sandstone, arkosic, calcareous, micaceous, fine- to coarse-grained; thick lenticular beds; medial shale, sandy, greenish 29

A 171
Shale, calcareous, medium-gray, fissile; slope; thin lenses of calcilutite, silty, laminated, gray to brownish 26

A 170
Interbedded: calcilutite, very silty, laminated, gray and tan; limy siltstone lenses; shale, calcareous, fissile 30

A 169
Sandstone, arkosic, calcareous, micaceous, dark-gray, medium-grained, crosslaminated; brownish prominent ledge 5½

A 168
Interbedded carbonaceous, dark-gray: limestone, argillaceous, fine-crystalline; hard thin beds; shale, fissile, slope 14½

A 167
Upper sandstone, limy, porous, olive, fine-grained; medium-bedded ledge; lower shale, silty, olive, fissile; slope 27

A 166
Upper third is calcilutite, silty, carbonaceous, laminated; siltstone lenses; lower shale, carbonaceous, dark-gray, fissile 28

A 165
Subgraywacke, limy, silty, micaceous, greenish, very fine-grained, crosslaminated, thin- to medium-bedded; ledge 1½

A 164
Interbedded: calcilutite, silty, gray laminated tan, thin-bedded; shale, calcareous, fissile; slope 53½

A 163
Calcarenite, silty, medium-grained; lenses of flat limestone pebble-conglomerate; basal sandstone, limy, weathers tan 8

A 162
Shale, dark-gray with limestone nodules; basal calcarenite, feldspathic, arenaceous, dark-gray, coarse-grained, friable 29

A 161
Shale, dark-gray, blocky; limestone concretions; some calcilutite, silty, argillaceous, dark-gray, laminated; thin ledges 41

A 160
Interbedded: sandstone, limy, arkosic, micaceous, silty, greenish, fine-grained; shale, sandy, calcareous, olive 27

A 159
Shale, blackish, fissile; ferruginous calcareous nodules; basal foot is calcilutite, silty, carbonaceous, dark-gray, laminated 26

A 158
Shale, sandy, greenish-gray; weathers dark yellow-

	ish-orange; fissile, slope; lenses and laminae of sandstone	39
A 157	Sandstone, arkosic, greenish, fine- to coarse-grained, crosslaminated, thin- to medium-bedded; ledges; *Triticites*	21½
A 156	Shale, sandy, greenish-gray, fissile; slope; medial foot is calcilutite, silty, carbonaceous, dark-gray, laminated	13½
A 155	Interbedded limy, greenish-gray: shale, sandy, fissile; sandstone, micaceous, silty, very fine-grained, platy	43
A 154	Sandstone, arkosic, calcareous, olive, fine- to medium-grained, thick-bedded; basal shale, sandy, greenish	32
A 153	Shale, dark-gray, fissile; sandy laminae; caliclutite lenses; several beds of limestone, carbonaceous, argillaceous	45
A 152	Interbedded: shale, calcareous to carbonaceous, blackish; calcilutite, carbonaceous, silty, dark-gray, laminated	88
A 151	Shale, carbonaceous, grayish-black, fissile to blocky; slope	47
A 150	Limestone, aphanitic, oolitic, algal; *Triticites* cf. *T. cullomensis;* calcarenite, calcilutite, and coquinoid lenses; ledge	8
A 149	Shale, calcareous, fissile; lenses of argillaceous limestone; scattered disc-shaped ferruginous concretions; slope	107
A 148	Alternating dark-gray: shale, calcareous, fissile; limestone, argillaceous, aphanitic; some fossils; thin-bedded	125
	Total thickness of Panther Seep formation	2,390

Local unconformity

Missouri series (lower upper Pennsylvanian)

A 147	Limestone, dark-gray, fine-crystalline, medium-bedded; ledges; reddish chert on undulating top surface	10
A 146	Limestone, cherty, silty, fine-crystalline, very thin-bedded, rubbly ledges; chert 20% as nodules and lenses	20
A 145	Limestone, cherty, fine-crystalline; nodular thin beds; primitive *Triticites;* calcareous shale lenses near base	17
A 144	Limestone, cherty, medium-crystalline, massive-bedded, cliff; chert 20% as nodules, lenses, and stringers	38
A 143	Limestone, light-gray, fine-crystalline; coquinoid lenses coarse-crystalline; massive-bedded; vertical cliff	16
A 142	Limestone, upper argillaceous, nodular thin beds; lower 40% chert nodules and flakes; *Wedekindellina aff. W. ultimata*	19
A 141	Limestone, upper dark-gray; thin- to thick-bedded ledges; lower shaly, nodular; *Wedekindellina ultimata;* slope	25
	Total thickness of Missouri series	145

Disconformity

Des Moines series (upper middle Pennsylvanian)

A 140	Limestone, cherty, dark-gray, aphanitic, to fine-crystalline, medium-bedded; ledges; 20% chert nodules	23
A 139	Limestone, upper third shaly, nodular; lower cherty, medium-crystalline, coquinoid lenses, *Fusulina,* medium-bedded, ledges	20½
A 138	Limestone, aphanitic to fine-crystalline, thick- to massive-bedded; ledges; upper lenses of limy shale	31½
A 137	Limestone, cherty; aphanitic to coarse-crystalline coquinoid lenses; *Fusulina;* medium-bedded; ledges and cliffs	64
A 136	Interbedded: limestone, argillaceous, aphanitic, thin nodular beds; shale, calcareous, light-gray, fissile	4
A 135	Sandstone, limy, coarse-grained, thick-bedded, ledges; crosslaminated; arenaceous calcarenite lenses	7
A 134	Limestone, fine- to medium-crystalline; thin nodular beds; coquinoid lenses; *Fusulina leei, Wedekindellina*	7
A 133	Limestone, medium-crystalline; upper massive bed; *Fusulina, Eoschubertella;* lower argillaceous nodular thin beds	4
A 132	Calcarenite, arenaceous, grades up into limy sandstone; very coarse-grained, thick-bedded; *Fusulina pumila;* ledges	9
A 131	Limestone, arenaceous, medium-crystalline, thick-bedded; ledges; *Fusulina, Wedekindellina;* recrystallized calcarenite	13
	Total thickness of Des Moines series	183

Unconformity

Derry series (lower middle Pennsylvanian)

A 130	Shale, carbonaceous, grayish-black, fissile; partly covered slope; thickness of unit variable	22
A 129	Limestone, siliceous, dark-gray, fine-crystalline; fossiliferous calcarenite lenses; *Millerella;* massive ledge	7
A 128	Limestone, light-gray, fine-crystalline; lenses of coquinoid calcarenite; *Staffella, Millerella;* medium- to thin-bedded	5
A 127	Shale, slightly calcareous, grayish-green, fissile to flaky; scattered ferruginous calcareous nodules; slope	13
A 126	Shale, calcareous, light-gray, fissile; lenses of argillaceous limestone and coquinoid calcarenite; slope	20
A 125	Shale, calcarenous, fissile; upper foot is intercalated calcarenite and limy sandstone; *Millerella* common; crosslaminated	5
A 124	Limestone, argillaceous, silty, micaceous, aphanitic, thin-bedded; laminae and lenses of shale, calcareous, siliceous, greenish	11
A 123	Calcarenite, arenaceous, siliceous, fossiliferous, medium-grained, medium-bedded, crosslaminated; limy sandstone lenses	12½
A 122	Limestone, argillaceous, medium-crystalline, fossilif-	

	erous, thin-bedded; top 18 inches is siliceous olive phosphatic cherty limestone	5½
A 121	Upper foot is shale, calcareous, dark gray, fossiliferous; lower limestone, argillaceous, sandy, fossiliferous; limy sandy siltstone lenses; grades laterally into limy sandy shale and arenaceous coarse-grained calcarenite with limy sandstone lenses and chert-limestone flat pebble-conglomerate beds	6
	Total thickness of Derry series	107

Unconformity

Lake Valley formation

Dona Ana member

A 120	Encrinite, light-gray; trace of pyrite; crinoid fragments 0.2-6.0 mm in diameter; top of upper Mississippian cliff	8
A 119	Encrinite, light-gray, fine- to coarse-crystalline; beds 6-36 inches thick; insoluble residue includes silt to very fine rounded quartz grains and abundant euhedral quartz crystals; a few large white chert nodules	62
	Total thickness of Dona Ana member	70

Arcente member

A 118	Limestone, dark-gray, microcrystalline, silty; medium-bedded	3½
A 117	Limestone, light-gray, crinoidal, micro- to fine-crystalline; scattered small nodules of gray chert	4½
A 116	Siltstone, calcareous, argillaceous, dark-gray, medium-bedded; base of upper Mississippian cliff, top of steep slope	15
A 115	Limestone, dark-gray, aphanitic; with a few fragments of very light-gray crinoid stems; beds 6 inches thick	5
A 114	Siltstone, calcareous, pale yellowish-orange; poorly exposed	5
	Total thickness of Arcente member	33

Tierra Blanca member

A 113	Encrinite, light-gray, crinoid stem fragments 0.5-4.0 mm; thin-bedded with 5-foot bed at top	20
A 112	Limestone, gray, aphanitic; scattered crinoid stem fragments; slightly argillaceous and silty; thin-bedded	5
A 111	Limestone, medium- to light-gray, aphanitic to microcrystalline; abundant nodules and stringers of light-gray chert; base of steep slope	10
A 110	Encrinite, medium- to light-gray; crinoid stem fragments 1.0-3.0 mm; abundant nodules and stringers of light-gray chert; thin-bedded; 2-inch bed of light-gray chert at base; top of lower Mississippian cliff	27½
	Total thickness of Tierra Blanca member	62½

Alamogordo member

A 109	Limestone, silty, medium- to dark-gray, aphanitic to microcrystalline; scattered crinoid stem fragments	2½
A 108	Limestone, medium- to dark-gray, aphanitic to fine-crystalline; massive-bedded	20
A 107	Limestone, black; scattered nodules of black chert; massive-bedded; silty lenses	15
A 106	Limestone, dark-gray, aphanitic to fine-crystalline; medium- to massive-bedded; abundant nodules and lenses of black chert	55
A 105	Limestone, dark-gray, microcrystalline, medium-bedded; abundant nodules and lenses of black chert; base of lower Mississippian cliff	10
	Total thickness of Alamogordo member	102½

Unconformity

Andrecito member

A 104	Covered; along strike, limestone like A 103; top of slope	10

Section moved 800 feet east of north from canyon bottom up onto north wall, NE¼NE¼NW¼ sec. 28, T. 19 S., R. 4 E.

A 103	Limestone, silty, gray, micro- to fine-crystalline, thin-bedded; slope	5
A 102	Encrinite, dark-gray, slightly silty	10
A 101	Limestone, dark-gray, silty, aphanitic; thin-bedded with partings of calcareous silty hard light-gray shale	10
A 100	Encrinite, dark-gray; crinoid stems up to 2 cm in diameter	5
A 99	Limestone, silty, dark-gray, thin-bedded; partings of silty hard calcareous dark-gray shale	70
A 98	Limestone, silty, dark-gray, thin- to medium-bedded; partings of light-gray shale; abundant trilobite fragments; irregular ledge	10
	Total thickness of Andrecito member	120
	Total thickness of Lake Valley formation	388

Caballero formation

Section moved 600 feet north of east to NW¼NW¼ NE¼ sec. 28, T. 19 S., R. 4 E., on north wall of Ash Canyon

A 97	Limestone, arenaceous, gray, nodular, lenticular; interbeds of silty calcareous grayish-olive shale	5
A 96	Shale, pale-olive, silty, calcareous, soft, fissile	2
A 95	Siltstone, calcareous, dark-gray; weathers light-brown; nodular, lenticular; ledge	1
A 94	Shale, medium- to light-gray, silty, calcareous, fissile; abundant nodules and lenses of dark-gray silty aphanitic limestone; trilotite fragments, *Proetus*	52
	Total thickness of Caballero formation	60

Unconformity

Sly Gap formation

A 93	Covered; along strike shale as in A 92	10

A 92	Shale, black, micaceous, dolomitic, silty	5
A 91	Siltstone, mottled grayish-red, light olive-gray and dark-gray, micaceous, dolomitic; scattered very fine grains of quartz sand; shaly; irregular steep slope or rounded ledge	5
A 90	Covered; along strike is shale as in unit A 89	5
A 89	Shale, dolomitic, arenaceous, brownish-gray, fissile; abundant very fine-grained quartz sand	10
A 88	Shale, black, siliceous, micaceous, silty	4
A 87	Shale, dolomitic, arenaceous, micaceous, mottled grayish-red and light olive-gray, fissile; abundant silt and very fine-grained quartz sand	14
A 86	Shale, black to blackish-olive, siliceous, slightly silty and micaceous	17
A 85	Shale, olive-black, siliceous, clayey, fissile; in part micaceous	5
	Total thickness of Sly Gap formation	75

Onate formation

A 84	Shale, dolomitic, pale yellowish-orange, slightly micaceous	4
A 83	Sandstone, siliceous, yellowish-gray to grayish red-purple, weathers light-brown, silty to very fine-grained; ledge	1
A 82	Shale as in unit A 84; base of slope	5
	Total thickness of Onate formation	10

Unconformity

Fusselman dolomite

Section moved south 1,000 feet across Ash Canyon to SW¼NE¼ sec. 28, T. 19 S., R. 4 E., on southwest wall of Ash Canyon.

A 81	Dolomite, cherty, calcareous, light- to dark-gray, aphanitic to fine-crystalline, massive-bedded; chert is very light- to medium-gray, in rough irregular nodules and lenticular beds, 1-6 inches thick; top of Fusselman cliff	31½
A 80	Dolomite, calcareous, vuggy, medium- to dark-gray, micro- to medium-crystalline, massive-bedded; scattered lenses of medium- to dark-gray chert; numerous irregular vugs filled with quartz crystals	27½
A 79	Dolomite, calcareous, in part silicified, dark-gray, micro- to fine-crystalline, massive-bedded; a few lenticular beds of mottled medium- and dark-gray chert in upper part; highly silicified at base; numerous quartz-filled vugs in upper 5 feet	15
A 78	Dolomite, calcareous, in part silicified, medium-gray, micro- to fine-crystalline, massive-bedded; abundant irregular nodules of chert, mottled moderate-brown and dark-gray; lower 1½ feet is silicified dolomite, weathering dark-brown	11½
A 77	Dolomite, calcareous, light-gray, fine-crystalline, massive-bedded; relief of 6 inches at contact with Cutter dolomite; base of Fusselman cliff	9
	Total thickness of Fusselman dolomite	94½

Unconformity

Montoya group

Cutter dolomite

A 76	Dolomite, gray, aphanitic to microcrystalline, beds 2-24 inches thick; top of irregular slope	4½
A 75	Dolomite, light- to medium-gray, microcrystalline, thick-bedded; zone of nodular chert and thin lenticular chert bed occur 2½ feet below top	11
A 74	Dolomite, gray, aphanitic to microcrystalline; beds 2-30 inches thick; widely scattered nodules of gray and moderate-brown chert in upper 9 feet; beds of dark-brown-weathering siliceous dolomite occur at 11 feet and 16 feet below the top	34½
A 73	Covered; along strike dolomite like A 72	17½
A 72	Dolomite, light-gray, aphanitic to microcrystalline; beds 5-30 inches thick; scattered nodules of grayish-brown chert	7
A 71	Covered; along strike dolomite like A 70	20
A 70	Dolomite, argillaceous, soft, mottled light-gray, pale-orange, and yellowish-gray; poorly exposed	3
A 69	Limestone, cherty, light-gray, fine-crystalline, thin-bedded; small nodules of mottled medium- and dark-gray chert	2
A 68	Dolomite, dark-gray, aphanitic; beds 1-5 inches thick	5
A 67	Dolomite, light-gray, aphanitic; beds ½-5 inches thick	9
A 66	Dolomite, light- to dark-gray, fine-crystalline; beds irregular, average 1 inch thick	26
A 65	Dolomite, dark-gray, aphanitic to microcrystalline; beds 1-2 feet thick	12½
A 64	Dolomite, medium- to dark-gray, aphanitic; beds 1-5 inches thick	12½
A 63	Dolomite, gray, aphanitic to microcrystalline; one bed; scattered chert nodules	4
	Total thickness of Cutter dolomite	168½

Aleman dolomite

A 62	Dolomite, gray, aphanitic to microcrystalline; beds 6-8 inches thick, separated by thin irregular beds of black chert	4½
A 61	Dolomite, dark-gray, microcrystalline; in two 1½-foot beds; irregular nodules of black chert in lower bed	3
A 60	Dolomite, dark-gray, micro- to fine-crystalline; one bed	8½
A 59	Limestone, light-gray, aphanitic; one bed; scattered small round and lenticular nodules of black chert	9
A 58	Dolomite, gray, aphanitic; one bed; scattered small nodules of dark-gray to black chert	2
A 57	Dolomite, medium- to dark-gray, aphanitic to microcrystalline; massive-bedded in upper 9 feet; lower beds 6-30 inches thick	14½
A 56	Dolomite, cherty, dark-gray, microcrystalline; bed-	

ding indistinct; 11-inch bed of mottled light-grayish tan, black, and reddish-brown chert at base; chert as nodules and lenses above 8½

A 55

Dolomite, dark-gray, microcrystalline; bedding indistinct; scattered nodules of gray chert; top of Upham-Aleman cliff 5

A 54

Dolomite, cherty, dark-gray, microcrystalline, massive-bedded; dark-gray to black chert as large irregular nodules 14

A 53

Dolomite, cherty, dark-gray, microcrystalline; beds 1-6 feet thick; dark-gray to black chert as nodules and thin lenticular beds; vuggy in upper 2 feet 58½

A 52

Dolomite, cherty, dark-gray, microcrystalline, medium-bedded; 3-inch bed of dark-gray to black chert at base; thin lenticular beds of chert above 3½

Total thickness of Aleman dolomite 131

Upham dolomite

A 51

Dolomite, crinoidal, vuggy, dark-gray, micro- to medium-crystalline, massive-bedded; abundant small vugs filled with white calcite 15

A 50

Dolomite, dark-gray, micro- to fine-crystalline, massive-bedded 5

A 49

Dolomite, crinoidal, dark-gray to black, micro- to medium-crystalline, massive-bedded 30

A 48

Dolomite, crinoidal, medium- to dark-gray, micro- to medium-crystalline, massive-bedded 45

A 47

Dolomite, arenaceous, crinoidal, vuggy, dark-gray, micro- to medium-crystalline; bedding indistinct; quartz very fine to coarse-grained and pebbly 9

Total thickness of Upham dolomite 104

Cable Canyon sandstone

A 46

Sandstone, siliceous, conglomeratic, light-gray, fine-grained to pebbly; grains angular to well-rounded and frosted; crosslaminated; minor smoky, blue-gray, and purple quartz and white feldspar; base of cliff 21

Total thickness of Montoya group 424½

Unconformity

Section moved 2,200 feet east, across Ash Canyon to SW¼NW¼ sec. 27, T. 19 S., R. 4 E., on northeast wall of Ash Canyon at its mouth.

El Paso group

A 45

Dolomite, gray, micro- to fine-crystalline; bedding indistinct; top of irregular slope 21

A 44

Dolomite, light-gray, fine-crystalline; bedding indistinct 15

A 43

Dolomite, medium- to dark-gray, micro- to fine-crystalline; massive 50

A 42

Covered; along strike is dolomite like A 38 5

A 41

Dolomite, mottled light-gray and moderate reddish-brown, fine-crystalline; massive 5

A 40

Dolomite, dark-gray, micro- to fine-crystalline; massive; abundant hematite pseudomorphs of pyrite 35

A 39

Dolomite, light- to medium-gray, micro- to fine-crystalline; massive in upper part, 1-foot beds below 17

A 38

Dolomite, light- to dark-gray, micro- to fine-crystalline; beds 3-5 inches thick 28

A 37

Dolomite, light-gray, microcrystalline; beds 2-5 inches thick; a few thin discontinuous beds of black chert 10

A 36

Dolomite, dark-gray, micro- to fine-crystalline; beds 2-8 inches thick; black chert in thin continuous lenses and small irregular nodules 18½

A 35

Dolomite, light-gray, microcrystalline, platy to medium-bedded 5½

A 34

Dolomite, medium- to light-gray, micro- to fine-crystalline; platy to thin-bedded, in part nodular; siliceous silty irregular concretions 32

A 33

Dolomite, medium- to dark-gray, micro- to fine-crystalline; bedding indistinct, averages 6 inches; a few irregular thin lenses of dark-gray chert 49

A 32

Dolomite, medium- to dark-gray, micro- to fine-crystalline; bedding indistinct 25

A 31

Dolomite, light- to very light-gray, micro- to medium-crystalline; bedding indistinct 35

A 30

Dolomite, medium- to light-gray, fine-crystalline; bedding indistinct; base of irregular slope 55

A 29

Dolomite, gray, micro- to fine-crystalline; bedding indistinct; scattered round and oblate nodules of very light-gray to black chert; cliff 57

A 28

Dolomite, dark-gray, fine-crystalline, soft; bedding irregular, nodular; scattered small nodules of dark-gray chert; top of steep slope 7

A 27

Dolomite, light- to dark-gray, fine-crystalline; massive, bedding indistinct; cliff to steep ledgy slope 45

A 26

Dolomite, oolitic, medium- to dark-gray, micro- to fine-crystalline; beds 5-24 inches thick; very steep slope 26

A 25

Dolomite, arenaceous, oolitic, dark-gray, fine-crystalline; beds 6-18 inches thick; quartz is fine- to coarse-grained; grains well rounded, dull to frosted; steep slope 10

A 24

Dolomite, oolitic, light- to dark-gray, fine-crystalline; beds 6-24 inches thick; dark-gray oolites (0.5 mm) in matrix of light-gray dolomite; base of steep slope 15

A 23

Dolomite, gray, micro- to fine-crystalline; platy to medium-bedded; irregular slope 29

A 22

Dolomite, cherty, mottled light- and medium-gray, micro- to fine-crystalline; laminated; abundant very light- to medium-gray chert nodules; slope 6

A 21

Dolomite, gray, fine-crystalline, thick-bedded; cliff 6½

A 20

Dolomite, gray, micro- to fine-crystalline; interlaminated with aphanitic gray limestone; laminae are within 6-inch beds; top of irregular slope 8½

A 19

Dolomite, light- to medium-gray, fine- to medium-crystalline; beds average 4 inches thick; irregular

Unit no.	Description	Thickness (feet)
	cliff	15
A 18	Dolomite, medium- to light-gray, aphanitic to fine-crystalline; beds 3-9 inches thick; irregular slope	19
A 17	Dolomite, light-gray, fine-crystalline, laminated; weathers shaly at top	11
A 16	Dolomite, light-gray, fine- to medium-crystalline; laminated within 4-5 inch beds	10
A 15	Dolomite, light-gray, fine-crystalline; laminated as above	26
A 14	Limestone, medium- to light-gray, aphanitic to fine-crystalline; beds 6-24 inches thick, with laminations 1/8-1 inch thick	19
A 13	Limestone, arenaceous, dolomitic, medium- to light-gray, aphanitic to fine-crystalline, platy to medium-bedded; quartz is silty to very fine-grained; trace of muscovite and glauconite	20
A 12	Dolomite, arenaceous, medium brownish-gray, fine- to medium-crystalline; platy to medium-bedded; quartz is very fine-grained, angular to well-rounded; abundant glauconite 10 feet below top; shaly	20
A 11	Limestone, arenaceous, gray, fine-crystalline; cross-laminated; quartz is fine-grained, frosted, subrounded; trace of mica and limonite	4½
	Total thickness of El Paso group	760½
	Bliss sandstone	
A 10	Sandstone, calcareous, limonitic, banded light- and moderate olive-brown, silty to medium-grained; grains angular to subrounded and frosted; laminated; base of irregular slope	11½
A 9	Sandstone, siliceous, calcareous, pinkish to light brownish-gray, silty to coarse-grained; grains angular to well rounded and frosted; 14-inch bed of light-gray pebble-conglomerate at base; bedding indistinct; minor glauconite, hematite, and limonite; top of cliff	17½
A 8	Sandstone, quartzitic, in part highly glauconitic and calcareous; color varies with accessory minerals, light to dark greenish-gray, light- to dark-brown, light- to medium-gray, moderate-red, and black; silty to coarse-grained with pebbly lenses; grains angular to well rounded; crosslaminated; varying amounts of hematite, limonite, glauconite, pink quartzite, pyrite, mica, and feldspars; base of cliff	36
A 7	Sandstone, siliceous, slightly calcareous, pinkish-gray, silty to coarse-grained; grains angular; larger grains well rounded, frosted; crosslaminated; partings of shaly silty sandstone; top of steep irregular slope	10
A 6	Sandstone, glauconitic, siliceous, micaceous, hematitic, dark greenish-gray and pale reddish-brown; silty to coarse-grained; grains angular to rounded; laminated with micaceous partings; minor pyrite, calcite, mica, and micaceous hematite; abundant glauconite; steep slope	11½
A 5	Sandstone, siliceous, limonitic, pinkish-gray speckled with light-brown, well sorted, coarse-grained; grains angular; one bed	4
A 4	Sandstone, siliceous, quartzitic, glauconitic, banded dusky yellow-green and pink; silty to very coarse-grained; crosslaminated; minor mica and rock fragments	1
A 3	Sandstone, glauconitic, siliceous, dark greenish-gray, silty to medium-grained; grains subrounded to rounded; abundant glauconite; platy to very thin-bedded	9
A 2	Sandstone, glauconitic, calcareous, olive-gray, silty to coarse-grained; grains angular to rounded; laminated; 6-inch lenticular bed of pebbly sandstone at base; ledge	4
A 1	Hematite, oolitic, reddish-brown; ledge	1
	Total thickness of Bliss sandstone	105½
	Unconformity	
	Precambrian rocks	
	Pink microcline granite with inclusions of greenish mica schists; cut by thin pegmatite dikes	

SECTION L. LOVE RANCH FORMATION, CRETACEOUS FORMATIONS, AND PERMIAN FORMATIONS NEAR LOVE RANCH

Love Ranch formation measured northwest of Love ranch, beginning at center of south line of SW¼ sec. 19, T. 20 S., R. 4 E., 3,550 feet north-northwest of Love ranch headquarters. Cretaceous formations measured in series of low foothills between Love ranch and Horse tank. San Andres formation, Yeso formation, Abo redbeds, and upper Hueco formation measured south and southeast of Love ranch. Lower Hueco formation and upper Panther Seep formation measured northeast of Burke Spring.

Unit no.	Description	Thickness (feet)
	Love Ranch formation (lower part)	
L 182	Boulder-conglomerate, cement greenish limy silt and sandstone; boulders of limestone, sandstone, shale; ledge	15
L 181	Siltstone, calcareous, reddish-brown streaked gray, blocky; scattered rounded grains (0.2 mm) of frosted quartz	25
L 180	Boulder-conglomerate, limy sandstone matrix; lenses of reddish-brown siltstone and sandstone; massive ledges	55
L 179	Upper siltstone, calcareous, reddish, blocky, slope; lower limestone boulder-conglomerate, massive ledge	35
L 178	Upper sandstone, limy, arkosic, reddish, greenish, coarse-grained; lower siltstone, limy, reddish, blocky	15
L 177	Reddish calcareous siltstone between ledges of limestone pebble conglomeratic sandstone, calcareous, dusky-red	22
L 176	Andesite-tuff, reddish-brown mottled gray; scattered breccia blocks of pale-purple andesite; lens	3
L 175	Siltstone, reddish, calcareous; medial 25 feet is cliff of limestone boulder-conglomerate with arkosic limy sandstone matrix	82
L 174	Siltstone, calcareous, reddish; upper sandstone, limy, arkosic, reddish and greenish, coarse-grained, poorly sorted	18

L 173
Boulder-conglomerate; cement is sandstone, silty, limy, greenish; pebbles to boulders of limestone, sandstone, and shale; hard massive crossbedded ledges; lenses of reddish siltstone and silty sandstone 138

Partial thickness of Love Ranch formation 408

Unconformity

Eagle Ford formation

L 172
Upper fourth is shale, sandy, greenish; lower subgraywacke, porous, friable, arkosic, dark olive-gray; platy ledges 57

L 171
Interbedded silty, carbonaceous: shale, blackish, fissile; subgraywacke, arkosic, dark olive-gray, platy 20

L 170
Lower third subgraywacke, arkosic, silty, very thin-bedded; upper shale, silty, carbonaceous, blackish, fissile 40

L 169
Interbedded carbonaceous, silty: shale, blackish, fissile; subgraywacke, arkosic, dark olive-gray, platy 8½

L 168
Shale, silty, carbonaceous, blackish, fissile; along strike is shaly coal bed, up to 2 feet thick 1½

L 167
Interbedded silty, carbonaceous: subgraywacke, arkosic, olive-gray, platy; shale, blackish, fissile, slope 25

L 166
Upper subgraywacke, arkosic, dark-olive, partly calcareous; platy ledges; lower fourth is shale, sandy, limy 18½

L 165
Upper calcarenite, arenaceous, micaceous, greenish, fine-grained; lower sandstone, limy, arkosic, micaceous, greenish 4½

L 164
Upper shale, calcareous, sandy, dark-olive; lower calcarenite, conglomeratic, coquinoid, arenaceous, fine- to medium-grained 7

L 163
Subgraywacke, silty, arkosic, calcareous, olive-gray, fine-grained, thin- to massive-bedded; ledges 18

L 162
Upper shale, sandy, calcareous, fissile; lower calcarenite, arenaceous, micaceous, greenish, fine-grained; ledge 2½

L 161
Upper sandstone, limy, arkosic, micaceous, dark greenish-gray, fine-grained, very thin-bedded; grains are quartz, white feldspar, calcite, black biotite, muscovite; carbonaceous films; lower calcarenite, arenaceous, micaceous, greenish 4½

Section moved 2,200 feet north-northwest to center of SW¼ sec. 19, T. 20 S., R. 4 E., about 1/3 mile southeast of Davis well.

L 160
Sandstone, calcareous, olive, medium- to coarse-grained; pebbly lenses, porous; medial shale, carbonaceous, blackish 3

L 159
Sandstone, limy, olive, porous, fine-grained; upper foot is calcarenite, arenaceous, dark-gray, coquinoid, ledge 6

L 158
Intercalated limy sandstone and arenaceous calcarenite; fine-grained, coquinoid, dark-gray to olive-gray 2

L 157
Sandstone, calcareous, whitish to olive, fine-grained, thick-bedded; prominent light-gray rounded ledge 29

L 156
Sandstone, limy, fine-grained; upper is light gray to olive and massive bedded with nodules bearing *Turrilitoides* aff. *T. hugardianus, Inoceramus labiatus, Baculites* aff. *B. gracilis, Placenticeras;* lower is dark-gray platy beds 19

L 155
Upper subgraywacke, porous, olive, very fine-grained, thin-bedded; lower siltstone, sandy, calcareous, olive, fossiliferous 21

L 154
Shale, silty, carbonaceous, blackish, *Inoceramus labiatus;* lenses and basal calcarenite, arenaceous, coquinoid, brownish 30½

L 153
Subgraywacke, porous, olive, fine-grained, thin- to medium-bedded; woody and coaly plant stems 91½

L 152
Sandstone, limy, porous, light- to dark-gray, fine-grained to silty, thin- to medium-bedded 8

Section moved north 1.2 miles to SE¼NW¼ sec. 18, T. 20 S., R. 4 E., about ½ mile south-southwest of Horse tank. Part of Eagle Ford formation may have been omitted by this move.

L 151
Intercalated: limestone, arenaceous to siliceous, aphanitic; tan laminated calcilutite; shale, carbonaceous, blackish 3

L 150
Shale, mostly covered, carbonaceous, grayish-black, fissile to flaky; slope 5½

Total (?) thickness of Eagle Ford formation 425½

Unconformity

Dakota (?) sandstone

L 149
Sandstone, white, porous, medium- to coarse-grained, medium-bedded; hard laminated ledges 2

L 148
Interbedded, mostly covered: sandstone, calcareous, glauconitic, porous, fine-grained; shale, grayish-black 27

L 147
Sandstone, calcareous, porous, light-gray, fine-grained; wavy thin-bedded; greenish glauconitic lenses 41

L 146
Sandstone, whitish, weathers tan, medium- to fine-grained, thick-bedded; persistent outcropping ledges 15

L 145
Partly covered sandstone, siliceous, dark greenish-gray, very fine-grained to silty; shale lenses; slope 32½

L 144
Sandstone, quartzitic, whitish speckled tan, coarse- to medium-grained, thick- to massive-bedded; lenticular crossbedded hard ledges; basal pebbly lenses with chert, quartz, and red sandstone pebbles 28

L 143
Mostly covered sandstone, calcareous, silty, greenish, very fine-grained, very thin-bedded; siltstone lenses 26

L 142
Sandstone, siliceous, hard, porous, whitish speckled tan, fine-grained, thin- to thick-bedded; ledges 14½

Total thickness of Dakota (?) sandstone 186

Unconformity

Sarten formation

L 141
Mostly covered shale, blackish, fissile; lenses of

	greenish yellowish calcareous sandstone; medial greenish claystone	16
L 140	Interbedded: sandstone, calcareous, siliceous, tan, yellowish, red-purple, fine-grained; shale, carbonaceous, blackish	13
L 139	Upper carbonaceous blackish shale; lower sandstone, silty, calcareous, olive, fine-grained; some glauconite; slope	21
L 138	Sandstone, limy, weathers orange to tan, fine-grained; top is pelecypod-oyster coquina; single prominent ledge	3
L 137	Upper shale, calcareous, silty, pale red-purple; lower sandstone, silty, porous; weathers pink to purple	32
L 136	Upper shale, sandy, calcareous; fossiliferous lenses; lower sandstone, silty, porous, light-gray, weathers pale-red, yellowish, pale red-purple, fine- to very fine-grained; basal conglomeratic lenses, rounded pebbles	10½
	Total thickness of Sarten formation	95½

Unconformity

San Andres formation

L 135	Limestone, silty, fetid, dark-gray, fine-crystalline, thin-bedded; many vugs; top eroded	12-30
L 134	Interbedded: siltstone, limy, yellowish to pink, fissile; limestone, silty, fetid, dark-gray; calcite nodules	22
L 133	Siltstone, calcareous, yellowish to pink, unbedded to fissile, thinly-laminated; sandy laminae; slope	21
L 132	Limestone, argillaceous, fetid, dark-gray, laminated, fine-crystalline, thin- to medium-bedded; siltstone lenses	38
L 131	Interbedded silty: limestone, dark-gray, fine-crystalline; sandstone, calcareous, greenish, porous, very fine-grained	13
L 130	Sandy siltstone and silty sandstone, calcareous, yellowish to pink, shaly; medial foot is gypsum, mottled, granular	44
L 129	Limestone, silty, fetid, dark-gray, fine-crystalline; silicified fossils; algal lenses; thin-bedded; ledges	6
L 128	Interbedded: limestone, argillaceous, dark-gray, fetid, fine-crystalline, medium-bedded; siltstone, limy, yellowish, shaly	11
L 127	Sandy siltstone and silty sandstone, limy, pink to yellowish, friable to shaly; slope; partly covered	22
L 126	Limestone, silty, cherty, fetid, dark-gray, aphanitic, medium-bedded; calcite-filled vugs; gastropods	15

Section moved 2.9 miles south to SW¼SE¼SE¼ sec. 30, T. 20 S., R. 4 E., about ¼ mile south-southeast of Love ranch headquarters.

L 125	Limestone, argillaceous, medium light-gray to tan, thin-bedded; rubbly ledges; calcite-filled vugs	20
L 124	Limestone, silty, fetid, dark-gray, aphanitic, medium-bedded; ledges; scattered white calcite nodules and gastropods	37½
L 123	Limestone, argillaceous, fetid, dark-gray, aphanitic to medium-crystalline; limonitic laminae; very thin-bedded	12½
L 122	Upper sandstone, silty, limy, yellowish; slope; lower limestone, gypsiferous, light-gray, fine-crystalline	3
L 121	Upper limestone, silty, dark-gray; medium-bedded ledges; lower sandstone, calcareous, silty, tan, friable; slope	17
L 120	Limestone, argillaceous, dark-gray, fetid, medium-crystalline; coquinoid lenses; medium- to thin-bedded	36
L 119	Sandstone, calcareous, silty, tan to grayish-yellow, fine-grained, friable, platy, to very thin-bedded; slope	19
L 118	Limestone, argillaceous, dark-gray, fetid, medium-crystalline, medium-bedded; basal conglomeratic breccia lenses	10
L 117	Sandstone, conglomeratic, tan to yellowish, angular limestone pebbles and cobbles in silty calcareous sandstone matrix; lenses of well-sorted crosslaminated tan silty sandstone; massive bed, ledge; Glorieta sandstone ?	5
	Total thickness of San Andres formation	384

Yeso formation

L 116	Limestone, argillaceous, dark-gray, aphanitic, weathers tan to greenish, laminated, medium-bedded; ledges	17
L 115	Sandstone, silty, calcareous, tan to yellowish, fine-grained, friable; 30-inch ledge of limestone, shaly, dark-gray	13
L 114	Upper sandstone, very silty, calcareous, tan to pink; lower limestone, argillaceous, dark-gray; some chert flakes	8
L 113	Upper sandstone, silty, calcareous, yellowish, friable; lower limestone, argillaceous, dark-gray, laminated greenish	22
L 112	Sandstone, silty, very fine-grained, pink to reddish-orange; upper yellowish and whitish lenses; partly calcareous	68
L 111	Sandstone, calcareous lenses, pink to orange, very fine-grained, friable, porous; upper light-gray beds	42
L 110	Sandstone, silty, pinkish, very fine-grained, platy, friable; basal fourth is siltstone, calcareous, reddish, shaly	32½
L 109	Upper limestone, argillaceous, fetid, fine-crystalline, laminated; lower claystone, calcareous, silty, light-gray, soft	2½
L 108	Sandstone, calcareous lenses, pink, very fine-grained, porous, friable, crosslaminated, very thin-bedded; slope	41½
L 107	Sandstone, grayish-red, very fine-grained, thick-bedded; rounded ledges; upper light-gray ledge	18½
L 106	Sandstone, silty, greenish to orange, fine-grained, platy; slope; 3 feet of claystone, silty, whitish, calcareous	25

L 105	Interbedded calcareous, greenish to reddish, thin-bedded: sandstone, silty, fine-grained; siltstone, sandy, blocky	7½
L 104	Claystone, shaly, calcareous, whitish; basal 4½ feet is siltstone, calcareous, pinkish, soft; slope	26
	Total thickness of Yeso formation	323½

Abo redbeds

L 103	Siltstone, sandy, grayish-red, thin- to medium-bedded; hard ledges; crosslaminated; greenish sandstone laminae	9½
L 102	Shale, grayish-red to pale-red, fissile, silty, calcareous, blocky; slope	12
L 101	Intercalated grayish-red: shale, silty, fissile; siltstone, calcareous, crosslaminated; medium-bedded ledges	10
L 100	Siltstone, calcareous, siliceous, light-gray to tan, medium-bedded; prominent ledges; crosslaminated	2
L 99	Interbedded grayish-red: shale, fissile, slopes; siltstone, calcareous, crosslaminated, thin- to medium-bedded; ledges	48
L 98	Siltstone, sandy, grayish-red, laminated, lenticular, medium-bedded; prominent ledge	5
L 97	Interbedded grayish-red: siltstone, calcareous, thin- to medium-bedded; crosslaminated ledges; shale, fissile; slopes	10
L 96	Sandstone, calcareous, siliceous, silty, grayish-red mottled olive, very fine-grained, medium-bedded; ledge	1
L 95	Shale, grayish-red, fissile; laminae and lenses of siltstone, calcareous, sandy, nodular, gray to pink; slope	29
L 94	Siltstone, calcareous, medium-bedded; ledges; upper siliceous, whitish to tan; lower grayish-red	4
L 93	Shale, silty, grayish-red, fissile; slope; 6-inch lens of siltstone, olive to tan, calcareous; ledge	16
L 92	Shale, silty, grayish-red, blocky; bracketed by siltstones, limy, siliceous, whitish to olive; hard ledges	9
L 91	Shale, partly silty, reddish mottled greenish, fissile; slope; upper foot is siltstone, calcareous, reddish; ledge	26
L 90	Upper sandstone, silty, reddish, fine-grained; thin-bedded ledges; lower shale, silty, reddish banded greenish	23
L 89	Siltstone, calcareous, siliceous, pink to green, crosslaminated; one lenticular bed; hard ledge; grades southward into silty calcarenites and northward into reddish sandy siltstone	2
L 88	Shale, silty, reddish, fissile; lenses of silty limy olive sandstone; top foot is sandstone, reddish, siliceous, silty	8
L 87	Calcareous, silty: upper shale, reddish, fissile; lower sixth is sandstone, olive-gray, very fine-grained	39
L 86	Shale, partly calcareous, reddish grading down into greenish, fissile; siltstone lenses, siliceous, calcareous, gray	11
L 85	Siltstone, calcareous, siliceous, gray, thin-bedded; hard ledges; lower shale, calcareous, greenish, fissile; slope	10
L 84	Shale, calcareous, reddish, flaky; medial foot is siltstone, limy, siliceous, reddish mottled green; hard ledge	5
L 83	Shale, calcareous, reddish laminated greenish; limestone laminae; upper sandstone, silty, calcareous, reddish, shaly	3
L 82	Shale, calcareous, reddish laminated greenish; upper foot is siltstone, limy, siliceous, gray tinted red; ledge	7
L 81	Mostly covered shale, calcareous, grayish-red to dark greenish-gray, clayey to flaky; slope	15
L 80	Sandstone, calcareous, siliceous, silty, olive; tan to pink laminae; very fine-grained; medium-bedded ledges	5
L 79	Mostly covered shale; interbedded grayish-red and dark greenish-gray, calcareous, clayey to flaky; slope	15
	Total thickness of Abo redbeds	324½

Hueco formation

L 78	Shale, calcareous, dark-gray to greenish, fissile, slope; medial foot is limestone, silty, aphanitic, ledge	5
L 77	Interbedded calcareous: shale, dark-gray to greenish; siltstone, hard, light-gray, thick-bedded; ledges	19
L 76	Calcarenite, silty, arenaceous, siliceous, light-gray, very fine-grained; basal foot is shale, calcareous, reddish to tan	4
L 75	Calcarenite, arenaceous, silty, siliceous, very fine-grained, crosslaminated; medial foot is shale, calcareous, reddish	4
L 74	Shale, calcareous, light-gray, fissile; medial 5 feet is siltstone, calcareous, siliceous, gray, medium-bedded; ledges	13
L 73	Limestone, gray, fine-crystalline, weathers tan, medium- to massive-bedded; basal 7 feet is prominent ledge	10
L 72	Intercalated: limestone, argillaceous, dark-gray, aphanitic, medium-bedded; ledges; shale, calcareous, gray, flaky; slope	5
L 71	Interbedded calcareous: siltstone, siliceous, crosslaminated; hard ledges; shale, gray to dark-gray; slopes	34
L 70	Siltstone, calcareous, siliceous; hard medium-beds; upper limestone, argillaceous, dark-gray, aphanitic; shale partings	18
L 69	Limestone, argillaceous, dark-gray, aphanitic, medium-bedded; ledges; shale lenses, limy, dark-gray	18½
L 68	Interbedded calcareous: siltstone, sandy, micaceous; hard thick beds; shale, silty, fissile, fossiliferous	14½
L 67	Interbedded: shale, calcareous, fissile; limestone, argillaceous, dark-gray, aphanitic, medium-bedded; ledges	20
L 66	Interbedded dark-gray: limestone, argillaceous, silty	

	to carbonaceous, aphanitic; shale, calcareous, flaky	14
L 65	Calcarenite, arenaceous, very fine-grained, medium-bedded, crosslaminated; grades laterally into limy silty sandstone	7
L 64	Shale, calcareous, fissile to flaky; 3½ feet of limestone, gray, fine- to medium-crystalline, fossiliferous; ledge	13
L 63	Interbedded: limestone, carbonaceous, silty, fine-crystalline, thin-bedded; ledges; shale, calcareous, flaky; slopes	16
L 62	Sandstone, limy, siliceous, silty, olive, very fine-grained, thin-bedded; lenses of calcarenite and limy siltstone	8
L 61	Interbedded: limestone, argillaceous, dark-gray, aphanitic, thin- to medium-bedded; ledges; shale, calcareous, laminated	47
L 60	Limestone, argillaceous, dark-gray, fine-crystalline, medium- to thick-bedded, fossiliferous; ledges	25
L 59	Shale, calcareous, light-gray, fissile; limestone lenses, fine-crystalline, fossiliferous, thin-bedded; ledges	20
L 58	Limestone, argillaceous, dark-gray, aphanitic, medium-bedded; scattered fossils and chert nodules; shale lenses	40
L 57	Interbedded: limestone, dark-gray, fine-crystalline; medium-bedded ledges; shale, calcareous, light-gray, fissile	30
L 56	Limestone, dark-gray, fine-crystalline, thin- to thick-bedded, fossiliferous; shale partings and lenses	20
L 55	Interbedded dark-gray: shale, calcareous, fissile; limestone, aphanitic, argillaceous to silty, thin-bedded	25
L 54	Interbedded: limestone, argillaceous, dark-gray, fine-crystalline; algal calcarenite lenses; shale, calcareous, light-gray	35
L 53	Upper calcilutite, silty, arenaceous, gray to tan, crosslaminated; lower shale, sandy, calcareous, light-gray	10
L 52	Calcilutite, arenaceous, silty; medial sandstone, calcareous, tan, very fine-grained to silty; lenticular ledges	12
L 51	Shale, calcareous, light-gray; upper sandy, fissile; lower clayey with silty coquinoid calcarenite lenses; slope	16
L 50	Shale, calcareous, clayey, calcilutite lenses; top 2 feet is limestone, argillaceous, carbonaceous, dark-gray; many fossils	11
L 49	Calcarenite, coquinoid, argillaceous, silty, dark-gray, medium- to coarse-grained; medium lenticular ledges	2
L 48	Shale, partly covered, calcareous, light-gray, clayey, slope; calcilutite and fossiliferous silty limestone lenses	23
L 47	Interbedded: calcarenite, coquinoid, silty, algal, dark-gray, medium-grained; ledges; shale, limy, whitish, clayey; slopes	16
L 46	Shale, calcareous, whitish, clayey to fissile; limestone ledges, coquinoid, silty, aphanitic, thin-bedded	25
L 45	Limestone, argillaceous, carbonaceous, dark-gray, fine-crystalline, fossiliferous; basal shale, calcareous, dark-gray	7
L 44	Recrystallized calcarenite, arenaceous, tan, medium-grained; grades up into sandstone, limy, siliceous, silty, tan	5
L 43	Upper shale, calcareous, sandy; lower limestone, argillaceous, carbonaceous, dark-gray, fossiliferous, medium-bedded	22
L 42	Shale, grayish-black, carbonaceous, fissile; lower 6 inches is calcarenite, coquinoid, silty, dark-gray, crosslaminated	22½
L 41	Interbedded: shale, calcareous, light-gray, clayey; limestone, argillaceous, carbonaceous, dark-gray, fossiliferous	14
L 40	Upper calcilutite, silty, arenaceous, micaceous, crosslaminated; lower shale, calcareous, clayey; limestone nodules	10
L 39	Limestone, argillaceous, carbonaceous, dark-gray, fossiliferous, fine-crystalline; basal shale, calcareous, greenish	19½

Section moved 2.2 miles north to NW¼SW¼ sec. 17, T. 20 S., R 4 E., to ridge north of Burke Spring.

L 38	Interbedded, partly covered dip-slope outcrops: limestone, argillaceous, dark-gray, fine-crystalline, fossiliferous, medium-bedded; ledges; shale, calcareous, weathers greenish, fissile to clayey; slopes	81
L 37	Limestone, silty, dark-gray, aphanitic, fossiliferous, medium- to thick-bedded; ledges; medial shale, limy, yellowish	50
L 36	Shale, greenish, calcareous nodules, clayey; ledges of limestone, dark-gray, aphanitic, fossiliferous, medium-bedded	35
L 35	Limestone, medium dark-gray, fine-crystalline; thick-bedded ledges; scattered lenses and nodules of chert	25
L 34	Limestone, dark-gray, fine-crystalline, fossiliferous, medium-bedded; ledges; shale lenses, limy, whitish, clayey	30
L 33	Limestone, dark-gray, aphanitic, medium- to thick-bedded, ledges; *Pseudofusulina* aff. *P. huecoensis;* shale lenses	35
L 32	Limestone, silty, dark-gray, fine-crystalline, very thin-bedded; ledges; upper third is shale, calcareous, silty	36½
L 31	Limestone, silty, dark-gray, aphanitic, scattered fossils, thick-bedded; ledges; upper shale, calcareous, silty	23½
L 30	Calcilutite, silty, dark-gray, laminated; calcarenite lenses; thin rubbly ledges; top 6 inches is tan chert	16½
L 29	Shale, calcareous, light-gray, fissile; basal limestone, light-gray, fine-crystalline; massive ledge	18½
L 28	Interbedded: calcilutite, silty, laminated, medium-bedded; ledges; shale, calcareous, light-gray, fissile	30
L 27	Limestone pebble-conglomerate, dark-gray; medium-grained calcarenite matrix; thick lenticular beds; friable ledges	5

Unit	Description	Feet
L 26	Calcilutite, silty, dark-gray, laminated, thin- to thick-bedded; ledges; grades down into L 25	15
L 25	Calcarenite, arenaceous, silty, porous, dark-gray, laminated, fine-grained; thin-bedded ledges	8½
L 24	Calcarenite, conglomeratic, dark-gray, porous, fetid; subrounded elongate limestone pebbles in medium-grained matrix	6½
L 23	Calcarenite, arenaceous, porous, very coarse-grained; grades down into sandstone, limy, greenish, crosslaminated	15
L 22	Upper quartz pebble-conglomerate; lower limestone pebble-conglomerate; very coarse-grained sandy matrix; crossbedded	5½
L 21	Calcarenite, arenaceous, porous, friable, dark-gray, medium-grained, crosslaminated, thin- to medium-bedded; ledges	11
L 20	Interbedded: limestone, argillaceous, dark-gray, aphanitic, medium-bedded; shale, calcareous, olive, clayey to fissile	13
L 19	Interbedded: limestone, dark-gray, fine-crystalline; coquina lenses; shale, calcareous, light-gray to olive	60½
L 18	Calcarenite, gray, medium- to coarse-grained, friable, crosslaminated, thin- to medium-bedded; lenticular ledges	5
L 17	Limestone, gray to dark-gray, aphanitic to medium-crystalline; medium-bedded ledges; pebbly calcarenite lenses	10
L 16	Limestone, aphanitic to medium-crystalline; thick to massive ledges; coquinoid lenses; *Pseudoschwagerina texana, Schwagerina;* lower chert flakes	55
L 15	Limestone, light-gray, aphanitic; crinoid columnal coquina lenses; thin- to thick-bedded; ledges	30
L 14	Limestone, medium light-gray, aphanitic to lithographic; fine- to medium-crystalline lenses; coquinoid calcarenite lenses; algal beds; scattered chert flakes; thick-bedded; prominent vertical cliff (= A 219)	54
	Total thickness of Hueco formation	1355

Local unconformity

Panther Seep formation (uppermost Pennsylvanian)

Unit	Description	Feet
L 13	Shale, calcareous, carbonaceous, dark-gray, fissile to nodular, slope	31
L 12	Interbedded carbonaceous, dark-gray: limestone, silty, fetid, aphanitic; limestone pebble lenses; shale, calcareous, fissile	25
L 11	Interbedded limy, silty, greenish: shale, fissile; sandstone, micaceous, very fine-grained, crosslaminated; ledges	12
L 10	Siltstone, limy, sandy, gray, thin- to medium-bedded; lenticular ledges; grades down into L 9	6
L 9	Sandstone, limy, micaceous, greenish, medium- to coarse-grained; arenaceous calcarenite and limestone pebble-conglomerate lenses	8½
L 8	Upper shale, calcareous, fissile; limestone nodules; lower limestone, argillaceous, dark-gray, aphanitic; ledge	7½
L 7	Sandstone, calcareous, silty, gray to tan, very fine-grained, crosslaminated, thin-bedded; ledge	2½
L 6	Interbedded: limestone, argillaceous, dark-gray, aphanitic; shale, calcareous, fissile; many limestone nodules	3½
L 5	Shale, calcareous, light-gray, fissile; limestone lenses; medial sandstone, calcareous, silty, tan, very fine-grained	10
L 4	Limestone, silty to sandy, carbonaceous, dark-gray, aphanitic, thin- to medium-bedded, ledges; *Triticites*	30
L 3	Limestone, carbonaceous, argillaceous, dark-gray, aphanitic; upper shale, calcareous, fissile; weathers red-purple	18
L 2	Calcilutite, argillaceous, silty, laminated, thin-bedded; rubbly ledges; laminae and lenses of shale, limy, greenish	37
L 1	Gypsum, light-gray, medium-crystalline; limestone and calcareous siltstone laminae (= A 212)	65
	Partial thickness of Panther Seep formation	256

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