Geology of the Sierra Diablo Region Texas

GEOLOGICAL SURVEY PROFESSIONAL PAPER 480

Geology of the Sierra Diablo Region Texas

By PHILIP B. KING

With SPECIAL DETERMINATIVE STUDIES OF PERMIAN FOSSILS

By L. G. HENBEST, E. L. YOCHELSON, P. E. CLOUD, Jr., HELEN DUNCAN, R. M. FINKS, *and* I. G. SOHN

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Description and interpretation of the varied rocks and structures of a mountain range and its foothills in the Trans-Pecos Region, with special emphasis on the Lower Permian

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GEOLOGY OF THE SIERRA DIABLO REGION, TEXAS

By Philip B. King

ABSTRACT

The Sierra Diablo region covers an area 43 miles long and 33 miles wide in the western part of the State of Texas. The region includes the whole of the Sierra Diablo, a lofty plateau-like range whose summits exceed 6,000 feet in altitude. The surface of the range slopes gently westward from its crest, but to the east, north, and south it breaks off in abrupt escarpments as much as 2,000 feet high. To the southeast and south the range is flanked by lower foothills, beyond which are the intermontane desert basins of the Salt Basin and Eagle Flat.

In its broader outlines, the Sierra Diablo resembles block mountains elsewhere in the Basin and Range province. In detail, its geologic features are complex, as it is made up of rocks of many ages and types, which have been deformed during several periods.

The oldest rocks of the region, of Precambrian age, are exposed in the foothills south and southeast of the Sierra Diablo. They include ancient metasedimentary rocks—the Carrizo Mountain Formation, intruded by igneous rocks, and younger unmetamorphosed sedimentary and volcanic rocks—the Allamoore and Hazel Formations. The Carrizo Mountain Formation has been thrust over the younger Precambrian rocks, and for some miles north of the trace of the thrust the younger rocks have been intensely deformed; farther north they lie nearly flat. The thickness of the Precambrian rocks cannot be determined, but it is probably many thousands of feet.

Deformation of the Precambrian rocks occurred before deposition of the Van Horn Sandstone, which lies on their deeply eroded edges. The Van Horn is a coarse red clastic deposit, as much as 700 feet thick. As it contains no fossils, its age cannot be proved; but it is probably of late Precambrian age. The Van Horn was tilted and eroded before the succeeding Bliss Sandstone was laid down over it.

Pre-Permian Paleozoic rocks crop out in the southeastern and northeastern parts of the Sierra Diablo region and form a few inliers elsewhere; their most conspicuous outcrops are on Beach Mountain. They include the Bliss Sandstone, El Paso Limestone, beds of Middle Ordovician age, and Montoya Dolomite, all of Ordovician age; the Fusselman Dolomite of Silurian age; and chert, limestone, and shale of Devonian age. Total thickness of these units it about 2,000 feet.

In the northeastern part of the Sierra Diablo, these earlier Paleozoic rocks are succeeded by the Barnett Shale of Mississippian age and limestone and shale of Pennsylvanian age. Because of disconnected exposures, the thickness of the Mississippian and Pennsylvanian rocks cannot be determined; but they probably do not exceed a few thousand feet.

The Ordovician, Silurian, Devonian, Mississippian, and Pennsylvanian rocks were broadly folded and deeply eroded during Late Pennsylvanian time, so that the succeeding Hueco Limestone of Early Permian age overlies them with marked angular unconformity. In parts of the region the Hueco lies directly on Precambrian rocks, erosion having removed the intervening formations.

The most extensively exposed rocks in the Sierra Diablo are those of Permian age, which consist mostly of the Hueco Limestone of the Wolfcamp Series and the Bone Spring and Victorio Peak Limestones of the Leonard Series. These three units, which have an aggregate thickness of about 3,000 feet, lie at the surface over wide areas on the summits, and are prominently exposed on the bordering escarpments. They are traversed by two prominent monoclinal flexures, the Victorio and the Babb, one near the middle and the other at the north end of the range. These trend west-northwest and dip north-northeast. South of the Victorio flexure only the Hueco Limestone is preserved; to the north the Bone Spring and Victorio Peak Limestones overlie it. North of the Babb flexure the Victorio Peak Limestone is overlain by the Cutoff Shale, also of Leonard age, and by formations of the Guadalupe Series.

At the base of the Hueco, lying unconformably on the older rocks, are clastic rocks of the Powwow Member, but the main body of the formation is an evenly bedded limestone. The Bone Spring is more varied; in the northeastern part of the region it is a thin-bedded slope-making black limestone, but southwestward, especially near the flexures, this gives place to massive limestone reefs and banks. Near the flexures the Bone Spring is uncomfortable on the Hueco. The Victorio Peak is a gray thick-bedded limestone that forms cliffs above the black limestones of the Bone Spring; its lower part intergrades with the black limestones, and it is entirely replaced by them in the Delaware Mountains, east of the Sierra Diablo.

The formations of the Guadalupe Series north of the Babb flexure are the sandstone tongue of the Cherry Canyon Formation and the Goat Seep Limestone. The sandstone tongue lies on an eroded surface of the Cutoff Shale and is separated from it by a hiatus, as shown by the absence of the Brushy Canyon Formation that intervenes between the Cherry Canyon Formation and the rocks of the Leonard Series in the Delaware Mountains to the east.

Cretaceous rocks overlie the Permian and older rocks on the west slope of the Sierra Diablo and form smaller remnants elsewhere. They are separated from the older rocks by a marked unconformity. In places in the southwestern part of the map area they lie directly on the Precambrian, the intervening Paleozoic strata having been removed by erosion. The surface upon which they were deposited was a peneplain, exhumed remnants of which form the summits of other parts of the Sierra Diablo, where all trace of the Cretaceous rocks themselves has been removed.

The Cretaceous rocks overlapped northeastward from a geosyncline. Cretaceous rocks that were deposited along the edge of the geosyncline extend into the southwest corner of the map area, southwest of the Eagle Flat, and include at the base the Yucca and Bluff Mesa Formations, a body of sandstone and limestone of Early Cretaceous age that is more than 2,000 feet

thick. The Yucca and Bluff Mesa are absent elsewhere in the region, except for a thinned equivalent of their topmost beds in the Campagrande Limestone.

Elsewhere in the southern half of the Sierra Diablo region, the Cretaceous is represented by the Campagrande Limestone, 100 feet thick; the Cox Sandstone, 400 to 600 feet thick; and the Finlay Limestone, 50 to 100 feet thick. The Campagrande is of Trinity age and the Finlay of Fredericksburg age; the boundary between the Trinity and Fredericksburg may lie within the Cox Sandstone. On Cox Mountain, in the west-central part of the region, the Finlay is overlain by the Kiamichi Formation, or highest unit of the Fredericksburg Group.

Farther north, the Cox Sandstone apparently replaces both the Finlay and Kiamichi, for in Sierra Prieta, in the northwest corner of the region, it is overlain directly by the Washita Group. Here, as much as 350 feet of the Washita is preserved, with beds of Duck Creek age at the base and beds possibly as young as of Mainstreet age at the top.

The sedimentary rocks of the Sierra Diablo are intruded by igneous rocks of probable Tertiary age. These are most abundant near Mine and Marble Canyons in the northeastern part of the mountains, where two stocks and numerous dikes and sills lie in the Permian rocks; here, there is a great variety of igneous and contact-metamorphosed rocks. Sierra Prieta, in the northwestern part of the region, is formed by a thick sill-like body of alkalic composition which intrudes Permian and Cretaceous rocks. Extrusive basalt is preserved a few places in the central part of the region.

The Sierra Diablo was given its present form and outlines by disturbances during Cenozoic time. These disturbances probably occurred during several phases, extending from the early Tertiary into the Quaternary. The rocks near the Devil Ridge and Red Hills thrusts in the extreme southwest corner of the region were deformed in early Tertiary time, but most of the deformation in the Sierra Diabo to the northeast probably occurred during late Tertiary time. During this time the Sierra Diablo was raised nearly to its present height and was broken by faults. The faults belong to two systems: a fairly consistent set trending west-northwest and a less regular set trending generally north. Faults of the latter system follow the east base of the Sierra Diablo and Baylor Mountains. During Quaternary time faults of this system were displaced again, and in some places the alluvial fans were faulted.

The lower areas surrounding the Sierra Diablo are extensively covered by unconsolidated deposits of Cenozoic age, formed during erosion of the uplifted mountain blocks. The deposits at the surface are all probably of Quaternary age, but late Tertiary deposits doubtless underlie them in the deeper intermontane basins.

The economic products of the region are varied. In some places the rocks are mineralized, and have been extensively prospected. One mineralized area is in the exposed Precambrian rocks on the south, where copper and silver have been produced from the Hazel and Blackshaft mines and from many smaller workings. Another mineralized area is near Mine and Marble Canyons in the northeastern part of the Sierra Diablo. One of the stocks in that area contains small quantities of tungsten and beryllium. Near these stocks, and near the sill at Sierra Prieta, the metamorphosed, originally dolomitic, Hueco Limestone has been altered to a mixture of calcite and brucite, the latter perhaps a source of metallic magnesium. Since 1952 the phyllitic beds in the Allamoore Formation have been extensively worked for talc. At a locality 8 miles west of Van Horn the metaigneous rocks that intruded the Carrizo Mountain Formation have been quarried for many years for crushed stone.

The most needed resource in the area is ground water. The best and most abundant supplies have been obtained from wells in the Salt Basin near Van Horn; elsewhere, the occurrence, amount, and quality of ground water vary.

Probably the region contains no important reservoirs of oil or gas, as ancient rocks underlie it at relatively shallow depth. The region is of interest to petroleum geologists, however, because the rocks here exposed are about the same age and similar in character and structure to those which are deeply buried in the oil fields of the west Texas basin east of the mountain region.

INTRODUCTION

PRESENT INVESTIGATION

Between 1925 and 1939 the writer, with various colleagues, made a study of the Paleozoic and associated rocks exposed in the mountains of Trans-Pecos Texas, west and southwest of the west Texas Permian basin. This study was begun under the auspices of the Texas Bureau of Economic Geology and of Peabody Museum of Yale University, but after 1930 it was continued by the U.S. Geological Survey. Most of the results of this study have been published in official reports of the U.S. Geological Survey and the Texas Bureau of Economic Geology (King, P. B., 1931; King, R. E., 1931; King, P. B., 1937; King P. B., and Knight, J. B., 1944; King, P. B., and Fountain, H. C., 1944; King, P. B., King, R. E., and Knight, J. B., 1945; King, P. B., 1948, 1949; King P. B., and Flawn, P. T., 1953) and in various journal articles (King, P. B., 1934a, b, 1942; and others).

The present report presents the remaining results of the study—that part pertaining to the Sierra Diablo region. Field investigations in this region were largely completed by 1939, but preparation of a comprehensive report was delayed by emergency duties during World War II and by new Survey projects which began after the war; thus, only summaries of the results of the work in the Sierra Diablo region, or reports on special phases have appeared hitherto (King, P. B., 1942, p. 556–575, 613–634; King, P. B., and Knight, J. B., 1944; King P. B., and Flawn, P. T., 1953). Because the comprehensive report has been prepared more than 20 years after completion of the field investigations, it lacks the freshness and novelty it might have possessed earlier. Nevertheless, many of the geologic observations that were made before 1939 have not been duplicated subsequently, so that a report on the region, based primarily on these observations, is still of value to the public.

Field investigations in the Sierra Diablo region were made at intervals by the writer and his colleagues between 1928 and 1939, as follows:

1. In the summer of 1928 the writer and R. E. King spent 3 weeks in the region, under the auspices of the

Texas Bureau of Economic Geology and Yale Peabody Museum. The objective of this visit was a study of the Permian rocks; various sections were measured and fossils were collected. Some reconnaissance mapping was also done, and a few incidental observations were made on formations of other ages.

2. In the summer of 1931 the writer and J. Brookes Knight spent 4 weeks in the region for the U.S. Geological Survey. Again, chief study was made of the Permian stratigraphy and of fossils in the Permian rocks; but on this visit more attention was given to the associated rocks, and a start was made on detailed mapping of the region.

3. In the summer of 1936, again with J. Brookes Knight, 2 months were spent in the region, continuing the study of the Permian and associated rocks and extending the mapping.

4. In the summer of 1938 the writer and J. Brookes Knight spent 2½ months on a final review of the region, completing the stratigraphic study and most of the mapping. In the autumn of the same year the writer spent another month mapping the Precambrian and early Paleozoic rocks in the southern part of the region.

In addition, shorter visits and field checks were made by the writer during some intervening and subsequent years, as in 1933, 1935, 1939, 1949, and 1951.

Mapping during the investigation was done partly on enlargements of the excellent topographic map of the Van Horn 30-minute quadrangle, whose original scale was 1:125,000; but in that part of the region to the west and north where only inadequate topographic base maps were available, mapping was done by means of a net of speedometer and pacing traverses. Results of these surveys were published in a preliminary map in 1944 (King, P. B., and Knight, J. B., 1944). In 1945 small-scale air photographs of the region became available, in 1948 large-scale air photographs. In 1955 a topographic map based on photogrammetry was made the Army Map Service. In 1951 and 1955 the writer adjusted his earlier field traverses to the air photographs and transferred the results to the new topographic base. The resulting geologic map accompanying this report (pl. 1) represents the same features as those on the map of 1944, but with some revision and with greater precision of form and location.

Stratigraphic studies, measurement of sections, and collection of fossils were made largely by the author's colleague, the late J. Brookes Knight, at times with the assistance of the writer and others. Most of the sections were measured by hand level, and because the strata of the region are nearly flat lying, no correction for dip was necessary. Many of the fossil collections were made along the lines of the measured sections, although a few in outlying areas could not be tied into sections.

ACKNOWLEDGMENTS

In the investigation of the Sierra Diablo region the writer's greatest debt is to his field associate and collaborator, the late J. Brookes Knight, specialist in Paleozoic gastropods and one of the great paleontologists of our time. Much is due him, not only for his measurement of sections and collection of fossils, mentioned above, but also for his keen insight into problems of stratigraphy, paleontology, and paleoecology, which has contributed in no small measure to the merits of this report.

During the investigation, geologic features of the region were reviewed with many visitors, among whom the following are noteworthy.

In 1938, the late Samuel G. Lasky, of the U.S. Geological Survey, reviewed with the writer the mines, prospects, and mineral deposits of the region, mainly in the Precambrian rocks to the south, but also including those of the Mine Canyon and Marble Canyon area farther north. In 1941 Lasky made an independent examination of the tungsten deposits of the Mine Canyon area.

In 1936 Earl Ingerson, at that time with the Geophysical Laboratory of the Carnegie Institution of Washington, reviewed the intrusive rocks of the Marble Canyon area with Knight. In 1938 Ingerson reviewed with the writer the metamorphic rocks in the southern part of the region.

In 1938 the late Josiah Bridge and the late W. H. Hass, of the U.S. Geological Survey, reviewed with Knight and the writer the stratigraphy and paleontology of the Ordovician and other early Paleozoic rocks.

Study and identification of rocks and minerals of the region have been made by many petrographers and geochemists of the U.S. Geological Survey. Rock and mineral specimens have been identified by C. S. Ross, Charles Milton, and Donald E. Lee. Chemical analyses have been made by K. J. Murata. In addition, in 1941 Milton made an extensive study of specimens from the Marble Canyon intrusive and its associated contact-metamorphic rocks.

Study and identification of fossils from the various formations of the region were made by paleontologists of the U.S. Geological Survey. Ordovician fossils were identified by Josiah Bridge, P. E. Cloud, Jr., Helen Duncan, and Jean Berdan; collections of conodonts from the Devonian rocks, by W. H. Hass; Mississippian and Pennsylvanian fossils, by George H. Girty, Mackenzie Gordon, Jr., and E. L. Yochelson; larger Permian fossils, by P. E. Cloud, Jr., E. L. Yochelson,

R. M. Finks, Helen Duncan and I. G. Sohn, fusulinids and other foraminifers, by L. G. Henbest; and Cretaceous fossils, by Ralph W. Imlay.

Before the studies were made by Survey paleontologists, the brachiopods collected from the Permian rocks in 1928 had been identified by R. E. King, and the fusulinids collected in 1928 and 1931 had been identified by C. O. Dunbar and J. W. Skinner. The memoirs in which their results appeared (King, R. E., 1931; Dunbar and Skinner, 1937) are among the earliest of the modern studies on the Permian fossils of the West Texas Region, and were an invaluable guide in the later field investigations in the Sierra Diablo region.

RELATED INVESTIGATIONS

Besides the field investigation in the Sierra Diablo region that was made directly by the writer and his associates, other investigations were made in the region during the same period by geologists of the U.S. Geological Survey and Texas Bureau of Economic Geology, some of the results of which are included in this report. The areas covered by some of these investigations are shown in figure 1.

Between 1943 and 1946 P. E. Cloud, Jr., and V. E. Barnes, of the U.S. Geological Survey and Texas Bureau of Economic Geology, made a comprehensive investigation of the Ellenburger Group of central Texas. As part of this study they measured a detailed section of the Lower Ordovician rocks on Beach Mountain and made observations on these rocks elsewhere in the Sierra Diablo region (Cloud and Barnes, 1946, p. 66–71, 352–361).

In 1944 R. D. Sample and E. E. Gould, of the U.S. Geological Survey, made a detailed examination of the Hazel, Blackshaft, Sancho Panza, and other mines and mineral deposits of the southern part of the region. Between 1944 and 1946 Elliot Gillerman, of the U.S. Geological Survey, studied the fluorspar deposits of the Eagle Mountains southwest of the Sierra Diablo and mapped the rocks in which they occur (Gillerman, 1953). His geologic map extends a short distance into the south edge of the Sierra Diablo region, and was used in compilation of the geologic map which accompanies the present report. In 1948 and 1949 W. T. Holser made a detailed survey of the Cave Peak intrusive in the Mine Canyon area for the U.S. Geological Survey, as part of a study of the nonpegmatitic beryllium resources of the United States (Warner and others, 1959, p. 140–143).

In 1936 and 1937 J. Fred Smith, Jr., mapped the Devil Ridge area, part of which extends into the extreme southwest corner of the Sierra Diablo region (Smith, 1940). Between 1947 and 1951, under the auspices of the U.S. Geological Survey, Smith and C. C. Albritton, Jr., expanded this and other surveys into a comprehensive study of the Sierra Blanca region that adjoins the Sierra Diablo region on the west (Albritton and Smith, 1965). Geologic features in the southwest corner of the map which accompanies the present report are based on the surveys by Smith.

Between 1949 and 1951 Peter T. Flawn, of the Texas Bureau of Economic Geology, investigated the Precambrian rocks of the Carrizo Mountains and outlying areas to the south and also studied the Hazel Mine and the talc deposits which occur in the Precambrian rocks farther north. He collaborated with the writer in a report on the Precambrian rocks of the Van Horn area and their mineral deposits (King, P. B., and Flawn, P. T., 1953). Mapping and other data in the southern part of the present report are are based on this joint study.

Other studies of special phases of the geology of the region have been made by geologists with other affiliations and have been used in the present report so far as their published results are available. F. G. Stehli studied the Permian rocks and fossils near Victorio Peak for a dissertation at Columbia University (Stehli, 1954), and C. O. Dunbar investigated the fusulinids of the Permian rocks in the same area (Dunbar, 1953). H. J. Howe reviewed the stratigraphy of the Montoya Dolomite in west Texas and southern New Mexico and made significant observations in the Baylor Mountains (Howe, 1959). Hugh Hay-Roe and P. C. Twiss studied the Permian and associated rocks in the Wylie and Van Horn Mountains, southeast and south of the present report area, for dissertations at the University of Texas (Hay-Roe, 1957; Twiss, 1959). Some of the observations by geologists employed by oil companies have appeared in guidebooks of the West Texas Geological Society (Adams and others, 1949; De Ford and others, 1951; Haigh and others, 1953).

PREVIOUS INVESTIGATIONS

The Sierra Diablo region was given scant attention by the early geological explores and was not visited by geologists until the reorganization of the Geological Survey of Texas under E. T. Dumble in 1888. Investigation of the geology of the Trans-Pecos Region for this survey was assigned to W. H. von Streeruwitz, who was in the field with his assistants between the years 1888 and 1893 (Geiser, 1957). Although most of their work was done in areas farther south and west, the mines and prospects in the southern foothills of the Sierra Diablo were examined, including the Hazel mine, and brief observations were made on the surrounding rock formations (Streeruwitz, 1890, 1891, 1892, 1893).

Metamorphic rocks were observed in the Carrizo Mountains and the hills north of Eagle Flat, and their nature was interpreted in a petrographic report by Osann (1893, p. 137–138). Rocks farther north were thought to consist of a red Diabolo Sandstone, assigned to a Devonian age, and an overlying body of limestone, assigned to a Carboniferous age on the authority of C. D. Walcott, who examined a few fossil collections. Both of these supposed units are now known to consist of many formations of diverse ages.

First systematic geologic work in the Sierra Diablo region was by G. B. Richardson, under the joint auspices of the U.S. Geological Survey and the University of Texas Mineral Survey. In 1903 Richardson made a reconnaissance of the geology and ground-water resources of all the northern Trans-Pecos Region in Texas (Richardson, 1904); later he made more detailed surveys of the El Paso and Van Horn quadrangles, which were published as geologic folios (Richardson, 1909, 1914).

Richardson's work laid the foundation on which most of our modern geologic concepts of the Sierra Diablo and adjacent regions have been built. He recognized and defined many of the Paleozoic and Mesozoic formations which are still in use and set forth the broader outlines of the geomorphology and structure. However, as only a small amount of time could be spent on these surveys—even those for the geologic folios—many details have been added later, as may be seen by comparing the present map of the Sierra Diablo region with the map in the Van Horn folio.

Older Paleozoic formations—the Bliss, El Paso, Montoya, and Fusselman—were defined on the basis of the section in the Franklin Mountains north of El Paso (Richardson, 1908, p. 475–480), still the standard of reference. Presence of the El Paso and Montoya was also recognized by Richardson in the Sierra Diablo region, and occurrence of the Bliss and Fusselman has been proved there subsequently.

Stratigraphy of the more complex later Paleozoic strata was less clarified, although Richardson benefited from the advice of G. H. Girty, who was at that time working on his classic memoir on the Guadalupian fauna (Girty, 1908), based on collections of Permian fossils from the Guadalupe Mountains and adjacent regions. Permian formations, the Delaware Mountain, Capitan, and higher units, were recognized east of the Salt Basin; but the later Paleozoic rocks to the west were placed in the Hueco Limestone, supposed to be a nearly homogeneous body as much as 5,000 feet thick, of Pennsylvanian age. As mapped by Richardson, the Hueco is now known to include, at one place or another, formations of Mississippian, Pennsylvanian, and Early Permian ages. The "Hueco fauna," as understood by Girty, however, actually occurs only in one of these formations in the Hueco Mountains and elsewhere; the name is now restricted to this part of the original formation.

In the Sierra Diablo, the Hueco Limestone as mapped by Richardson is now known to consist of several formations of Early Permian age, the lowest of which is the restricted Hueco; the angular unconformity recognized by Richardson below the Hueco has proved to be basal Permian, rather than basal Pennsylvanian. Mississippian and Pennsylvanian elements, which form large parts of the original Hueco in the Hueco and Franklin Mountains, are scantily preserved in the Sierra Diablo region.

Few geologic observations were made in the Sierra Diablo region in the decades immediately following the work of Richardson and Girty. The next period in which it was studied began in the midtwenties as an outgrowth of petroleum exploration and development in the West Texas basin to the east. This period corresponds to that during which the present investigation was made by the writer and his colleagues; work done during that time in the Sierra Diablo region by other geologists has already been mentioned.

The following annotated bibliography lists chronologically all publications which deal with the geology of the Sierra Diablo regions.

ANNOTATED BIBLIOGRAPHY

Perry, C. C., and others, 1857, Geological reports, *in* Emory, W. H., Report on the United States and Mexican boundary survey: U.S. 34th Cong., 1st sess., S. Ex. Doc. 108 (H. Ex. Doc. 135), v. 1, pt. 2, 174 p.

Reports (p. 4–5) that west of the igneous rocks of the Limpia (Davis) Mountains are ridges of stratified limestone, dipping southwest; on the basis of a few fossils (*Terebratula*) James Hall assigns the limestone to the Carboniferous (p. 107). Elevated alluvial basins near Eagle Spring are shut off from the Rio Grande by a "variable mountain range, composed of Carboniferous limestone and variously associated igneous rocks." The Sierra Diablo region to the north is not mentioned in this account.

Jenny, W. P., 1874, Notes on the geology of western Texas near the thirty-second parallel: Am. Jour. Sci., 3d ser., v. 7, p. 25–28.

Discusses the probable Silurian and Carboniferous ages of rocks in the mountains of northern Trans-Pecos Texas, mostly north and northwest of the Sierra Diablo region.

Cummins, W. F., 1888, Mining districts in El Paso County: Geol. and Sci. Bull. (Texas State Geol. and Sci. Assoc., Houston, Tex.), v. 1, no. 2.

Includes a paragraph on the "Diabolo district" that is, the mineralized area in the southern foothills of the Sierra Diablo. Mentions the nature of the copper and silver ores and states that these occur in steeply dipping veins in massive fine-grained red argillaceous sandstone of unknown age (sandstone of Hazel Formation of present terminology), which is overlain by Carboniferous limestone.

Streeruwitz, W. H. von, 1889, Mines worked in western Texas: Geol. and Sci. Bull. (Texas State Geol. and Sci. Assoc., Houston, Tex.), v. 1, no. 12.

Includes brief description of Hazel mine, its ores, and mining operations then in progress.

Hill, R. T., 1890, The Eagle Flats formation and the basins of the trans-Pecos or mountainous region of Texas [abs.]: Am. Assoc. Adv. Sci. Proc., v. 38, p. 42.

Quaternary intermontane deposits of Trans-Pecos Texas are interpreted to be of lacustrine origin and are named the Eagle Flats Formation, presumably after Eagle Flat in the Sierra Diablo region, although this is not so stated.

Streeruwitz, W. H. von, 1890, Geology of trans-Pecos Texas: Texas Geol. Survey 1st Ann. Rept. (1889), p. 219–235.

Contains general summary of geology and resources of Trans-Pecos Region but includes some notes on geology and mineral deposits in Sierra Diablo foothills (p. 221–222, 224).

——— 1891, Report on the geology and mineral resources of trans-Pecos Texas: Texas Geol. Survey 2d Ann. Rept. (1890), p. 665–713.

Lengthy description of geology and resources of Trans-Pecos Texas, including notes on geology and mines in Carrizo Mountains and Sierra Diablo foothills (p. 681–684), accompanied by geologic structure sections (pl. 26).

——— 1892, Trans-Pecos Texas: Texas Geol. Survey 3d Ann. Rept. (1891), p. 383–389.

General remarks on Trans-Pecos Region, including notes on geology and mineral deposits of Carrizo Mountains and Sierra Diablo foothills, and a detailed report on Hazel Mine, with plans and sections (pl. 16).

——— 1893, Trans-Pecos Texas: Texas Geol. Survey 4th Ann. Rept. (1892), p. 141–175.

Final summary of the author's 5 yr of observation on the geology and resources of Trans-Pecos Texas; includes stratigraphic sections and lists of identified fossils from the Paleozoic rocks of the Sierra Diablo (p. 167–175).

Osann, C. A., 1893, Report on the rocks of trans-Pecos Texas: Texas Geol. Survey 4th Ann. Rept. (1892), p. 123–141.

Includes petrographic reports on a diabase from the Sierra Diablo (p. 125–126) and various metamorphic rocks from the Carrizo Mountains (p. 137–138).

——— 1896, Beiträge zur Geologie und Petrographie der Apache (Davis) Mts., Westtexas: Tschermak's mineralog. petrog. Mitt., v. 15, p. 394–456.

Includes description of Precambrian metamorphic rocks in Carrizo Mountains and adjacent areas.

Hill, R. T., 1900, Physical geography of the Texas region: U.S. Geol. Survey Topog. Atlas, Folio 3, 12 p.

Includes brief description of topography of Sierra Diablo region (p. 5) and several photographs (figs. 24, 35).

Dumble, E. T., 1902, The red sandstone of the Diablo Mountains, Texas: Texas Acad. Sci. Trans., v. 4, pt. 2, p. 1–3.

Discussion of stratigraphy of older rocks of Sierra Diablo region, based on exposures on west side of Beach Mountain, where the red Hazel Sandstone is differentiated from an overlying red sandstone (Van Horn Sandstone of present usage), believed by the author to be of early Paleozoic age.

Phillips, W. B., 1902, Sulphur, oil, and quicksilver in trans-Pecos Texas: Texas Univ. Bull. 9 (Mineral Survey Ser. Bull. 2) 43 p.

Contains mineral appraisals and brief notes on geology of various land-survey blocks in El Paso County (including present Culberson and Hudspeth Counties) by B. F. Hill, some of which are in Sierra Diablo region (p. 15, 16, 20, etc.).

Richardson, G. B., 1904, Report of a reconnaissance in trans-Pecos Texas north of the Texas and Pacific Railway: Texas Univ. Bull. 23 (Mineral Survey Ser. Bull. 9), 119 p.

Report on a survey of an extensive region, of which the Sierra Diablo region is a part, with special reference to ground-water resources but containing the first modern account of the stratigraphy, structure, and geomorphology.

Girty, G. H., 1908, The Guadalupian fauna: U.S. Geol. Survey Prof. Paper 58, 651 p.

Comprehensive memoir on Permian fossils, mainly from Guadalupe Mountains north of Sierra Diablo region. Includes remarks on some fossils collected from an unknown locality in the Sierra Diablo which also appear to be of "Guadalupian" character (p. 26); these probably came from Bone Spring Limestone.

Richardson, G. B., 1908, Paleozoic formations in trans-Pecos Texas: Am. Jour. Sci., 4th ser., v. 25, p. 474–484.

Contains the first definitions of many of the stratigraphic units which occur in the Sierra Diablo and other parts of northern trans-Pecos Texas and emendations of definitions of other units that had been proposed by Richardson in report of 1904.

Van Hise, C. R., and Leith, C. K., 1909, Pre-Cambrian geology of North America: U.S. Geol. Survey Bull. 360, 939 p.

Includes summary of observations by Richardson and earlier geologists on Precambrian rocks in southern Sierra Diablo region (p. 746–749).

Richardson, G. B., 1914, Description of the Van Horn quadrangle: U.S. Geol. Survey Geol. Atlas, Folio 194, 9 p.

Report on the geology of an area which includes the eastern half of the Sierra Diablo region, ably presenting the larger features, although many details have been added by later work.

Beede, J. W., 1920, Notes on the geology and oil possibilities of the northern Diablo Plateau in Texas: Texas Univ. Bull. 1852, 40 p. [1918].

Deals mainly with region northwest of the Sierra Diablo, but includes first report of occurrence of strata of "Word" (Guadalupe) age at north end of Sierra Diablo (p. 24–26).

Baker, C. L., 1927, Exploratory geology of a part of southwestern trans-Pecos Texas: Texas Univ. Bull. 2745, 70 p.

Reconnaissance survey of an extensive area south and southwest of Sierra Diablo region, including notes on Precambrian rocks and Permian (Hueco) limestone in Carrizo and Wylie Mountains.

Baker, C. L., 1928, Desert range tectonics of trans-Pecos Texas: Pan-Am. Geologist, v. 50, p. 341–373.

Appraisal of evidence for Basin and Range structure in Trans-Pecos Texas and New Mexico, with mention of Sierra Diablo region (p. 369–371).

Carter, W. T., and others, 1928, Soil survey (reconnaissance) of the trans-Pecos area, Texas: U.S. Dept. Agri. ser. 1928, no. 35, 66 p.

General account and map of geography and soils of Trans-Pecos Region, with some specific notes on Sierra Diablo region.

Baker, C. L., 1929, Overthrusting in trans-Pecos Texas: Pan-Am. Geologist, p. 53, p. 23–28.

Discussion of folding and thrust-faulting of Cretaceous rocks in southern Hudspeth County, including southwestern corner of report area. At northeastern border of disturbed belt, thrust sheets moved toward nearly horizontal strata of Diablo Plateau, the boundary between them being localized by "shoaling of Cretacic sea" (p. 24).

Blanchard, W. G., Jr., and Davis, M. J., Jr., 1929, Permian stratigraphy and structure of parts of southeastern New Mexico and southwestern Texas: Am. Assoc. Petroleum Geologists Bull., v. 13, p. 957–995.

Deals mainly with Guadalupe Mountain area, but includes remarks on Permian rocks of Sierra Diablo and Wylie Mountains (p. 960–962).

King, P. B., and King, R. E., 1929, Stratigraphy of outcropping Carboniferous and Permian rocks of trans-Pecos Texas: Am. Assoc. Petroleum Geologists Bull., v. 13, p. 907–926.

Includes results of first field season of present investigation in Sierra Diablo region on Pennsylvanian and Permian rocks (p. 911, 922–923), many of which have been superseded by later work.

King, R. E., 1929, Mississippian and Pennsylvanian stratigraphy of trans-Pecos, Texas [abs.]: Geol. Soc. America Bull., v. 40, p. 190–191.

Mentions occurrence of limestone of Strawn age in the Sierra Diablo (the limestone of Pennsylvanian age south of Marble Canyon of present report).

Mohr, C. L., 1929, Secondary gypsum in the Delaware Mountain region: Am. Assoc. Petroleum Geologists Bull., v. 13, p. 1395.

Presents evidence that the alleged "Dos Alamos gypsum member" in the Guadalupe series of the northern Sierra Diablo is not an original part of the stratigraphic sequence.

King, P. B., and Leonard, R. J., 1930, Contact metamorphism of Hueco limestone in trans-Pecos Texas [abs.]: Pam-Am. Geologist, v. 53, p. 316.

Note on contact metamorphism adjacent to the Marble Canyon intrusive of northeastern Sierra Diablo.

King, R. E., 1931, Faunal summary and correlation of the Permian formations, with description of the Brachiopoda, pt. 2 *of* Geology of the Glass Mountains: Texas Univ. Bull. 3042, 245 p. [1930].

Includes an account of Permian stratigraphy of Sierra Diablo region based on first field season of present investigation (p. 14–16) and description of Permian brachiopods, in part collected in Sierra Diablo region. Many of stratigraphic interpretations have been superseded by later work.

Girty, G. H., 1931, New Carboniferous invertebrates, pt. 3: Washington Acad. Sci. Jour., v. 21, p. 390–397.

Includes description of the brachiopod *Schizophoria peculiaris* Girty from Bone Spring Limestone of Sierra Diablo.

Adkins, W. S., 1933, The Mesozic systems in Texas, *in* Stratigraphy, v. 1 *of* The geology of Texas: Texas Univ. Bull. 3232, p. 239–518.

Description and interpretation of all Mesozoic formations in Texas, with many incidental notes on Cretaceous rocks in and near the Sierra Diablo region.

Arick, M. B., 1932, Occurrence of strata of Bend age in Sierra Diablo, Texas: Am. Assoc. Petroleum Geologists Bull., v. 16, p. 484–486.

Reports discovery of fossiliferous strata of Bend age north of Marble Canyon in the Sierra Diablo ("shale of Smithwick age" of Plummer and Scott, 1937, "fossiliferous shale of Pennsylvianian age" of present report).

Darton, N. H., 1932, Algonkian strata of Arizona and western Texas [abs.]: Geol. Soc. America Bull., v. 43, p. 123.

Mentions resemblance of the Millican Formation (Allamoore and Hazel Formations of present usage) to Grand Canyon Series and Apache Group of Arizona.

King, P. B., 1932, Possible Silurian and Devonian strata in Van Horn region, Texas: Am. Assoc. Peroleum Geologists Bull., v. 16, p. 95–97.

Reports discovery of Fusselman Limestone and beds of Devonian age in Sierra Diablo region during second field season of present investigation.

King, P. B., 1932, Permian limestone reefs in the Van Horn region, Texas [abs.]: Washington Acad. Sci. Jour., v. 22, p. 288–289; Geol. Soc. America Bull., v. 43, p. 280–281.

Notes on reefs and related deposits in Bone Spring Limestone of Sierra Diablo region, based on observations during second field season of present investigation.

Mansfield, G. R., and Boardman, Leona, 1932, Nitrate deposits of the United States: U.S. Geol. Survey Bull. 838, 107 p.

Includes description of a nitrate prospect ("Potash mine") in Van Horn Sandstone (erroneously ascribed to Cretaceous) in Sierra Diablo foothills (p. 66–68).

Sellards, E. H., 1933, Pre-Paleozoic and Paleozoic system in Texas, *in* Stratigraphy, v. 1 *of* The geology of Texas: Texas Univ. Bull. 3232, p. 15–238.

Brief descriptions of all pre-Paleozoic and Paleozoic formations in Texas, including those in Sierra Diablo region.

Darton, N. H., and King, P. B., 1933, Western Texas and Carlsbad Caverns: Internat. Geol. Cong., 16th, United States 1933, Guidebook 13, 38 p.

Contains a summary of geology of Sierra Diablo region (p. 19–27), based on results of first two field seasons of present investigation.

Baker, C. L., 1935, Structural features of trans-Pecos Texas, Pt. 2 *in* Structural and economic geology, v. 2 *of* The geology of Texas: Texas Univ. Bull. 3401, p. 137–214.

Includes brief description of geologic structure of Sierra Diablo region and adjacent areas (p. 180–185) and discussion of "Texas lineament" (p. 206–214).

King, P. B., 1934, Permian stratigraphy of trans-Pecos Texas: Geol. Soc. America Bull., v. 45, p. 697–798.

Describes Permian stratigraphy of Sierra Diablo region on basis of results of first two field seasons of present investigation (p. 745–746, 748–763), some of which have been superseded by later work.

King, P. B., 1934, Notes on upper Mississippian rocks in trans-Pecos Texas: Am. Assoc. Petroleum Geologists Bull., v. 18, p. 1537–1543.

Includes description of Mississippian and adjacent strata in Sierra Diablo region (p. 1541–1543).

Kirk, Edwin, 1934, The Lower Ordovician El Paso limestone of Texas and its correlatives: Am Jour. Sci., 5th ser., v. 28, p. 443–463.

Discusses subdivisions and correlation of El Paso Limestone, with special reference to the Franklin Mountains section but with incidental reference to Sierra Diablo region (p. 451). Subsequent work has added many details to these results, but has not modified the general conclusions.

Sellards, E. H., and others, 1935, Economic geology of Texas, *in* Structural and economic geology, v. 2 *of* The geology of Texas: Texas Univ. Bull. 3401, p. 215–868.

Contains summaries, compiled by C. L. Baker, of copper deposits (p. 410–411), ground water (p. 373–380), and other resources of Sierra Diablo region.

Arick, M. B., 1935, Early Paleozoic unconformities in trans-Pecos Texas: Texas Univ. Bull. 3501, p. 117–121.

Observations on Sierra Diablo region (p. 118–119) include reference to unconformity between Van Horn and Bliss Sandstones and to supposed occurrence of Middle Ordovician rocks in the northeastern Sierra Diablo.

Baker, C. L., 1935, Precambrian unconformities in the trans-Pecos region: Texas Univ. Bull. 3501, p. 113–114.

Includes interpretation of Precambrian sequence in Sierra Diablo region, based on existing publications by Richardson and King.

King, P. B., 1935a, Unconformities in the later Paleozoic of trans-Pecos Texas: Texas Univ. Bull. 3501, p. 131–135.

Includes remarks on unconformity at base of Hueco Limestone in Sierra Diablo region and elsewhere and on supposed absence of an unconformity at top of Hueco (p. 133–134).

——— 1935b, Outline of structural development of trans-Pecos Texas: Am. Assoc. Petroleum Geologists Bull., v. 19, p. 221–261.

General account of structure of Trans-Pecos Texas, including preliminary results of investigation in Sierra Diablo region.

Dunbar, C. O., and Skinner, J. W., 1937, Permian Fusulinidae of Texas, *in* Upper Paleozoic ammonities and fusulinids, v. 3 *of* The geology of Texas: Texas Univ. Bull. 3701, p. 519–825.

Contains notes on stratigraphy of Sierra Diablo region (p. 587–590), description of fusulinid species, and lists of fusulinids identified from Sierra Diablo region (p. 722–725).

Plummer, F. B., and Scott, Gayle, 1937, Upper Paleozoic ammonities in Texas, *in* Upper Paleozoic ammonities and fusulinids, v. 3 *of* The geology of Texas: Texas Univ. Bull. 3701, p. 13–516.

Includes identifications of ammonites from shale of Smithwick age north of Marble Canyon in the Sierra Diablo (p. 25) ("fossiliferous shale of Pennsylvanian age" of present report).

King, R. E., Adams, J. E., and Hills, J. M., 1939, Van Horn region: West Texas Geol. Soc. Field Trip Guidebook, May 20–21, 1939, 8 p.

Road log in southern part of the Sierra Diablo, describing localities in Permian and older rocks, based on field results of P. B. King.

Bridge, Josiah, 1940, Correlation of early Paleozoic sections in central and western Texas [abs.]: Geol. Soc. America Bull., v. 51, p. 1921–1922.

Includes brief comment on correlation of El Paso Limestone and Bliss Sandstone of Sierra Diablo region.

King, P. B., 1940, Older rocks of Van Horn region, Texas: Am. Assoc. Petroleum Geologists Bull., v. 24, p. 143–156.

Summary of results of present investigation on Precambrian rocks of Sierra Diablo region, which are given in more detail in King and Flawn (1953) and present report.

Miller, A. K., and Furnish, W. M., 1940a, Permian ammonoids of the Guadalupe Mountain region and adjacent areas: Geol. Soc. America Spec. Paper 26, 242 p.

Includes description of *Propinacoceras knighti* Miller and Furnish from Bone Spring Limestone of Sierra Diablo region (p. 42–44).

——— 1940b, Studies of Carboniferous ammonoids, Pts. 5–7: Jour. Paleontology, v. 14, no. 6, p. 521–543.

Includes description of the ammonoids *Diaboloceras varicostatum* Miller and Furnish and *Pseudoparalegoceras bellilineatum* Miller and Furnish from "Smithwick horizon of Magdalena limestone" in Sierra Diablo (p. 527–532) ("fossiliferous shale of Pennsylvanian age" of present report).

Smith, J. F., Jr., 1940, Stratigraphy and structure of the Devil Ridge area, Texas: Geol. Soc. America Bull., v. 51, p. 597–638.

Geology of deformed Cretaceous rocks in an area southwest of Sierra Diablo region, part of which forms southwest corner of present report area.

——— 1941, Geology of the Eagle Spring area, Eagle Mountains, Hudspeth County, Texas: Field and Lab., v. 9, p. 70–79.

Description of a small area just south of southwestern part of report area.

King, P. B., 1942, Permian of west Texas and southeastern New Mexico: Am. Assoc. Petroleum Geologists Bull., v. 26, p. 535–763.

Summarizes final results of present investigation in Sierra Diablo region on Permian stratigraphy (p. 556–575) and associated structural features (p. 613–634).

Wheeler, R. R., 1942, Cambro-Ordovician of southwest [abs.]: Geol. Soc. America Bull., v. 53, p. 1812–1813.

Proposes correlations of El Paso Limestone and Bliss Sandstone of Franklin Mountains and Sierra Diablo which have not been substantiated by any other stratigrapher.

Evans, G. L., 1943, Progress report on copper investigations: Texas Univ. Bur. Econ. Geology Mineral Resources Circ. 24, 6 p.

Brief summary of an extensive investigation of copper mines and prospects in Sierra Diablo region and adjacent areas.

Adams, J. E., 1944, Highest structural point in Texas: Am. Assoc. Petroleum Geologists Bull., v. 28, p. 562–564.

Analyzes criteria for recognition of structurally high areas and concludes that "Van Horn dome" in southern part of Sierra Diablo region is not the highest structural point in Texas.

King, P. B., and Knight, J. B., 1944 [Geologic map of the] Sierra Diablo region, Hudspeth and Culberson Counties, Texas: U.S. Geol. Survey Oil and Gas Inv. Map 2.

Map of present report area, based on field surveys of present investigation, but not adjusted to an accurate topographic base.

King, P. B., King, R. E., and Knight, J. B., 1945, Geology of Hueco Mountains, El Paso and Hudspeth Counties, Texas: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 36, 2 sheets.

Includes comment on possible correlation of Pennsylvanian rocks exposed in Sierra Diablo (sheet 2).

Miller, A. K., 1945, Permian nautiloids from the Glass Mountains and the Sierra Diablo of west Texas: Jour. Paleontology, v. 19, p. 282–294.

Includes identification and description of nautiloid species from Bone Spring Limestone in the Sierra Diablo.

Sample, R. D., and Gould, E. E., 1945, Geology and ore deposits of the Allamoore-Van Horn district, Hudspeth and Culberson Counties, Texas: U.S. Geol. Survey open-file report, 22 p.

Report on examination of Blackshaft, Hazel, and other mines and prospects of southern foothills of the Sierra Diablo, and their geological environment. Many of the data in this report are reproduced in King, P. B., and Flawn, P. T. (1953).

Cloud, P. E., Jr., and Barnes, V. E., 1946, The Ellenburger group of central Texas: Texas Univ. Pub. 4621, 473 p. [1948].

Deals mainly with central Texas, but includes discussion of subdivisions and correlation of Bliss Sandstone and El Paso Limestone in Sierra Diablo region and Franklin Mountains (p. 66–74) and detailed section of these formations on Beach Mountain (p. 352–361).

Miller, A. K., and Youngquist, W. L., 1947, American Permian nautiloids: Geol. Soc. America Mem. 41, 218 p.

Deals further with nautiloids from Bone Spring Limestone in the Sierra Diablo that were reported on by Miller (1945).

Cloud, P. E., Jr., 1948, Brachiopods from the Lower Ordovician of Texas: Harvard Coll. Mus. Comp. Zoology Bull., v. 100, p. 451–472.

Lists nine species of brachiopods from El Paso Limestone of Sierra Diablo region (p. 453); descriptions of two of the species (*Syntrophina magna* Ulrich and Cooper and *Diaphelasma oklahomense* Ulrich and Cooper) are based in part on specimens collected in Beach Mountain section.

Jackson, A. T., 1948, West Texas caves and shelters, *in* The caves of Texas: Natl. Speleol. Soc. Bull. 10, p. 69–76.

Includes notes on Bat Cave and Potash Mine shelter in Sierra Diablo region (p. 71–72); photographs of Bat Cave on p. 113.

King, P. B., 1948, Geology of the southern Guadalupe Mountains, Texas: U.S. Geol. Survey Prof. Paper 215, 183 p. [1949].

Detailed description of sequence of Permian rocks of Leonard and Guadalupe age in Guadalupe Mountains north of Sierra Diablo region, with incidental reference to rocks of Wolfcamp and Leonard age in Sierra Diablo region (p. 12–13). Maps and text also summarize structure and geomorphology of Sierra Diablo region (p. 118–120, pls. 21, 23).

Adams, J. E., and others, 1949, The Permian rocks of the trans-Pecos region: West Texas Geol. Soc. Field Trip Guidebook, Nov. 6–9, 1949, 94 p.

Includes road log in Sierra Diablo region (p. 58–81), based partly on publications, but including original observations.

King, P. B., 1949, Regional geologic map of parts of Culberson and Hudspeth Counties, Texas: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 90.

Map of a large part of northern Trans-Pecos Texas, including Sierra Diablo region, where it is based on results of present investigation.

King, P. B., and others, 1949, Pre-Permian rocks of the trans-Pecos area and southern New Mexico: West Texas Geol. Soc. Field Trip Guidebook, Nov. 6–9, 1949, 67 p.

Includes a summary of pre-Permian rocks and road log in Sierra Diablo region (p. 18–34), mostly compiled from publications.

Smith, J. F., Jr., and Albritton, C. C., Jr., 1949, Conglomerates of western trans-Pecos Texas and their relation to a tectonic boundary [abs.]: Geol. Soc. America Bull., v. 60, p. 1921.

Discusses relation of conglomerates in Precambrian, Permian, and Cretaceous rocks in Sierra Diablo region and west of it to an unstable area toward the southwest.

Albritton, C. C., Jr., and Smith, J. F., Jr., 1950, Evidence for aridity in west Texas during Early Cretaceous [abs.]: Geol. Soc. America Bull., v. 61, p. 1440.

Interprets chalky limestone and limestone conglomerate at base of Campagrande Limestone as an ancient soil profile, formed in an arid or semiarid climate.

Broadhurst, W. L., Sundstrom, R. W., and Weaver, D. E., 1951, Public water supplies in western Texas: U.S. Geol. Survey Water-Supply Paper 1106, 168 p.

Gives data on municipal water wells at Van Horn (p. 37).

DeFord, R. K., and others, 1951, Apache Mountains of trans-Pecos Texas: West Texas Geol. Soc. 1951 Fall Field Trip Guidebook, Oct. 26–27, 1951, 56 p.

Deals primarily with Apache Mountains east of Sierra Diablo region, but includes a note on pre-Permian rocks of the Beach and Baylor Mountains (p. 52–53).

Hood, J. W., and Scalapino, R. A., 1951, Summary of the development of ground water for irrigation in the Lobo Flats area, Culberson and Jeff Davis Counties, Texas: Texas Board Water Engineers Bull. 5102, 25 p.

Discusses occurrence of ground water in Lobo Flats, a southern extension of the Salt Basin just south of the report area.

Flawn, P. T., 1952, The Hazel copper-silver mine, Culberson County, Texas: Texas Univ. Bur. Econ. Geology Rept. Inv. 9, 23 p.

Report on the Hazel mine preliminary to that given in publication of King and Flawn (1953).

Dunbar, C. O., 1953, A zone of *Pseudoschwagerina* low in the Leonard series in the Sierra Diablo, trans-Pecos Texas: Am. Jour. Sci., v. 251, p. 798–813.

Describes a new species of fusulinid from lower part of Bone Spring Limestone and discusses its occurrence, and that of other fusulinids, in the Victorio Peak section in the Sierra Diablo.

Gillerman, Elliot, 1953, Fluorspar deposits of the Eagle Mountains, trans-Pecos Texas: U.S. Geol. Survey Bull. 987, 98 p.

Report on geology and fluorspar deposits of an area southwest of Sierra Diablo region, whose extreme north edge extends into present report area.

Haigh, B. R., and others, 1953, Sierra Diablo, Guadalupe, and Hueco areas of trans-Pecos Texas: West Texas Geol. Soc. 1953 Fall Field Trip Guidebook, Nov. 6–7, 1953, 91 p.

Includes road log in Sierra Diablo region (p. 5–37), based partly on publications, but including original observations.

King, P. B., and Flawn, P. T., 1953, Geology and mineral deposits of Precambrian rocks of the Van Horn area, Texas: Texas Univ. Pub. 5301, 215 p.

Comprehensive report on Precambrian rocks and associated formations of Van Horn area, part of which lies within present map area. Chapters by Flawn describe Precambrian rocks of Wylie and Carrizo Mountains (p. 41–44, 51–69); a chapter by King describes Precambrian rocks of Sierra Diablo foothills (p. 71–121). Also includes descriptions of copper, silver, talc, and other mineral deposits in Sierra Diablo foothills, Carrizo Mountains, and elsewhere (p. 150–173).

Follett, C. R., 1954, Records of water-level measurements in Culberson, Hudspeth, and Jeff Davis Counties, Texas: Texas Board Water Engineers Bull. 5415, 31 p.

Includes data on wells in Lobo Flats and Wildhorse Valley districts, just south and east of report area.

Stehli, F. G., 1954, Lower Leonardian Brachiopoda of the Sierra Diablo: Am. Mus. Nat. History Bull., v. 105, p. 261–358.

Summarizes stratigraphy of Permian rocks in the Sierra Diablo, interprets their conditions of deposition, and treats in detail the brachiopods and their ecology in lower part of Bone Spring Limestone near Victorio Peak.

Cooper, G. A., and Stehli, F. G., 1955, New genera of Permian brachiopods from west Texas: Jour. Paleontology, v. 29, p. 469–474.

Includes description of *Spyridophoroa reticulata* (King) from Bone Spring Limestone of the Sierra Diablo (p. 472–473).

King, P. B., 1955, Orogeny and epeirogeny through time, *in* Poldervaart, Arie, ed., The crust of the earth: Geol. Soc. America Spec. Paper 62, p. 723–740.

Mentions the deformational history of Precambrian time in the Van Horn region as an example of preservation of the record of orogeny (p. 723–726).

Flawn, P. T., 1956, Basement rocks of Texas and southeastern New Mexico: Texas Univ. Pub. 5605, 261 p.

Includes discussion of Van Horn mobile belt, based mainly on outcrops in and near Sierra Diablo region, with speculations as to subsurface extent of the belt (p. 32–36).

Masson, P. B., 1956, Age of igneous rocks at Pump Station Hills, Hudspeth County, Texas: Am. Assoc. Petroleum Geologists Bull., v. 40, p. 501–518.

Discussion of petrography and structure of Precambrian rocks exposed northwest of Sierra Diablo region, with incidental mention of Precambrian rocks in southern Sierra Diablo and Carrizo Mountains.

Moody, J. D., and Hill, M. J., 1956, Wrench-fault tectonics: Geol. Soc. America Bull., v. 67, p. 1207–1246.

Interprets Hillside fault of southern part of Sierra Diablo region as having large left-lateral strike-slip displacement, and as being a major unit of the "Texas lineament" (p. 1223–1224).

Yochelson, E. L., 1956, Euomphalacea, Trochonematacea, Pseudophoracea, Anomphalacea, Craspedostomatacea, and Platyceratacea, pt. 1 *of* Permian Gastropoda of the southwestern United States: Am. Mus. Nat. History Bull., v. 110, p. 179–276.

Description of gastropods from Permian rocks in many parts of Texas, New Mexico, and Arizona, including those from 38 collections from Sierra Diablo region, with an interpretation of the habitat of the groups considered. "Molluscan ledges" of Bone Spring Limestone in Sierra Diablo discussed (p. 189–190).

Albritton, C. C., and Smith, J. F., 1957, The Texas lineament: Internat. Geol. Cong., 20th, Mexico City 1956, sec. 6, pt. 2, p. 501–518.

Summarizes earlier published accounts of the lineament and new evidence for an against its validity. Proposes that the type locality of the lineament be along Eagle Flat, in the southern parts of the Sierra Diablo and Sierra Blanca regions, west Texas.

Hay-Roe, Hugh, 1957, Geology of Wylie Mountains and vicinity, Culberson and Jeff Davis Counties, Texas: Texas Univ. Bur. Econ. Geology Geol. Quad. Map 21.

Geologic map and text dealing with an area mainly east and south of Sierra Diablo region, but extending into southeast corner of present map area.

Ramírez, J. C., and Avecedo, C. F., 1957, Notas sobre le geología de Chihuahua: Assoc. Mexicana Geólogos Petroleros Bol., v. 9, p. 583–770.

An extensive account of the geology of the State of Chihuahua, adjoining Trans-Pecos Texas on the southwest, with incidental references to formations and structures in the Sierra Diablo region (p. 605–607, 613–614, 620, 630, etc.).

Yochelson, E. L., and Bridge, Josiah, 1957, The Lower Ordovician gastropod *Ceratopea:* U.S. Geol. Survey Prof. Paper 294, p. 281–304.

Analysis of a gastropod genus which is abundant in some Lower Ordovician sequences, including a summary of its occurrence in the El Paso Limestone of the Sierra Diablo region and other areas (fig. 103), and a description of *Ceratopea unguis* Yochelson and Bridge, based on specimens from Beach Mountain.

Batten, R. L., 1958, Pleurotomariacea, Portlockiellidae, Pymatopleuridae, and Eotomatiidae, pt. 2 *of* Permian Gastropoda of the southwestern United States: Am. Mus. Nat. History Bull., v. 114, p. 159–246.

Includes description of gastropod specimens from Sierra Diablo region.

DeFord, R. K., and Brand, J. P., 1958, Cretaceous platform and geosyncline, Culberson and Hudspeth Counties, trans-Pecos Texas: Soc. Econ. Paleontologists and Mineralogists, Permian Basin Sec., 1958 Field Trip Guidebook, 90 p.

Description of a traverse across the Cretaceous rocks just east and south of the report area. Includes two charts of plotted stratigraphic sections of Cretaceous rocks in Sierra Blanca and Sierra Diablo regions (fig. 11, p. 23; fig. 12, p. 25).

Fillman, Louise, chm., 1958, Lexicon of pre-Pennsylvanian stratigraphic names of west Texas and southeastern New Mexico: Midland, Tex., West Texas Geol. Soc., 153 p.

Short discussions of all pre-Permian formations of west Texas-southeastern New Mexico region, including those in the Sierra Diablo region. Incidental mention is made of occurrences in the Sierra Diablo and other outcrop areas, but main emphasis is on subsurface character and distribution in West Texas basin.

Flawn, P. T., 1958, Texas miners boost talc output: Eng. and Mining Jour., v. 159, p. 104–105; repr., Texas Bur. Econ. Geology Rept. Inv. 35.

Notes on geologic occurrence, mining methods, and production of talc from Precambrian rocks in southern foothills of Sierra Diablo.

Pratt, W. E., 1958, Large-scale polygonal jointing: Am. Assoc. Petroleum Geol. Bull., v. 42, p. 2249–2251.

Unconsolidated deposits of the Salt Basin east of Baylor Mountains are fractured into polygons about 2,000 ft across, as a result of undetermined processes.

Howe, H. J., 1959, Montoya group stratigraphy (Ordovician) of trans-Pecos Texas: Am. Assoc. Petroleum Geologists Bull., v. 43, p. 2285–2332.

A regional survey and interpretation of Montoya Limestone, including observations on the formation in the Baylor Mountains and a detailed stratigraphic section there (fig. 29, p. 2328).

Twiss, P. C., 1959, Geology of Van Horn Mountains, Texas: Texas Univ. Bur. Econ. Geology Geol. Quad. Map 23.

Geologic map and descriptive text, covering the area just south of the present report area, including data on the Carrizo Moutain Formation and Hueco Limestone.

Warner, L. A., Holser, W. T., Wilmarth, V. R., and Cameron, E. N., 1959, Occurrence of nonpegmatite beryllium in the United States: U.S. Geol. Survey Prof. Paper 318, 198 p.

Includes description by Holser of Cave Peak intrusive complex (Mine Canyon stock of present report) (p. 140–143), notes on Sierra Prieta intrusive (p. 133), and observations on related igneous rocks elsewhere in the Trans-Pecos Region (p. 130–135).

Finks, R. M., 1960, Late Paleozoic sponge faunas of the Texas region; the siliceous sponges: Am. Mus. Nat. History Bull., v. 120, p. 3–160.

Includes description of specimens of Permian sponges from Sierra Diablo region and a discussion of faunal facies of the sponges, including those of Leonard age in the Sierra Diablo (p. 28–33).

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Includes road log in Sierra Diablo region, and articles on geology by five authors.

Underwood, J. R., Jr., 1962, Geologic map of Eagle Mountains and vicinity, Hudspeth County, Texas: Texas Bur. Econ. Geol. Quad. Map 24, scale 1:48,000.

Geologic map includes southwestern part of present report area and adjacent regions to south and west.

GEOGRAPHY

The Sierra Diablo region lies in the Trans-Pecos province of Texas, or the west-projecting part of the State between the Pecos River and the Rio Grande (fig. 1). Topography, climate, and vegetation of this dry mountainous province are more like those of New Mexico, Arizona, and Chihuahua than those of the rest of Texas. The northern part of the province, in which the Sierra Diablo region is situated, has the characteristic topography of the Basin and Range province of the States to the west and northwest, with broad, plateau-like mountain masses that rise in steep escarpments above intermontane plains or basins. The report area is dominated by one of the mountain masses, the Sierra Diablo, which rises steeply on the east above one of the

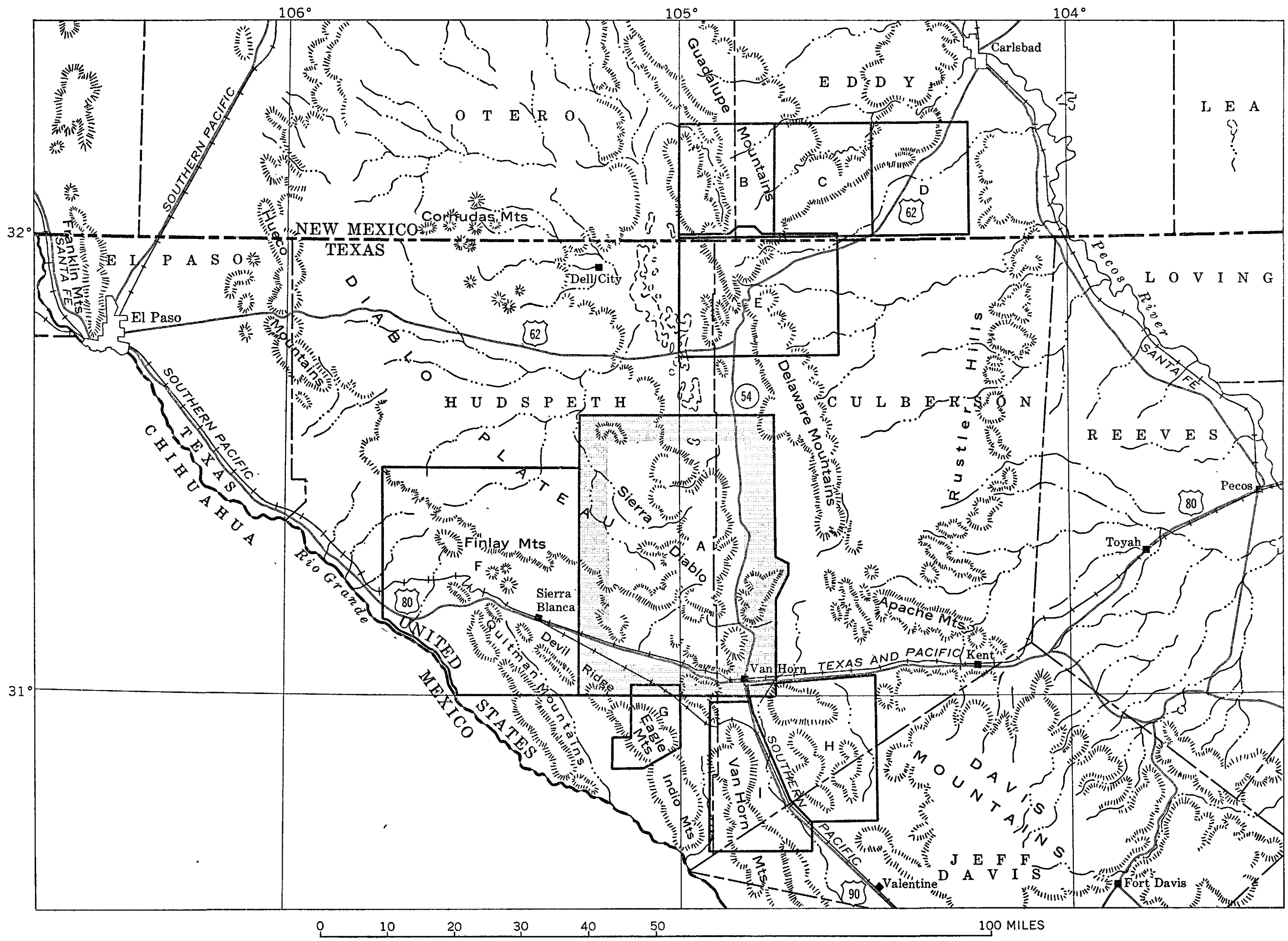

FIGURE 1.—Map of parts of western Texas and southern New Mexico, showing area covered by report on Sierra Diablo region, *A*, and areas covered by recently published reports on adjacent areas: *B*, Boyd, 1958, El Paso Gap quadrangle; *C*, Hayes and Koogle, 1958, Carlsbad Caverns West quadrangle; *D*, Hayes, 1957, Carlsbad Cavern East quadrangle; *E*, King, 1947, southern Guadalupe Mountains; *F*, Albritton and Smith, 1965, Sierra Blanca area; *G*, Gillerman, 1953, Eagle Mountains fluorspar districts; *H*, Twiss, 1959, Van Horn Mountains; and *I*, Hay-Roe, 1957, Wylie Mountains.

intermontane plains, the Salt Basin, and slopes gently on the west into the less diversified expanse of the Diablo Plateau.[1]

The climate of the report area is arid to semiarid. A 20-year record at Van Horn (1939–58) indicates an annual rainfall that fluctuated between less than 5 inches and more than 27 inches, averaging 9.39 inches. Rainfall increases with altitude, as shown by a greater density of vegetation in the Sierra Diablo and other mountains than in the lower country near Van Horn. An arid or semiarid climate has existed in the region since the last glacial period and at least intermittently into far earlier times. It has thus conditioned not only the modern erosional regime and vegetation, but also the soils and landforms that require a longer period for their creation (Carter and others, 1928, p. 7–11, 25–48).

MOUNTAIN AREAS

The Sierra Diablo, or dominant mountain mass of the region, is about 25 miles long, and has extensive summit areas more than 6,000 feet in altitude; its highest peak (at North Diablo triangulation station) attains 6,638 feet (pl. 9). West of the crest the summit areas descend 2,000 feet in about 10 miles, and the range merges with the lower, less diversified Diablo Plateau. The summit areas, formed of Permian limestone, are conspicuously even crested. In most places the even crests are nearly parallel to the strata beneath, but they truncate the abruptly flexed strata near the middle of the range and the limestone units that form the crests to the north and south belong to different formations. The even-crested summit areas were shaped by a peneplain on which Cretaceous rocks were once deposited, but from which these have now been stripped. Their westward slope carries the peneplain under Cretaceous rocks, still preserved in buttes and mesas in the Diablo Plateau in the western part of the report area. Rising abruptly nearly a thousand feet above the plateau northwest of the Sierra Diablo is the dark jagged, rocky Sierra Prieta, formed by a body of igneous rock that was intruded into the Permian and Cretaceous strata.

To the east, north, and south the Sierra Diablo ends abruptly in steep escarpments that face toward the intermontane plains of the Salt Basin and Eagle Flat. Its northeastern part rises directly 3,000 feet above the floor of the Salt Basin, without intervening foothills, but the lower 500–1,000 feet of the slope is alluvial (sections *F–F′* and *G–G′*, pl. 16). Farther south the lower Baylor Mountains and Beach Mountain stand between the Sierra Diablo and the Salt Basin, and a belt of discontinuous foothills stands between it and Eagle Flat.

[1] In some geologic publications the Sierra Diablo has itself been referred to as the Diablo Plateau, but this usage is erroneous and misleading. For the relative extent of the two features, see figure 1.

The escarpments of the Sierra Diablo are outlined by faults that have downthrown the rocks on their topographically lower sides—on the east by a fault of generaly northerly trend but with bight-and-cusp pattern, on the north and south by faults that trend west-northwest. The Baylor Mountains are likewise a fault block, implanted in the southern bight of the fault on the east. The summits of the Baylor Mountains are even crested like those of the Sierra Diablo and, like them, were probably derived from the pre-Cretaceous peneplain, but they stand about a thousand feet lower (sections *H–H′* and *I–I′*, pl. 16). The Baylor Mountain block forms an intermediate step between the heights of the Sierra Diablo and the depths of the Salt Basin.

The eastern escarpments of the Sierra Diablo and Baylor Mountains were shaped directly by faulting, although they were for the most part modified by subsequent erosion. The Baylor Mountains escarpment is now much indented at the mouths of valleys issuing from the mountains. The upper part of the Sierra Diablo escarpment has receded a mile or so from the trace of the fault along its base; it is also deeply breached by Victorio and Apache Canyons, which extend far headward into the range. These canyons probably originated from major valleys that drained westward before they were diverted to their present courses. However, uplift of the Sierra Diablo was so prolonged that the lower part of its escarpment in the segment north of the Baylor Mountains is newer, and is consequently less eroded. Here, the escarpment ends on an even baseline, bordered on the mountainward side by a steep rock bench and on the basinward side by a high extensive alluvial slope, which is itself broken by a low fault scarp at its north end.

The eastern escarpment of the Sierra Diablo is divided into three topographically contrasting segments as a result of intersection of the bordering fault by two west-northwestward-trending monoclinal flexures, each of which has depressed the strata on the north so far as to preserve a different sequence of formations. In the southeastern Sierra Diablo, south of the southern, or Victorio, flexure, the escarpment consists of smoothly rounded lower slopes, cut on red sandstone of the Precambrian Hazel Formation, and an upper sheer cliff of Hueco Limestone, the lowest unit of the Permian sequence (left end of upper view, pl. 10). In the northeastern Sierra Diablo, north of the Victorio flexure, the red sandstone is beneath the surface, and the escarpment is formed entirely of Permian limestones. Here it is two-storied, with a bench of Hueco Limestone below and cliffs of light-gray Victorio Peak Limestone at the top, separated by smoothly rounded slopes cut on the intervening less resistant thin-bedded or shaly Bone Spring Limestone (left end of lower view, pl. 10). On the northern, or Babb, flexure, at the north end of the Sierra Diablo, the Hueco and Bone Spring Limestones in their turn pass beneath the surface (upper view, pl. 12). In the hills which are a continuation of the Sierra Diablo on the north, the top of the Victorio Peak Limestone forms a bench at the edge of the Salt Basin which is surmounted by widely spaced mesas, capped by a resistant layer in the Guadalupe Series, the Goat Seep Limestone.

By contrast with the escarpment on the east side of the Sierra Diablo, that on the south side was produced merely by erosion of a terrain that was faulted at a remote period. The escarpment is the southernmost of several, each formed along faults downthrown to the south, by which both the strata and the topographic surface step down from the heights of the northern part of the range (section *P–P′*, pl. 16). The escarpments were produced, at least in part, by stripping of weak Cretaceous beds off the strong Permian limestone beds; Cretaceous beds are still preserved on the downthrown sides of some of the faults toward the west. Toward the east the escarpments have been further modified by undercutting of weak red sandstone of the Precambrian Hazel Formation, so that the capping Permian limestone is greatly frayed, and has receded irregularly from the original fault traces.

Relief in the southern foothills, between the Sierra Diablo and Eagle Flat, is likewise a product of unequal erosion of rocks of diverse structures and ages. The Streeruwitz, Bean, and Millican Hills to the west are low and are separated by broad alluvium-covered rock-cut plains, but the Carrizo Mountains and Beach Mountain to the east are higher and rise steeply above the Salt Basin, probably with an intervening fault. Beach Mountain, a rugged mass with an area of about 15 square miles, projects a thousand feet above the lower hills to the west, and is capped by a remnant of strong Ordovician limestone (pl. 2). The underlying red massive Van Horn Sandstone, exposed west and southwest of Beach Mountain in the Red Valley and along Hackberry Creek, has been carved into tables, battlements, and towers to produce some of the most picturesque scenery in the region. Differential erosion is further demonstrated along the Hillside fault in the Carrizo Mountains to the south. The downthrown northern side of the fault is bordered by a steep obsequent faultline scarp of Permian limestone and Cretaceous sandstone, whereas the metamorphic rocks of the Precambrian Carrizo Mountain Formation on the southern upthrown side have been cut into a valley that is utilized by the line of the Texas and Pacific Railway in its course through the mountains (section *T–T′*, pl. 16).

LOWLAND AREAS

Largely because of the long-continued aridity, the region has an interior drainage, leading to the Salt Basin on the east and the smaller basin of Eagle Flat on the southwest, which have no outlets to the sea. South of the region, however, this area of interior drainage is being attacked by streams that are cutting headward from the through-flowing Rio Grande.

The Salt Basin, or dominant lowland of the report area, lies east of the mountains and extends far northward, past the Texas-New Mexico State line (fig. 1). The Salt Basin is 90 miles long, 5 to 15 miles wide, and trends north-northwestward parallel to the grain of the mountains and plateaus which border it (King, P.B., 1948, pl. 23). Its lowest part, east of the northeastern Sierra Diablo, stands at an altitude a little below 3,600 feet. It is a closed depression and the focus of a large region of interior drainage. At its north and south ends it receives drainage from the high relatively well-watered Sacramento and Davis Mountains; on the west it receives drainage from the Sierra Diablo and Diablo Plateau. Along the Guadalupe and Delaware Mountains on the east the drainage area is smaller, the crests of these mountains being so close to the basin that most of their water courses lead eastward to the Pecos River.

Eagle Flat, a less extensive lowland, lies southwest of the Sierra Diablo, trending west-northwest across the regional grain for about 25 miles. It receives drainage from the southern Sierra Diablo and Diablo Plateau, and to a lesser extent from the mountains on the south, most of whose water courses lead southwestward to the Rio Grande. The eastern part of Eagle Flat drains by a roundabout course south of the Carrizo Mountains into the Salt Basin; but the western part is an independent depression whose lowest point is at Grayton Lake, which has an altitude of a little more than 4,000 feet.

Both the Salt Basin and Eagle Flat are tectonic depressions, produced mainly by downfaulting of their floors relative to the mountains that surround them. They have been deeply filled by unconsolidated deposits of Quaternary and possibly of late Tertiary age washed in from higher lands around them. The unconsolidated deposits have been extensively drilled for water in the Salt Basin, but in few places deeply enough to determine the configuration of their base. A well in the basin north of the Sierra Diablo region is reported to have been sunk 1,620 feet without reaching the base of the deposits. Wells at Van Horn are shallower, as are those in the irrigation districts of Wildhorse Valley and Lobo, to the east and south; but a few of them have penetrated bedrock. Less is known of the depths of the unconsolidated deposits in Eagle Flat, but the Southern Pacific railroad well at Hot Wells was drilled into them to a depth of more than 1,000 feet (Baker, 1927, p. 37–40; Broadhurst and others, 1951, p. 57; Hood and Scalapino, 1951, p. 4–5; Follett, 1954, p. 6–15).

The surface of the southern part of the Salt Basin, as far as the north end of the Baylor Mountains, consists of alluvial slopes extending from the bordering mountains to the axis of the depression along which Wildhorse Creek drains northward. North of the Baylor Mountains the alluvial slopes on each side do not meet, and between them is a nearly level floor more than 5 miles wide, formed probably by deposition on the bottoms of lakes during late Pleistocene time or earlier. On the alluvial slopes streams are mostly actively transporting material away from the mountains, although near their lower ends on the east side the sandy constituents are now being shifted even more vigorously by the wind. Streams are thus prograding material toward the basin floor, yet they are not depositing material on the floor itself. The floor appears to be virtually stable, except for minor leveling or deleveling by the wind. As the Salt Basin has interior drainage, theoretically its streams should be adjusted to a slowly rising base level; but the stability of the floor indicates that this condition is not now attained.

The floor of the Salt Basin is diversified by alkali flats (locally called salt lakes) and by hills of gypsiferous clay. One set of alkali flats is east of the northern part of the Sierra Diablo, another just north of the end of the range. They may be final remnants of more extensive lakes of an earlier period, yet today they contain water only at long intervals. They are maintained principally by the wind, which sweeps material from their surfaces down to ground-water level, an effective limit to downward erosion. The peculiarly fretted outlines of the alkali flats north of the Sierra Diablo were probably shaped by this wind work. The hills of gypsiferous clay were also formed by the wind. Over extensive areas to the north they have no clearly discernible pattern, but on the east side of the floor opposite the northern part of the Sierra Diablo they form a remarkable set of closely spaced parallel ridges, trending north-northwest, which curve westward at the south end of the floor, just north of the Baylor Mountains. These, and others like them farther north, probably mark the shores of the shallow lakes of Pleistocene time, along which the clays were raised into low dunes. A later modification by the wind of the clay hills is indicated on air photographs by superposition on the gross features of a more delicate grain trending east or east-southeast. Between the alkali flats and hills of gypsiferous clay are tracts of level meadowland, underlain by brown clay which supports more grass cover than that on the gypsiferous clay hills.

The alluvial slopes, formed by coalescence of the fans built by streams which issue from the mountains, are continuous along the entire western border of the Salt Basin at the bases of the Sierra Diablo and other ranges, except at the northeast corner of the Baylor Mountains where the rock hills have been partly submerged by more distantly derived detritus. The radii and gradients of the fans, and the texture of their components, are related to the areas of drainage in the mountains of the streams which supply them and to the recency of faulting along the mountain bases. Large fans of low gradient, composed of relatively fine material, have been built by Hackberry and Sulphur Creeks near Van Horn and by Red Wash, Victorio Canyon, and Apache Canyon farther north; lesser fans with steeper gradients, composed of coarser material, have been built by smaller streams in the intervening segments. The steepest coarsest fans are those along the segment of the Sierra Diablo north of the Baylor Mountains where relatively recent faulting is most likely. One of the fans in this segment, 1 mile north of Victorio Canyon, has a gradient of 1,000 feet per mile, a radius of six-tenths of a mile, and was built below a gulch on the escarpment with a drainage area of less than half a square mile. On some of the steeper fans the courses of recent drainage are marked by trains of fresh boulders and gravel, but drainage on fans of somewhat larger dimensions is generally incised in the fan surface, in places as much as 40 feet, the depth decreasing downslope. Most of the drainage on the largest fans is fainter and less incised, but Sulphur Creek forms a wide braided gravel-covered channel nearly to the lower edge of its fan.

Most of the streams draining eastward from the mountains into the Salt Basin have cut downward into the rocks of the mountains and have built up alluvial fans in front; they have done little leveling of the bedrock by sideward cutting. Chief exceptions are Hackberry Creek, Sulphur Creek, and Red Wash, which drain the edges of Beach Mountain and the Baylor Mountains and which have cut broad areas of lowland in rocks that are mainly not calcareous. Recently leveled areas are partly masked by alluvial deposits; areas leveled earlier are indicated by terraces a hunded feet or more above modern drainage, which are in part capped by older alluvial deposits. Cause of the dissection of the earlier terraces is undetermined, but it may be related to continued downfaulting of the Salt Basin relative to the adjacent mountain areas.

In Eagle Flat, southwest of the Sierra Diablo, erosional and depositional processes appear to be less active than in the Salt Basin, partly because of its greater tectonic stability in the recent past, partly because of the circuitous drainage connection between it and the main basin. Alluvial slopes thus extend to the axis of Eagle Flat, and extensive rock-cut surfaces have been formed on its north and south sides. Within the flat itself the fine debris has been raised by the wind into low sand dunes in extensive areas, as shown on the topographic base map (pls. 1, 9).

On the north, in the southern foothills of the Sierra Diablo, these rock-cut surfaces, now largely mantled by alluvium, extend between the Streeruwitz, Bean, and Millican Hills which were carved from the more resistant conglomerate, limestone, and volcanic units of the Hazel and Allamoore Formations of the Precambrian sequence. In the hills a time of earlier planation is suggested by accordant levels on their summits.

Toward the east, Sulphur and Hackberry Creeks, which drain into the Salt Basin, are dissecting the eastward extensions of the rock-cut surfaces on which the streams draining into Eagle Flat are now flowing. The bedrock of red sandstone of the Hazel Formation has been scored into a network of valleys and ravines, on whose crests are gravel deposits that are remnants of a surface that once sloped continuously toward Eagle Flat. Westward, the alluvium of the valley bottoms in the Hackberry and Sulphur Creek drainage areas rises and merges with the gravel caps, so that the two sets of deposits cannot be differentiated in the drainage area of Eagle Flat.

HUMAN GEOGRAPHY AND HISTORY

The valley of the Rio Grande near El Paso, west of the Sierra Diablo region, was long a focus of settlement, first by agricultural Indians, later by the Spaniards and Mexicans. Missions were founded as early as the 17th century by Franciscan monks, and by the time of establishment of United States sovereignty in 1847 there were several towns and farming communities. However, the interior of the Trans-Pecos province, including the Sierra Diablo region, remained empty country, which was the haunt of roving and marauding bands of Indians.

Under the American regime several stage and caravan routes were laid out across the interior of the Trans-Pecos province to connect the settlements on the Rio Grande with those farther east. A trail from San Antonio to El Paso, which was subsidized as a mail route in 1850, passed south of the Sierra Diablo, through Bass Canyon and Eagle Spring. The Butterfield Trail, which was subsidized as a mail route in 1857, passed north of the Sierra Diablo, through Guadalupe Pass and Crow Flat. Although American authority over the interior of the Trans-Pecos province was virtually relinquished during the Civil War period, a road was laid out in 1863 by public subscription from the Rio Grande settlements to the salt deposits of the Salt Basin, which passed near Sierra Prieta in the northwestern part of the report area.

The last Indian battle in Texas was fought in January 1881, when Capt. George W. Baylor, of the Texas Rangers, defeated an Apache band under the leadership of their chief Victorio, in the heights of the Sierra Diablo near the peak which now bears his name. With the construction of the Southern Pacific and Texas and Pacific railroads a few years later, much of the isolation of the region ended, and it was available for occupancy.

The Sierra Diablo region was originally included in El Paso County, which at first covered most of the northern Trans-Pecos Texas. In 1911 Culberson County was established with Van Horn as the county seat, and in 1917, Hudspeth County, with Sierra Blanca as the county seat. The only town in the report area is Van Horn, with about a thousand people, first located as a station on the Texas and Pacific Railway because of the availability of excellent well water from the deposits of the Salt Basin. Its growth has been furthered because of its position on the transcontinental highway, at the junction of U.S. Highways 80 and 90. Minor settlements are Allamoore on the Texas and Pacific Railway and U.S. Highway 80 west of Van Horn, and Hot Wells on the Southern Pacific railroad to the southwest.

Because of the arid climate and forbidding terrain, the Sierra Diablo region has remained sparsely peopled until today—a region of extensive landholdings used for pasturage of cattle, sheep, and goats. During the last quarter of a century, modern paved highways have been built across it—U.S. Highways 80 and 90 on the south and U.S. Highway 62 on the north, which have brought large numbers of automobile travelers and have encouraged the development of businesses catering to them. Also, after the Second World War, extensive reservoirs of ground water were discovered in the northern and southern parts of the Salt Basin, and these have been developed by pumping for irrigation. Agricultural areas of 10 square miles or more have thus come into existence at Dell City, Wildhorse Valley, and Lobo, to the north, east, and south of the Sierra Diablo region (Scalapino, 1950; Hood and Scalapino, 1951; L. A. Wood, written commun., 1959).

Existence of copper and silver in mineralized veins in the Precambrian rocks of the southern part of the Sierra Diablo region was discovered by some of the earliest American visitors. The vein at the Hazel mine is reported to have been prospected as early as 1856; practically all the veins which have been mined were mentioned in the reports of Streeruwitz of 1890 and 1891 (Streeruwitz, 1891, 1892). The district has produced about 2 million pounds of copper and 4 million ounces of silver, but operations have been spasmodic and the possibilities of the district have seemingly not been great enough to attract large-scale capital. Long after discovery of the metallic deposits in 1952, talc was found in beds of Precambrian phyllite of the same area; the talc is now being mined at various places by six companies, who by 1957 had produced about 120,000 tons.

STRATIGRAPHY

Most of the bedrock that crops out in the Sierra Diablo region consists of consolidated sedimentary rocks of Precambrian, Paleozoic, and Mesozoic ages (pl. 1). Intrusive and extrusive igneous rocks of Precambrian and Cenozoic ages occupy smaller areas. Within the mountain and foothill areas the bedrock also underlies the alluvial deposits at shallow depth, but in the lowland areas of the Salt Basin and Eagle Flat it is probably buried to great depth beneath unconsolidated sedimentary rocks of Cenozoic age.

Precambrian rocks crop out in the foothills south and southeast of the Sierra Diablo; they are a varied sequence of sedimentary rocks many thousands of feet thick, classed as the Carrizo Mountain, Allamoore, and Hazel Formations. The Carrizo Mountain Formation is variably metamorphosed and is intruded by igneous rocks; the Allamoore Formation contains interbedded volcanic rocks. The Precambrian formations are overlain by the Van Horn Sandstone, as much as 700 feet thick, which is classed as of Precambrian(?) age.

Paleozoic rocks form the greater part of the mass of the Sierra Diablo, as well as some of the adjacent smaller mountains, and include all the systems except the Cambrian. The Paleozoic rocks are dominantly limestone or dolomite, but there are minor beds or units of shale, sandstone, conglomerate, and chert. The Ordovician, Silurian, and Devonian rocks are about 2,000 feet thick. Mississippian and Pennsylvanian rocks occur only in fragmentary exposures, and their total thickness probably does not exceed 1,000 feet. By contrast, the Permian rocks are extensive and attain a thickness of more than 3,000 feet, although only the lower part of the system is preserved.

The Mesozoic is represented by the Cretaceous System only. A sequence nearly 5,000 feet thick occurs in the southwestern part of the report area and extends from the lower part of the Lower Cretaceous into the lower part of the Upper Cretaceous. In the Sierra Diablo itself, only the Lower Cretaceous is preserved; it consists mostly of sandstone with subordinate limestone and marl with a thickness of less than a thousand feet.

The Tertiary is represented at the surface only by widely separated intrusive igneous rocks and by small remnants of extrusive igneous rocks. Poorly consolidated sedimentary rocks of Tertiary age may underlie the unconsolidated sedimentary rocks of Quaternary age in the lowland areas of the Salt Basin and Eagle Flat.

Nearly all the sedimentary rocks younger than the Precambrian and Precambrian(?) contain marine invertebrate fossils. They are especially abundant, varied, and well preserved in the Permian rocks, from which large collections were made during the present investigation.

The stratified rocks of the Sierra Diablo region were laid down during progressively changing geographic conditions, which are partly expressed by contrasts between the successive deposits and faunas and partly by the many unconformities in the sequence. Some of the unconformities, such as those which occur between most of the pre-Permian Paleozoic formations, express merely gaps in the record, and are not accompanied by appreciable tilting or erosion of the underlying beds. Several of the other unconformities indicate deep or prolonged erosion, deformation of the underlying beds, and even marked orogeny. The Van Horn Sandstone thus lies on the eroded edges of the strongly deformed and partly metamorphosed earlier Precambrian rocks. A lesser angular unconformity separates the Van Horn from the Ordovician above. The pre-Permian Paleozoic rocks were broadly folded, deeply eroded, and in places removed entirely before the Permian was laid down over them. Mild deformation occurred again between Permian and Cretaceous time, and the Cretaceous was deposited over a peneplain which bevels all the earlier rocks.

Table 1 summarizes the formations exposed in the Sierra Diablo region.

TABLE 1.—*Rock formations of Sierra Diablo region, Texas*

System	Series		Formation	Remarks	Approximate thickness (feet)
Quaternary			In mountain areas, alluvium, older gravel deposits, and landslide deposits; in Salt Basin, bolson deposits, fanglomerate, and drifted sand.		
Tertiary			Basalt flows and plugs		
			Intrusive igneous rocks		
Unconformity					
Cretaceous	Upper Cretaceous	Gulf	Eagle Ford Formation	Preserved only in southwestern part of report area.	1, 500
	Lower Cretaceous	Comanche	Washita Group		350–1, 000
			Kiamichi Formation	Replaced northward by Cox sandstone.	65
			Finlay Limestone		60–350
			Cox Sandstone		500–1, 000
			Campagrande Limestone	Lies on pre-Cretaceous rocks, except in southwestern part of report area.	25–200
			Bluff Mesa Formation	In southwestern part of report area only; partly equivalent to Campagrande limestone.	1, 000–1, 300
			Yucca Formation	In southwestern part of report area only	350–1, 500
Major unconformity					
Permian	Guadalupe		Goat Seep Limestone		>200
			Sandstone tongue of Cherry Canyon Formation	Lies on Cutoff shale in Sierra Diablo	150–200
			Brushy Canyon Formation	In northeastern part of report area only	
	Unconformity				
	Leonard		Cutoff Shale		275
			Victorio Peak Limestone	Intergrades with Bone Spring Limestone	900–1, 500
			Bone Spring Limestone	Wedges out southwestward by intergradation and overlap	900–1, 300
	Unconformity				
	Wolfcamp		Hueco Limestone	Varies in thickness by overlap at base and by pre-Leonard erosion at top	300–1, 500

TABLE 1.—*Rock formations of Sierra Diablo region, Texas*—Continued

System	Series	Formation	Remarks	Approximate thickness (feet)
Major unconformity				
Carboniferous: Pennsylvanian		Beds of Pennsylvanian age	Disconnected exposures only	Undetermined
Carboniferous: Mississippian		Barnett Shale	Disconnected exposures only	>135
Devonian	Upper Devonian	Beds of Devonian age		125
Silurian	Middle Silurian	Fusselman Dolomite		300–450
Ordovician	Upper Ordovician	Montoya Dolomite		230–450
	Middle(?) Ordovician	Beds of Middle(?) Ordovician age		60–80
	Lower Ordovician	El Paso Limestone		1150
		Bliss Sandstone		100–160
Unconformity				
Precambrian(?)		Van Horn Sandstone		As much as 700
Major unconformity				
Precambrian		Hazel Formation		5, 000?
		Allamoore Formation		2, 500?
		Sequence broken		
		Metarhyolite and greenstone	Intrusive into Carrizo Mountain Formation	
		Carrizo Mountain Formation		As much as 19, 000
Base concealed				

PRECAMBRIAN AND PRECAMBRIAN(?) ROCKS

Rocks older than the Ordovician are extensively exposed in the southern part of the Sierra Diablo region and for some miles south of it (pl. 1). Three formations—the Carrizo Mountain, Allamoore, and Hazel Formations—are classed as of Precambrian age; a fourth, the Van Horn Sandstone, is classed as of Precambrian(?) age. History of the terminology of these units is indicated in the table below. The Precambrian and Precambrian(?) rocks of the Sierra Diablo region and adjoining areas were described in detail in an earlier publication (King, P. B., and Flawn, P. T., 1953), of which the following account is a summary.

The largest area of exposure of the Precambrian and Precambrian(?) rocks is in the foothills of the Sierra Diablo, extending northward along the east side nearly to Victorio Peak and westward along the south side beyond Eagle Flat section house. Near the Texas and Pacific Railway this area is separated by a downfaulted block of Paleozoic and Cretaceous rocks from another area of exposure in the Carrizo Mountains. South of the Carrizo Mountains and beyond the Sierra Diablo region, Precambrian rocks emerge in smaller areas in other mountain uplifts—on the northeast side of the Eagle Mountains, on the west side of the Wylie Mountains, and in two areas in the Van Horn Mountains. (See fig. 8.)

CARRIZO MOUNTAIN FORMATION

The Carrizo Mountain Formation, probably the oldest Precambrian unit of the Sierra Diablo region, is named for exposures in the Carrizo Mountains, south of the Texas and Pacific Railway at the south edge of

Development of stratigraphic nomenclature of Precambrian rocks of Sierra Diablo region

Streeruwitz ,1891	Dumble, 1902	Richardson, 1914		King, P. B., 1940		King, P. B., and Flawn, P. T., 1953		This report	
Carboniferous	Silurian	Ordovician	El Paso limestone	Ordovician	El Paso Limestone	Ordovician	El Paso Limestone	Ordovician	El Paso Limestone
Diabolo Sandstone (Devonian?)	Potsdam Sandstone (Cambrian)	Upper Cambrian (?)	Van Horn Sandstone		Bliss Sandstone		Bliss Sandstone		Bliss Sandstone
				Cambrian or Precambrian	Van Horn Sandstone	Precambrian(?)	Van Horn Sandstone	Precambrian(?)	Van Horn Sandstone
	Hazel Sandstone	Algonkian	Millican Formation	Precambrian	Hazel Sandstone	Precambrian	Hazel Formation	Precambrian	Hazel formation
(not classified)	Texan Marble (placed above Hazel Sandstone)				Allamoore Limestone		Allamoore Formation		Allamoore Formation
Carrizo Schist	(not discussed)		Carrizo Formation		Carrizo Mountain Schist		Carrizo Mountain Group		Intrusives in Carrizo Mountain Formation
									Carrizo Mountain Formation

the map area, where it forms the surface in about 25 square miles (pl. 1). It also crops out at the west base of the Wylie Mountains in the southeast corner of the map area (Flawn, in King P. B., and Flawn, P. T., 1953, p. 41–44; Hay-Roe, 1957), as well as in the Eagle and Van Horn Mountains farther south beyond the map area.

The Carrizo Mountain Formation is a thick body of variously metamorphosed sedimentary rocks, which have been intruded by large volumes of igneous rocks; the latter are separately described under the succeeding heading. On the geologic map (pl. 1) the only differentiation made in the sedimentary rock is between arkose and quartzite on the one hand, and various other rocks, mainly schist, slate, and limestone, on the other. However, in most areas the formation includes distinctive, varied units that could ranks as formations, were it not for their small areas of exposure. In each of the areas these units lie in a stratigraphic sequence, partly disrupted by igneous intrusions or obscurred by metamorphism, but correlation between sequences in the different areas has not been established.

SEQUENCE IN CARRIZO MOUNTAINS

In the Carrizo Mountains the Carrizo Mountain Formation, and the igneous rocks which intrude it, project in jagged parallel ridges, mostly trending northeast, separated by lowlands cut on the less resistant rocks of the formation. The formation dips steeply southeastward and strikes mostly northeastward (section *T–T′*, pl. 16). Some of the intrusive bodies are irregular but most are sill-like, so that they only partly disorder the bedded succession. Where sedimentary structures are preserved, mainly in the arkose and quartzite units, they indicate that tops of the beds are to the southeast, and as the units of the formation are not repeated, the whole sequence is probably homoclinal. The sedimentary rocks of the sequence are nearly 19,000 feet thick, although this may exceed their original thickness because of contortion and injection of minor sills. The sequence has been distended another 7,000 or 8,000 feet by much thicker sills that are separately mapped.

The sequence consists of the following units, in descending stratigraphic order. The sequence is interrupted by intrusive igneous rocks, but these are indicated only where they break the succession completely. Titles of the units are those used by Flawn in his original description (in King, P. B., and Flawn, P. T., 1953, p. 52–58).

Stratigraphic units of Carrizo Mountain Formation in Carrizo Mountains

	Approximate thickness (feet)
11. Limestone: Fine-grained hard brown calcareous rock, exposed on one hill at east edge of mountains. Separated by metarhyolite from rest of sequence; so relations to other units are uncertain; it may overlie them	(?)
(Metarhyolite intrusive)	
10. Feldspathic metaquartzite and meta-arkose: Fine-grained light-gray feldspathic metaquartzite and sericitic meta-arkose, exposed in low hills on southeast edge of mountains. Foliation is probably parallel to bedding, but original bedding planes are not apparent. Contains thin interbedded layers of sericite schist in lower part, lowest of which is garnetiferous. Basal contact preserved only in Bass Canyon, south of map area	2, 700
9. Mixed unit: Fine-grained schist and phyllite, with some layers of schistose quartzite and a thin bed of chert conglomerate. Contains numerous small bodies of greenstone, granodiorite, and metarhyolite, and is much contorted	4, 000
(Thick sills of metarhyolite and greenstone)	

Stratigrayhic units of Carrizo Mountain Formation in Carrizo Mountains—Continued

	Approximate thickness (feet)
8. Feldspathic metaquartzite and meta-arkose: Light-gray sericitic feldspathic metaquartzite toward northeast, where it forms a prominent ridge, passing southwestward into rocks that are more schistose and micaceous. Bedding and crossbedding are visible and indicate that top of beds are to southeast	300
7. Mixed Unit: Fine-grained sericitic quartzite; fine-grained biotite-sericite schist, and phyllite; some thin beds of limestone and numerous thin sills of greenstone. A few hundred feet of similar rocks underlie the metarhyolite sill near its northeast end, and are probably part of the same unit, separated by the intrusion	2,000
(Thick sill of metarhyolite, underlain by a thick sill of greenstone)	
6. Phyllite: Blue-gray phyllite or slate, in narrow lowland between flanking ridges of greenstone and meta-arkose. Slaty cleavage may be parallel to bedding, but bedding is not visible	600
5. Meta-arkose: Mainly gray fine-grained thin- to medium-bedded meta-arkose, containing well-marked bedding laminae, crossbedding, pebble bands, and a few ripple marks. Sedimentary structures indicate that tops of beds are to southeast. Upper 250 ft is hard red-brown meta-arkose in 2-ft beds. Unit forms a prominent ridge on southeast side of Cat Draw, and is well exposed in cuts on U.S. Highway 80	1,700
4. Mixed unit: Fine-grained gray or blue quartzite, light-gray sericite schist an dark phyllite, dark lustrous slate, thin-bedded blue chert, and laminated brown and black cherty limestone, all of which are interbedded in thin layers. Contains many thin greenstone sills. Forms the broad belt of lowland along Cat Draw	1,700
3. Meta-arkose and feldspathic metaquartzite: Fine-grained thin-bedded light-gray feldspathic metaquartzite and meta-arkose. Contains well-marked bedding and crossbedding which indicate that tops of beds are to southeast. Forms prominent line of knobs and ridges on northwest side of Cat Draw	1,800–2,000
(Thick greenstone sill, underlain by irregular bodies of metarhyolite)	
2. Chlorite-mica schist: Fine-grained lustrous dark-colored sericite-chlorite-biotite schist, thin beds of dark slate, and thick beds of coarse pebbly meta-arkose. Forms a low hilly area near Mineral Creek in northwestern part of mountains, nearly surrounded by intrusive metarhyolite and greenstone, so that relations to adjoining units are preserved in only a few places	3,700

Stratigraphic units of Carrizo Mountain Formation in Carrizo Mountains—Continued

	Approximate thickness (feet)
1. Meta-arkose: Fine-grained light-gray meta-arkose, with thin layers of sericite schist and phyllite, in small areas in a large greenstone intrusive south of Mineral Creek. At one locality the unit dips beneath the chlorite-mica schist, indicating that it is the lowest part of the sequence	(?)
Total thickness	+18,700

METAMORPHIC FEATURES

The sedimentary rocks of the Carrizo Mountain Formation in the Carrizo Mountains have been subjected to at least two periods of metamorphism and have been injected several times by igneous rocks, so that part of their stratigraphic character has been destroyed.

The quartzite and arkose units preserve many original sedimentary structures, such as bedding laminae, crossbedding, and pebbly seams; but the quartz and feldspar are recrystallized, and contain variable amounts of chlorite and sericite. The finer grained, originally more argillaceous, units mostly contain biotite, which has been partly converted to chlorite. These units, and to a lesser extent the quartzite and arkose units, contain a foliation that is closely parallel to the general homoclinal structure and to the bedding where this can be observed. The mica, some of the chlorite, and the foliation are products of an early regional metamorphism whose grade increases progressively southeastward to a visible climax in exposures in the Van Horn Mountains, where some of the rocks are garnetiferous.

Alteration of biotite to chlorite (and in some areas garnet to chlorite) indicates a later period of retrogressive and cataclastic metamorphism, whose effects increase perceptibly northwestward across the exposed breadth of the Carrizo Mountains. In many of the schist and phyllite units the foliation is distorted by crinkles and chevron folds whose axes cross the foliation planes at wide angles. In the Carrizo Mountains these structures are most abundant where effects of retrogressive metamorphism are greatest, and especially where incompetent units abut the competent metarhyolite intrusions.

The nature of the different rocks of the sequence influenced their response to this complex metamorphic history. Preservation of sedimentary features in the quartzite and arkose units resulted from alteration by mass recrystallization. Greater complexity of the structures in the finer grained units, where original sedimentary features are poorly preserved, probably developed because these units absorbed much of the applied stress during progressive and retrogressive metamorphism.

The earlier progressive regional metamorphism of the sedimentary rocks of the Carrizo Mountain Formation preceded their intrusion by metarhyolite and greenstone. These were injected in large part as sills along the planes of earlier bedding and foliation. The intrusive rocks now show strong effects of cataclastic and retrogressive metamorphism, evidently related to the retrogressive metamorphism of the sedimentary rocks.

STRATIGRAPHIC RELATIONS

The sequence of sedimentary rocks of the Carrizo Mountain Formation exposed in the Carrizo Mountains preserves neither its top nor base, nor can top or base be observed in exposures of the formation elsewhere. The lower part of the sequence is intruded by metarhyolite and greenstone. Northwest of the Carrizo Mountains, in the foothills of the Sierra Diablo, these intrusive rocks are faulted over other sedimentary rocks of the Allamoore Formation along a major discontinuity in the Precambrian rocks, the Streeruwitz thrust fault. Thus, relations between the Carrizo Mountain and Allamoore Formations cannot be determined directly, although rather tenuous evidence suggests that the Carrizo Mountain is the older formation.

IGNEOUS ROCKS INTRUSIVE INTO CARRIZO MOUNTAIN FORMATION

Large masses of rhyolite and somewhat smaller masses of greenstone intrude the Carrizo Mountain Formation. In the Carrizo Mountains they form thin to thick sills in the homoclinal sequence of sedimentary rocks, as well as a large body at the base of the sequence to the northwest (section *T–T′*, pl. 16). The instrusive rocks also crop out discontinuously north of the Texas and Pacific Railway, along the south edge of the Sierra Diablo foothills next to the alluvial area of Eagle Flat, from northeast of Allamoore to northwest of Eagle Flat section house (pl. 1). Here, none of the sedimentary rocks of the Carrizo Mountain Formation are preserved, and the intrusive rocks are faulted over the Allamoore Formation along the Streeruwitz thrust fault. A few bodies of the igneous rocks in the Millican Hills west of the Garren Ranch are entirely surrounded by Allamoore Formation; they are probably klippen of the Streeruwitz thrust sheet (section *O–O′*, pl. 16).

Igneous rocks of the large body in the northwestern Carrizo Mountains, referred to above, consisting of metarhyolite and minor sills of greenstone, are well exposed in low hills southeast of Allamoore and higher ridges beyond. They are shown in numerous cuts along U.S. Highway 80, 2 to 4 miles southeast of Allamoore, and in quarry openings of the Holley Plant of Gifford-Hill Co. northeast of the highway.

METARHYOLITE

The metarhyolite superficially has the appearance of an extrusive volcanic rock, as though it were part of the stratigraphic sequence of the Carrizo Mountain Formation. Much of it is layered, some of it contains intercalations of sericite schist and phyllite, and the part to the southeast is interbedded in thick units with the sedimentary rocks. However, the layering and schistose intercalations were produced during metamorphism, and the metarhyolite bodies to the southeast are sills, which branch or pinch out along the strike and have irregular contacts with the enclosing rocks.

The metarhyolite is a hard, blocky or slabby siliceous rock of red, pink, brown, buff, or gray color. It is formed of feldspar and quartz phenocrysts generally less than 2 mm in diameter, now largely broken, set in an aphanitic groundmass. Texture and appearance of the rock are similar in all exposures, except for variable effects produced by metamorphism. Microscopic study, however, indicates that the feldspar in the southeastern Carrizo Mountains is microcline, whereas that in the northwestern Carrizo Mountains and the Sierra Diablo foothills is microcline-microperthite and albite; this difference may have resulted from albitization of an original potassium feldspar in the northwestern areas.

Cataclastic metamorphism has produced a well-developed layering or foliation in much of the metarhyolite, on the surfaces of which phenocrysts and mineral aggregates have been crushed, streaked, and drawn out to form a pronounced lineation. In the Carrizo Mountains the foliation generally strikes northeast and dips southeast, broadly parallel to the foliation of the sedimentary rocks; in the Sierra Diablo foothills the strike is east or even southeast, parallel to the trace of the Streeruwitz thrust. The lineation extends down the dip, mostly southeastward in the Carrizo Mountains, but in more varied directions in the Sierra Diable foothills. In places, thin layers of schist or phyllite are intercalated in the more massive rhyolite; microscopic study indicates that these also are of cataclastic origin, as they contain broken remnants of microcline phenocrysts. However, much of the potassium feldspar in the schist and phyllite has been crushed and converted to sericite as a result of intense shearing. The cataclastic metamorphism is strongest in the northwestern bodies of metarhyolite and weakest in the southeastern, where layering is not conspicuous and lineation and schistose layers are not common.

In the Sierra Diablo foothills, and to a lesser extent in the northwestern part of the Carrizo Mountains, part of the metarhyolite has been converted to a dense siliceous thinly laminated mylonite, in which the original phenocrysts are nearly destroyed. Ordinarily the mylonite is interlayered with less altered rhyolite in beds a few feet thick, which are most abundant close to the sole of the Streeruwitz thrust fault.

GREENSTONE

Both the metarhyolite and the sedimentary rocks of the Carrizo Mountain Formation are intruded by greenstone, mainly as sills which follow the foliation of the host rocks. A few of the sills in the southeastern Carrizo Mountains are as much as 1,800 feet thick; but the rest are thinner, and many are only a few feet thick. However, even the thicker sills contain numerous septa of the rhyolitic or sedimentary host rocks. The greenstone occurs throughout the exposures of both the Carrizo Mountain Formation and the metarhyolite, in the Carrizo Mountains and the Sierra Diablo foothills, but only the thicker sills are large enough to be shown on the map (pl. 1).

The greenstone is a fine- to coarse-grained green to black rock, now largely an amphibolite but probably originally a diorite. The centers of the larger sills are hypidiomorphic hornblende diorite, but the walls were largely changed to amphibolite during shearing and retrogressive metamorphism. Andesine was converted to albite or oligoclase, and the epidote and prismatic hornblende grains were reduced to felty masses of acicular or fibrous hornblende. The thinner sills are thoroughly schistose, with schistosity parallel to that of the adjacent metarhyolite and the sedimentary rocks. Some of the greenstone also contains a lineation which is parallel to that of the enclosing metarhyolite.

VEINS

The Carrizo Mountain Formation, the metarhyolite, and the greenstone all contain vein material, generally in narrow stringers and irregular blebs a few inches thick, but partly in larger bodies. Some veins also occur in altered limestone of the Allamoore Formation, close to the Streeruwitz thrust, and the overriding metarhylite and greenstone.

The veins are largely milky or vitreous quartz, but they also contain small amounts of pink feldspar, muscovite, specular hematite, and other minerals. In the Carrizo Mountains they contain some tourmaline, as well as iron and copper sulfides.

Structural relations of the veins are complex, and they probably formed at various times late in the igneous and tectonic history of the enclosing rocks. Many veins follow the foliation of the rocks or spread through them irregularly; some are slickensided parallel to the prevailing lineation. Other veins lie on joints that cross the foliation, and some cement the brecciated metarhyolite. The younger cross joints break and offset the veins; they contain no minerals, except scant coatings of specular hematite or chlorite.

ALLAMOORE FORMATION

The Allamoore Formation crops out mainly well south of the Sierra Diablo scarp near Eagle Flat, in a belt about 5 miles wide that trends west-northwest (pl. 1). It projects in low barren subparallel ridges.

The most prominently exposed parts of the Allamoore are its limestone units, but these are interlayered with great masses of volcanic rocks, including flows, pyroclastic rocks, and perhaps shallow intrusives. Thin units of argillaceous rocks, now altered to phyllite, are also interbedded.

As the Allamoore is exposed mainly to the south where deformation of the Precambrian rocks is greatest, the formation is mostly tilted at high angles and is complexly folded and faulted (sections *K–K′*, *O–O′*, and *P–P′*, pl. 16). Determination of the stratigraphic sequence is therefore difficult, and an estimate of its total thickness is almost impossible. On Tumbledown Mountain (sec. 27, Block 66, Twp. 7), where relations are unusually plain, about 1,630 feet of the formation is exposed with neither the top nor base preserved; the sequence is at least partly duplicated by thrust faults (King, P. B., and Flawn, P. T., 1953, table 17, p. 80) (upper view, pl. 2). Any traverse across the strike of the formation crosses a wide expanse of steeply dipping beds that can hardly have been produced by repetition of a few thin layers, so that the formation is probably as much as several thousand feet thick.

LIMESTONE

Limestone beds of the Allamoore Formation stand in jagged ledges and ridges. They are characteristically seamed by bands of chert a quarter to half an inch thick, parallel to the bedding and spaced at intervals of a few inches. Differential weathering of chert and limestone imparts a ribbed appearance to the ledges. The chert may be a primary or diagenetic feature; at least it antedates the Precambrian orogeny because the chert seams are sliced and broken where the rocks are strongly deformed, whereas the less brittle intervening limestone is deformed by flowage.

The limestone itself, where least altered, is mainly thin bedded and compact, with some more granular or more crystalline layers. Most of the limestone is blue, gray, or brown, but some is reddish or purplish. Some limestone beds are very thinly and evenly laminated by light and dark seams; others as much as 8 feet thick are massive and contain no chert. At a few places the limestone is interbedded with intraformational limestone-pebble conglomerate.

A specimen of dark gray fine-grained little-altered limestone of the Allamoore Formation from Tumbledown Mountain was analyzed by K. J. Murata in the chemical laboratory of the U.S. Geological Survey (written commun., 1937), and yielded 83.82 percent $CaCO_3$ and 9.32 percent $MgCO_3$; it also contained 0.05 percent of organic insolubles, which are apparently like the bituminous material which darkens the Paleozoic limestones of the region. Another specimen reported by Richardson (1904, p. 25) is more dolomitic, with a higher magnesian content. According to Flawn (written commun., 1959), inclusions of carbonate rock in the talc-bearing phyllite layers are also dolomitic.

The organic matter in the limestone beds of the Allamoore Formation seems to prove existence of life during formation of these ancient rocks, yet searches for fossils that have so far been made reveal nothing but possible algal remains. Many of the chert-banded or laminated limestone beds have a crinkled wavy or domelike structure similar to the *Cryptozoon* or stromatoporiod growths in the earlier Paleozoic rocks; in places these structures project into the beds above as low mounds or reefs. Other beds resemble the mottled limestones of the earlier Paleozoic, which were perhaps formed by organic growth.

VOLCANIC ROCKS

Volcanic rocks probably make up a quarter to a half of the total volume of the Allamoore Formation, but they are less conspicuous than the limestone beds and are generally worn down to soil-covered slopes, sags, and valleys. Their best exposures are in creek banks and prospect holes. In a few places more massive parts of the volcanic rocks project in rugged black hills. The volcanic rocks are interbedded with the limestone in units a few feet to hundreds of feet thick, and in places they contain thin limestone beds.

Some of the volcanic rocks are very massive and weather to brown or black bouldery surfaces; where fresh, these surfaces are dark green or red. Diabasic structure is prominent in some of the volcanic rocks, and in others amygdules are abundant. Most of the dark massive volcanic rocks were probably spread out as subaerial or subaqueous lava flows, but little remains of primary flow structure, except the rather common amygdules. Some of the thicker more massive bodies may have been shallow sill-like intrusives.

Some of the less massive volcanic rocks are of pyroclastic or sedimentary origin, for they contain detrital fragments of igneous rocks and are well stratified. Coarser varieties include dark red, brown, or green sandstone with seams of volcanic pebbles and interbedded layers of volcanic conglomerate. Finer grained beds include brown or green siliceous shales, thinly laminated pink siliceous rock, and light-green schistose laminated rock, all probably derived from different sorts of tuffs. Interbedded with the volcanic sediments are thin beds of reddish limestone that contain igneous fragments.

PHYLLITE

Phyllite is almost as widely distributed as the limestone and volcanic rocks in the Allamoore Formation, but it has a smaller volume and generally forms units less than a hundred feet thick. These units are grouped with the limestone on the geologic map (pl. 1). Like the volcanic rocks, the phyllite is poorly resistant to erosion and is commonly worn down to low ground between the limestone ledges. In many places the phyllite and volcanic rocks are interbedded, and a single interval between limestone units may consist of phyllite at one place, of volcanics at another, and of both rocks at others. The phyllite beds were originally shale units in the Allamoore Formation; their rather intimate association with the volcanic units suggests that they may in part have had a volcanic source.

The original argillaceous constitutents of the phyllite have been thoroughly altered to foliated, sericitic, or talcose minerals. Most of the rock is gray to dark gray; but parts are black and apparently graphitic, and others are calcareous. Bedding is indicated by alteration of the gray, black, and calcareous varieties, in part in thin laminae, in part in layers several inches thick. Bedding is intensely contorted and is crossed by strongly marked slaty cleavage nearly parallel to the axial planes of the folds. The rock weathers white or ashen and splits into flakes, plates, or papery sheets parallel to the cleavage.

Since 1952 talc has been mined from the phyllite units of the Allamoore Formation at various places in the southern Millican Hills, Bean Hills, and Streeruwitz Hills, and these units have been extensively prospected elsewhere (Flawn, 1958). The amount of talc in the phyllite beds varies from place to place. The mineral may have formed from an original fine-grained magnesium-bearing tuff. Carbonate rocks adjacent to the phyllite beds contain little magnesium, and are mainly limestone rather than dolomite, but dolomite forms inclusions in the talc bodies. Large masses of pure ceramic-grade foliated to fibrous talc as much as 150 feet thick occur in places, but in others the talc bodies contain layers or irregular masses of chert and carbonate rock.

ROCK ALTERATION

Most of the rocks of the Allamoore Formation have been more or less changed from their original character, perhaps mainly by the deformation to which they have been subjected, but probably with the aid of hydrothermal solutions. Alteration is least toward the north, as on Tumbledown Mountain, and increases southward to a maximum near outcrops of the metarhyolite that forms the overriding Streeruwitz thrust sheet.

The limestone beds are variously altered. The most striking alteration is by marmorization, which occurs in small erratically placed areas, perhaps related to intense flowage, squeezing, or hydrothermal activity. The limestone is recrystallized to marble, mostly white, but with reddish and bluish streaks that may be inherited from original bedding. Where the limestone was originally impure or shaly, it has been made schistose, and original bedding laminae are thrown into tight isoclinal folds.

In a wide band just north of the trace of the Streeruwitz thrust, the limestone of the Allamoore Formation has been extensively silicified to jasperoid. The jasperoid has lost all traces of bedding and other structures of the original limestone and is traversed by many quartz veinlets. Its weathered surfaces are brown and felty and are recessed like other carbonate-bearing rocks around quartz veins and siliceous knots. Nevertheless, the jasperoid probably now contains little carbonate, as it breaks with conchoidal fracture into dark-gray steel-hard chips.

Where cherty limestone beds have been sheared, the chert layers are sliced, offset, and broken along innumerable planes of fracture cleavage, and the intervening less brittle limestone has flowed around the chert. Where most sheared, the rocks have become a rubble of angular chert fragments, set in a carbonate matrix.

The more massive diabasic volcanic rocks may have been much changed mineralogically, but this is little apparent to the eye and even the amygdules are little compressed. By contrast, the fine-grained tuffaceous volcanics and the phyllite units are highly contorted and are thoroughly schistose.

STRATIGRAPHIC RELATIONS

The base of the Allamoore Formation is not exposed. It is in contact on the south with possibly older metarhyolite; but this rock has been emplaced along the Streeruwitz thrust fault, so that it now overlies rather than underlies the Allamoore. Farther southeast in the Carrizo Mountains, the metarhyolite intrudes the thick sedimentary sequence of the Carrizo Mountain Formation. Relations of these sedimentary rocks to those of the Allamoore Formation have not been determined; the Carrizo Mountain may represent a downward continuation of the Allamoore, or the two might be far apart in age.

The Allamoore Formation is also in contact with the Hazel Formation. From structural relations alone it is not possible to determine the original nature of their succession, as either formation overlies the other, depending on locality. However, the conglomerate of the Hazel consists largely of fragments of limestone and volcanic rocks derived from erosion of the Allamoore Formation, which indicates clearly that the Hazel is younger.

The conglomerate beds show that the Hazel lies unconformably on the Allamoore, and the great thickness and the coarse and angular fragments of the conglomerates suggest that the Allamoore epoch was closed by an orogeny that probably continued into early Hazel time. Moreover, some of the limestone fragments in the conglomerate beds are marmorized in the same manner as parts of the limestone still in place in the Allamoore.

The nature of the deformation caused by the pre-Hazel orogeny is obscure, as most of the structure now visible in the Allamoore is shared by the adjacent Hazel and formed during a later, post-Hazel, orogeny. The contact between the two formations is strongly discordant in most places; but it is generally sheared and faulted along a "surface of movement" (pl. 1), so that it is difficult to determine their original angular divergence, or the irregularity of the surface on which the conglomerate was deposited.

HAZEL FORMATION

The Hazel Formation crops out in many parts of the deformed area in the southern part of the Sierra Diablo foothills where its rocks are intimately infolded with the Allamoore formation (pl. 1). Unlike the Allamoore, the Hazel is also exposed much farther north in areas that were less deformed. It crops out around the south and east sides of the scarps of the Sierra Diablo where it extends to within a few miles of Victorio Peak (upper view, pl. 10); it also forms a large inlier in the interior of the range near Sheep Peak.

The Hazel Formation includes red sandstone which characterizes the upper and northern part, and conglomerate, which characterizes the lower and southern part. The two rocks are intimately interbedded. Adjacent to the Allamoore Formation are thick massive layers of conglomerate; but farther from it and higher in the sequence conglomerate beds are thinner and more sandy and are separated by increasingly thicker beds of red sandstone, which finally dominate altogether. The conglomerate may wedge out northward in the sandstone, away from the uplifted masses of Allamoore formation from which it was derived; but this is difficult to prove because of the complex structure.

The Hazel is a very thick formation, but estimates of thickness are incomplete. North of the Allamoore formation in the central Streeruwitz Hills is a continuous steeply dipping succession which appears to be at least 5,000 feet thick; of this, more than half is conglomerate. On the eastern scarps of the Sierra Diablo near the Pecos mine there is more than 2,250 feet of gently dipping sandstone.

CONGLOMERATE

The conglomerate of the Hazel Formation is one of the more resistant rock units of the Precambrian succession, and in places forms ridges as high as, or higher than, those of the limestone of the Allamoore Formation. In the southern belts of outcrop in the Streeruwitz and Millican Hills, these ridges are covered by deep-brown or black-surfaced craggy ledges. Farther north the conglomerate is less consolidated and makes fewer ledges, although it forms high hills.

The conglomerate is formed almost entirely of fragments derived from the Allamoore Formation and especially of its limestone. All varieties occur in the fragments, including chert-seamed, laminated, carbonaceous, and marmorized limestone. There are also scattered cobbles of bright red jaspery limestone or chert. Fragments of the volcanic rocks are common as well, including massive diabasic or amygdaloidal lava and coarse to fine pyroclastic rocks. The finer pyroclastic rocks in some of the fragments seem to have been rendered schistose before they were incorporated in the conglomerate.

In a few places the conglomerate also contains cobbles or boulders of red granite and coarse rhyolite porphyry. They are especially abundant between Carrizo Spring and Tumbledown Mountain in the eastern Millican Hills, but a few were observed in the northwestern Streeruwitz Hills. The granite and porphyry are unlike the igneous rocks that intrude the Carrizo Mountain Formation, but they closely resemble those in boulders in the succeeding Van Horn Sandstone. Like those in the Van Horn, they resemble Precambrian granite and porphyry exposed some distance northwest of the Sierra Diablo region. The known distribution of boulders in the Hazel does not suggest a northwestern source, and they may have been derived from other areas, as yet unknown, where they are now concealed by younger strata.

Fragments in the conglomerate are of all sizes, from small pebbles to large blocks, mainly limestone, and 6 feet or more across. The large blocks are most abundant in the lower part, near the contact with the Allamoore Formation, yet they are surprisingly common at hundreds or even thousands of feet above the base. The fragments are generally poorly rounded and many are angular, thus differing from those in the overlying Van Horn Sandstone; their angularity provides a means of distinguishing the Hazel fragments from those of the Van Horn.

The matrix of the conglomerate varies. In the lower and southern conglomerate beds, which are most resistant to erosion, it may originally have been calcareous, but generally it has been silicified and impregnated by iron on weathered surfaces. In the higher and more northern conglomerate beds the matrix includes more sand and arkose, so that the rock is softer and less coherent.

Most of the fragments lie helter-skelter in the conglomerate, pieces of all sizes, shapes, and compositions being mingled without sorting. Little or no grain gradation is visible from base to top of a single layer and in the more massive phases bedding itself is obscure. In the higher conglomerate beds are scattered gritty seams or lenses and thin interbedded layers of red sandstone. However, rocks transitional from conglomerate to sandstone are of small volume. No coarse sandstone or pebbly sandstone of any thickness occurs near the conglomerate beds, and many of the coarse conglomerate beds are inserted abruptly between red sandstone that is as fine and silty as that elsewhere in the area.

The thickness of the conglomeratic part of the Hazel Formation varies from place to place along the outcrop, but it is uncertain whether the variation results from original differences in amount of conglomerate deposited or from structural complication. In the central Streeruwitz Hills, next to the southern outcrops of the Allamoore Formation, conglomerate beds are as much as 3,000 feet thick, of which the lower half is solid conglomerate and the upper half is interbedded conglomerate and sandstone. Conglomerate with a similar structure in the southern Millican Hills is about 2,000 feet thick.

Near other belts of the Allamoore Formation farther north, conglomerate beds of the Hazel Formation are more varied and in places much thinner. Here, the conglomerate may have been partly removed along the "surface of movement" between the two formations, but at least a part of the variation is original.

RED SANDSTONE

Red sandstone forms the most conspicuous and extensive outcrops of the Hazel Formation. It crops out on smoothly rounded red slopes, only lightly masked by vegetation, which extend to considerable heights on the scarps south and east of the Sierra Diablo, surmounted by light-gray cliffs of the Hueco Limestone. At the bases of the scarps the slopes flatten into broad pediments, capped in many places by Quaternary gravels but mostly carved into an intricate network of hills and valleys, such as those between Beach Mountain and the Hazel mine. The hills, which are domelike, have rounded crests that descend steeply toward the incising streams.

The red color of the sandstone is universal, varying from brick red in the northern exposures to a darker maroon red farther south. Most of the sandstone is very fine grained, verging on, or grading into, siltstone. It coarsens somewhat southward where it varies more in texture from bed to bed; here, some of the coarser layers form long strike ridges. Part of the sandstone is poorly consolidated, but most is fairly hard and well cemented and has a conchoidal fracture.

Bedding of the sandstone is indicated in most places by thin closely spaced dark laminae. Much of it is crossbedded on a small scale, and in places it is ripple marked on bedding surfaces. The sandstone generally does not split along bedding planes, as these are thoroughly welded together; instead, it breaks into angular blocks along innumerable vertical or inclined joints, so that in many places the bedding can be determined only by close scrutiny.

The thickness of the red sandstone has not been determined, but it is as much as thousands of feet. On the east-facing escarpment of the Sierra Diablo from the Pecos mine northward, south-dipping lines of bedding are visible on the red sandstone slopes below the cliffs of Hueco Limestone and indicate that more than 2,250 feet is exposed (section *P–P′*, pl. 16).

ROCK ALTERATION

The Hazel Formation is less altered than the Allamoore Formation, partly because most of it lies farther from the belt of strong deformation, and partly because its sandstone and conglomerate beds are more competent than the Allamoore.

In the strongly deformed belt toward the south, the conglomerate has been sliced in many places along a multitude of closely spaced shear or cleavage planes. These planes cut through both the matrix and the fragments, but most of the fragments are not flattened.

The sandstone is little altered and pressures were evidently dispersed along innumerable clean-cut vertical or inclined joints. The sandstone was not sheared or squeezed in the strongly deformed areas, but was sliced and offset by many minor thrust faults. The thrusts are especially abundant in the outcrop of sandstone in the Millican Hills that extends east from the Garren Ranch, where they are marked by slickensided surfaces, many of which are coated with a black highly polished substance a few millimeters thick that also extends in ramifying stringers through the rock. According to Charles Milton (written commun., 1951), the substance is a fine-grained aggregate of crystalline tourmaline and hematite dust.

Near some of the large high-angle faults north of the Millican Hills the sandstone has been mashed and reconstituted, so that it loses its flinty conchoidal aspect, and is massive, soft, and earthy.

Near many faults, joints, and fractures in the northern area the sandstone is decolorized. The red rock is bleached to buff or yellow for several inches or feet away from the fractures. The bleaching is caused by reduction or removal of hematite by percolating solutions; it is best developed near prospective or productive veins, and it is considered to be a favorable indication of mineralization by local prospectors. Bleaching of the red sandstone was also observed beneath the unconformity at the base of the Hueco Limestone in buttes 3 miles south-southeast of the Old Circle Ranch (sec. 4 Block 67, Twp. 7); this bleaching either occurred during pre-Hueco erosion or during later circulation of ground water along the unconformity.

STRATIGRAPHIC RELATIONS

The Hazel Formation is overlain by varied strata of much younger age, including those of the Permian and Cretaceous systems, but the next younger formation with which it is in contact is the Van Horn Sandstone. Its relations are strongly unconformable, even with the Van Horn, and the times of formation of the Hazel and Van Horn deposits are separated by a major period of orogeny by which the Hazel and Allamoore Formations were strongly deformed and by a prolonged period of erosion during which they were deeply truncated. Emplacement of the Carrizo Mountain Formation and its intrusive rocks along the Streeruwitz thrust fault probably occurred during this orogeny, as the conglomerate of the Van Horn is the earliest deposit which contains fragments of lineated and mylonitized metarhyolite. The Van Horn Sandstone in the Sierra Diablo foothills lies on both the Hazel and Allamoore Formations; in the eastern Carrizo Mountains it lies on the Carrizo Moutain Formation.

VAN HORN SANDSTONE

The Van Horn Sandstone is preserved in relatively small areas in the Sierra Diablo region, the wide dispersal and isolation of its outcrops being caused by its unconformable relations with various formations that overlie it. The most extensive outcrops are in the Red Valley, northwest of the town of Van Horn and southwest of Beach Mountain, which Richardson (1904, p.

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28) designated as the type area (pl. 1). It is also exposed on the northwest corner of Beach Mountain south of the B-Bar Ranch, at several places in the Baylor Mountains, on the southeast corner of the Sierra Diablo between the Hazel and Pecos mines, on the south-facing scarp of the Sierra Diablo 4 to 7 miles west of the Old Circle Ranch, and in the eastern Carrizo Mountains south of the Texas and Pacific Railway.

The Van Horn is characteristically a coarse red arkosic sandstone in thick massive beds, mostly friable and poorly consolidated, crossbedded in many places, and containing scattered pebbles and cobbles. No fossils are known. The sandstone is interbedded with, and underlain by, thin to thick beds of conglomerate containing rounded pebbles, cobbles, and boulders made up not only of the older rocks of the immediate vicinity, but also of granite and rhyolite porphyry unlike any exposed in the Sierra Diablo region. The greatest thickness of the formation preserved at any one place is about 800 feet, but it is generally much thinner.

The red massive clastic rocks of the Van Horn form some of the most picturesque outcrops in the region (pl. 2). Its sandstone beds project in great rounded ledges, largely barren of vegetation, which rise on the faces of escarpments into picturesque towers, prows, and battlements. Tables, pedestals, and other fantastic erosion forms are common. The massive ledge-making beds are separated by others, less resistant to erosion and generally more conglomeratic, which form intervening shelves. Widely spaced joints, commonly set at right angles, are worn into creases or crevices that extend across the outcrops and are prominently visible from adjacent mountain tops or in air photographs. Stream channels cross the shelves in rounded swales, but descend from one ledge to the next in narrow slots that follow the prevailing joints, with many swirls and potholes.

CONGLOMERATE

The conglomerate beds of the Van Horn are a few feet to several hundred feet thick and are commonly thickest and coarsest at the base and thinner and finer grained higher up. Its basal conglomerate varies. On the Sierra Diablo scarp 4 miles west of the Old Circle Ranch, the conglomerate is more than 300 feet thick, but it thins both eastward and westward; eastward up the dip it apparently thins against a buried hill of the Allamoore Formation. In other places, as near the Yates Ranch, basal conglomerate is not well defined, and conglomerate beds and dispersed pebbles are common throughout the sequence.

Fragments in the conglomerate are pebbles, cobbles, and boulders, those in the basal beds 4 miles west of the Old Circle Ranch being as much as 3 feet in diameter. Most are smoothly rounded and some have almost polished surfaces; a few of obvious local derivation are somewhat less rounded. Many fragments have been shattered, sheared, and offset by deformation, but some were afterwards recemented. The fragments are set in an arkosic sandy matrix, somewhat less consolidated than that of the adjacent sandstone beds; in places the fragments are closely packed, but in others they are widely dispersed in the matrix. Weathering of the poorly consolidated matrix sets free vast quantities of the rounded fragments, which strew the outcrops of the formation.

The fragments in the conglomerate were derived from many older rocks, but the dominant fragments, especially in the northern and northwestern exposures, are red granite and red rhyolite porphyry. These differ greatly from any igneous rocks exposed in place in the Sierra Diablo region. They are unlike the metarhyolite intruded in the Carrizo Mountain Formation; moreover, fragments clearly derived from the metarhyolite also occur in the Van Horn. The porphyry and granite fragments resemble most the Precambrian igneous rocks exposed some distance to the northwest, as the red rhyolite porphyry of the Pump Station Hills (King, P. B., and Flawn, P. T., 1953, p. 123–124; Masson, 1956) and the coarse red granite at the south end of the Hueco Mountains (King, P. B., King, R. E., and Knight, J. B., 1945, sheet 1).

Metarhyolite derived from intrusives in the Carrizo Mountain Formation is a significant but not a dominant constituent. The fragments have the same lineation and cataclastic structure as the rocks of the parent ledges. The metarhyolite occurs in nearly every outcrop of the formation, but is perhaps most abundant toward the south.

Other fragments are fine- to coarse-grained mafic igneous rocks, probably derived from the volcanic rocks and the greenstone intrusives of the Allamoore and Carrizo Mountain Formations; limestone, chert, and jasper from the Allamoore Formation; red sandstone from the Hazel Formation; and vein quartz.

SANDSTONE

The sandstone beds of the Van Horn are dominantly red, but they are generally slightly darker than those of the Hazel, being mostly maroon red or purplish red. The strong colors die out upward, and the highest beds of the formation, where preserved, are orange red or red brown. The sandstone which is coarse, has grains as much as a millimeter in diameter and scattered larger grits and small pebbles; it contrasts with the fine silty red sandstone of the Hazel. Quartz and feldspar grains occur in about equal proportions; much mica is found at some localities. In most of the rock, beds are 3–10 feet thick, but some are thicker. Within many layers are well-marked crossbeds. Most of these slope southward; the others slopes southeastward or southwestward but nowhere northward (King, P. B., and Flawn, P. T., 1953, p. 93, fig. 8). These dips are maintained even where the enclosing strata are inclined in an opposite direction.

In the higher parts of the formation are some interbedded layers of buff or brown sandstone a foot or two thick, which are more cleanly washed than the rest and contain more quartz than feldspar. On the south-facing scarp of the Sierra Diablo west of the Old Circle Ranch, one of these layers near the middle of the formation extends more than 2 miles. Similar layers are common south of Threemile Mountain, east of Hillside siding. Near a tank at the summit of the Sierra Diablo escarpment 7 miles west of the Old Circle Ranch (sec. 29, Block 52½), the massive arkosic sandstone is interbedded with 5-foot layers of soft flaggy sandstone and greenish clay shale, which are nearly unconsolidated and contain possible fucoidal markings.

SECTIONS OF VAN HORN SANDSTONE

The greatest thickness of Van Horn Sandstone in the region is on the south-facing escarpment of the Sierra Diablo 4 miles west of the Old Circle Ranch (sec. 2, Block 56), where 759 feet was measured, of which the lower 335 feet is conglomerate (King, P. B., and Flawn, P. T., 1953, p. 94, table 19). Here, the Van Horn lies unconformably on the Allamoore Formation and is overlain unconformably by the Hueco Limestone, so that its original thickness is no longer preserved.

At the northwest corner of Beach Mountain (sec. 19, Block 66, Twp. 7) 300 or 400 feet of Van Horn Sandstone is exposed on steep slopes below the cliffs of Bliss Sandstone and El Paso Limestone and above red sandstone of the Hazel Formation. The Bliss truncates the Van Horn, and 1 mile to the east only 75 feet of the latter remains.

On the west side of Beach Mountain three-quarters of a mile south of the Yates Ranch (sec. 4, Block 66, Twp. 8), about 325 feet of Van Horn is exposed between the Hazel Formation west of Hackberry Creek and the Bliss Sandstone on the face of the mountain to the east. Farther south in the Red Valley the formation is probably thicker, as it crops out over wide areas and in places dips as steeply as 45°.

STRATIGRAPHIC RELATIONS

In most places the Van Horn Sandstone is overlain by the much younger Hueco Limestone of Permian age, but in a few places, as on Beach Mountain, it is overlain by the Bliss Sandstone of Ordovician age.

The Van Horn and Bliss were not differentiated by the earlier geologists (Dumble, 1902; Richardson, 1904, p. 28; 1914, p. 4), who interpreted the two units as gradational deposits; but they are actually distinct, and the contact between them can be located with confidence in all exposures. A marked change in sedimentation occurred between Van Horn and Bliss time—from coarse arkosic continental unfossiliferous deposits in the Van Horn to fine-grained cleanly washed quartzose marine fossiliferous deposits in the Bliss.

The Bliss lies unconformably on the Van Horn and in nearly all exposures it truncates the tilted beds of the underlying formation at a low angle. The sandstone of the Van Horn for a few feet below the base of the Bliss is commonly bleached from red to yellow by either pre-Bliss weathering or later circulation of ground water along the contact.

The unconformity between the Bliss and Van Horn is well shown on the north face of Beach Mountain east of its northwest corner (sec. 19, Block 66, Twp. 7) where the angular divergence between their beds is 20°, causing more than 200 feet of the Van Horn to be removed within a mile along the scarp. The unconformity is also well marked on Tumbledown Mountain (sec. 27, Block 66, Twp. 7) where the Van Horn is dropped against the Allamoore Formation along two faults, the Dallas and Grapevine, on which there was movement between Van Horn and Bliss time. The faulted terrane is truncated by the Bliss Sandstone, which lies on the Van Horn on the downthrown sides and on the Allamoore on the upthrown sides in the angle between the two faults. The Dallas fault has not moved since Bliss time, but the Grapevine fault was displaced in the same direction later.

AGE

Dumble (1902, p. 1–3) and Richardson (1914, p. 4) interpreted the Van Horn as being of "Potsdam" or "Upper Cambrian(?)" age, a conclusion based partly on the marked unconformity between it and the underlying Hazel and Allamoore Formations and on the occurrence of *Scolithus*, or worm tubes, in its upper part. With the discovery that this upper part was equivalent to the Bliss Sandstone and was separated by a marked unconformity from the lower part, a Cambrian age for the Van Horn became less plausible. Moreover, the Van Horn has little resemblance to rocks of known Cambrian age elsewhere. It is therefore now classed as of Precambrian(?) age.

Arguments favoring a later age for the Van Horn are relatively insubstantial. The sandstone lies with marked unconformity on the older formations as a result of a time of orogeny and deep erosion, but these events need not necessarily mark the end of Precambrian time. It is poorly consolidated, but so also is the still earlier Hazel Formation in regions of slight deformation. It is the next formation below the fossiliferous Bliss, but the unconformity between them indicates that there was a hiatus of unknown duration between Van Horn and Ordovician time.

Arguments favoring an earlier age are stronger. The unconformity between the Van Horn and Bliss involved tilting, faulting, erosion, and changes in sedimentation. The Van Horn is unfossiliferous. It was laid down in a continental environment in a region of considerable relief, unlike any nearby Cambrian deposits. Its deposits are much more like those of the Hazel than those of the Paleozoic, and they seem to imply a repetition of some of the conditions under which the earlier formation was deposited, after an intervening period of orogeny.

ORDOVICIAN

BLISS SANDSTONE

The Bliss Sandstone was named for Fort Bliss, northeast of El Paso, Tex., its typical exposures being in the southern part of the Franklin Mountains immediately adjacent (Richardson, 1904, p. 27; 1909, p. 3). In the Sierra Diablo region the sandstone here termed the Bliss was at first grouped with the Van Horn Sandstone (Richardson, 1904, p. 38; 1914, p. 4) or with the El Paso Limestone (Sellards, 1932, p. 153–156), and was only differentiated later (King, P. B., 1940, p. 153–156). Its designation as Bliss has been queried in some reports because of uncertainty of correlation with the type Bliss, but present knowledge now permits this correlation to be made with greater assurance.

DISTRIBUTION

The Bliss Sandstone crops out only in small areas in the Sierra Diablo region (pl. 1); elsewhere, it is concealed beneath younger Paleozoic formations or removed by pre-Hueco erosion. The most extensive exposures are on the north, west, and southwest sides of Beach Mountain (pl. 2), where it forms a brown band on the escarpment, consisting of slopes and thin ledges between the red Van Horn Sandstone below and the gray and buff sandstone and limestone ledges of the El Paso above. The Bliss reappears in small areas in the Baylor Mountains to the north, especially in the southern part (geologic section 5), and in hills near Hawkins Tank in the northwestern part (geologic section 8).

THICKNESS

In Beach Mountain the Bliss Sandstone maintains a nearly uniform thickness of 105 to 125 feet (geologic sections 1–4, pl. 3, and p. 123–127 [2]), but it thickens in the Baylor Mountains from 145 feet in the south (geologic section 5) to 160 feet in the northwest (geologic section 8), most of the thickening being caused by wedging in of a calcareous division at the top.

MAIN BODY OF FORMATION

The Bliss is characteristically a white or light-brown quartzose sandstone, forming beds a few inches to a foot thick. According to Cloud and Barnes (1946, p. 67), most of the layers are perceptibly calcareous; but in the field this is apparent only in the upper division, the main body of the formation appearing to be much more quartzitic than the sandstone beds of the overlying El Paso. Most of the sandstone beds in the Bliss are laminated, crossbedded, and ripple marked, and many of them, especially in the upper part, contain vertical worm tubes, or *Scolithus*. Some of the bedding surfaces are marked by obscure fucoidal structures. Between the sandstone beds the partings of softer, more marly sandstone, which are gray, brown, purple or green. According to C. S. Ross (written commun., 1940), the green coloration is caused by an unidentified iron-bearing clay mineral and not by glauconite.

The basal few feet of beds of the Bliss, lying unconformably on the Van Horn Sandstone, is a conglomerate of rounded pebbles less than 1 inch to as much as 3 inches in diameter, mostly of vein quartz but with some of chert, quartzite, and schist. In places, pebbly layers are interbedded as high as 60 feet above the base. Some of the matrix of the basal sandstone is red, from detritus reworked from the Van Horn Sandstone.

CALCAREOUS DIVISION

On the north side of Beach Mountain, Cloud and Barnes (1946, p. 67) observed a 10-inch bed of dolomite near the middle of the Bliss. Sections measured by J. Brookes Knight and the writer in this vicinity and farther north indicate that the upper part of the Bliss differs somewhat from the main body and consists of fine-grained slightly calcareous or dolomitic yellowish-gray sandstone in beds a foot or so thick, with partings of marl and with ramifying mottlings on the bedding surfaces. This upper calcareous division of the Bliss is 20–28 feet thick on the north side of Beach Mountain (geologic section 4), but thickens to 43 feet in the southern Baylor Mountains (geologic section 5) and to 52 feet farther northwest (geologic section 8). Its sandstone beds lack *Scolithus* tubes, and no other fossils are

[2] Stratigraphic sections of rocks of Ordovician to Cretaceous age which have been measured during the present investigation are described at the end of this report and are illustrated graphically on plates 3, 5–9.

recorded. In the southern Baylor Mountains the top layer of the division is a crossbedded sandstone.

The sandstone beds of the calcareous division have some features like those of the basal sandy part of the El Paso Limestone, yet they appear to be distinct and to be more closely allied to the main body of the Bliss. Occurrence of thin dolomite beds in the typical Bliss on the north side of Beach Mountain suggests that the calcareous division fades out into the main body of the formation southward. Nevertheless, the northward thickening of the division, and with it the formation as a whole, suggests that in this direction beds younger than any on Beach Mountain may wedge in beneath the disconformity at the base of the El Paso Limestone.

STRATIGRAPHIC RELATIONS

The Bliss appears to be disconformable beneath the El Paso Limestone. On Beach Mountain the contact between them is sharply marked, and the poorly calcareous quartzose sandstone beds of the Bliss are succeeded abruptly by the calcareous sandstone and limestone beds of the El Paso. In the Baylor Mountains, where the calcareous division of the Bliss intervenes, the contrast between the two formations appears to be equally striking. Moreover, as observed by Cloud and Barnes (1946, p. 68), "commonly as much as 10 inches of the basal El Paso is a calcareous reworked sand, and locally it contains pebbles and cobbles of quartz and sandstone." However, the hiatus between the two formations is slight, as both are of Early Ordovician age; the Bliss is approximately equivalent to the Tanyard Formation, the basal El Paso to the next younger Gorman Formation of the sequence in the Ellenburger Group of central Texas.

FOSSILS AND AGE

The most abundant indication of life in the Bliss is the trace fossil *Scolithus*, probably the tube of a burrowing worm, which occurs in every outcrop of the main body of the formation, most abundantly in the upper part but at some localities to within a few feet of the base. The *Scolithus* of the Bliss is of the type with undulating vertical tubes, termed "*Sabellarifex*" by R. Richter (Cloud and Barnes, 1946, p. 67). Although *Scolithus* was cited by Walcott as evidence for the Cambrian (Potsdam) age of the beds containing it (Dumble, 1902), the fossil ranges widely through lower Paleozoic strata, from Lower Cambrian to Silurian, in deposits laid down near the shore, and has ecologic analogues in existing shoal water to intertidal sandflat environments (P. E. Cloud, Jr., written commun., 1954).

Many of the bedding surfaces of the sandstone, especially in the upper part of the main body of the Bliss, are marked by poorly preserved impressions of fossil shells, mainly gastropods and linguloid brachiopods. The most extensive fossil collections have been made on the west side of Beach Mountain, up the slope from the old Dallas mine (geologic section 3, unit 2). Here, 4–8 feet below the top of the formation, several collectors have obtained a fragment of the cephalopod *Clarkoceras*, various gastropods including *Lytospira*, *Ophileta*, and *Helicotoma*, the trilobite *Hystricurus*, and archaeostracan crustaceans. At a lower level, 27 feet below the top of the formation, the linguloid brachiopod *Lingulepis* has been collected in beds which also contain gastropod cross sections.

The higher fauna is clearly of Early Ordovician age, and according to Cloud and Barnes (1946, p. 68), is equivalent to that in the Tanyard Formation, or basal unit of the Ellenburger Group in central Texas. The *Lingulepis* at a lower level is generally considered to be an index fossil of the Upper Cambrian, but, as remarked by Cloud and Barnes (idem)—

> the abundance of gastropods in the Bliss Sandstone of the Beach Mountain sequence, below as well as above *Lingulepis*, is a feature unusual in Cambrian strata; and in view of the striking similarity of the various parts of this sandstone the authors are inclined to regard it as a single unit * * * of Lower Ordovician age throughout.

REGIONAL RELATIONS

The Bliss Sandstone forms the base of the Paleozoic sequence in the Hueco and Franklin Mountains, west of the Sierra Diablo in Trans-Pecos Texas, and throughout southern and southwestern New Mexico. Everywhere in this region the Bliss Sandstone maintains much the same character and thickness and is a single rock-stratigraphic unit, although, as indicated below, its stratigraphy is probably complex in detail.

The type Bliss of the Franklin Mountains was originally designated as Upper Cambrian by Walcott (in Richardson, 1909, p. 3) on the basis of *Lingulepis* and other linguloid brachiopods; but in the Sierra Diablo similar brachiopods are associated with gastropods of Ordovician aspect, and Cloud and Barnes (1946, p. 74) conclude that the Bliss of the Franklin Mountains should "be considered lowest Ordovician until diagnostic evidence is found." Flower (1958, p. 65) concurs with this conclusion.

However, in New Mexico to the north and west Flower (1953, p. 2055; 1958, p. 65–66) has found in the Bliss at various levels, from one place to another, fossils of Early Ordovician age and of late and middle Late Cambrian (Trempealeau and Franconia) ages, and he suggests the probable existence of corresponding lithologic subdivisions. Still farther west, in southeastern Arizona, the basal sandy deposit is the Bolsa

Quartzite of Middle Cambrian age. This quartzite is followed by the Abrigo Limestone of Middle and Late Cambrian age, although the Early Ordovician El Paso Limestone is also preserved locally.

The Bliss is thus "part of a homotaxic blanket of sediments which began to form in the eastward-expanding Sonoran seaway in southeastern Arizona during Middle Cambrian time," and which was not laid down farther east, in New Mexico and west Texas, until Late Cambrian and Early Ordovician time (Kelley and Silver, 1952, p. 55). This general concept requires modification in detail. The Bolsa and Bliss are probably distinct sand wedges (Epis, 1958, p. 2754–2756), and the Bliss itself may "represent a period of slow and evidently highly intermittent deposition of sandy material" whose base "may be as old as the middle of the Franconia, and its top may extend into the basal Ordovician" (Flower, 1953, p. 2055).

EL PASO LIMESTONE

The El Paso Limestone was named for exposures in the southern part of the Franklin Mountains near El Paso, Tex. (Richardson, 1904, p. 29), and was later restricted to the rocks of Early Ordovician age in that area, the Sierra Diablo, and elsewhere (Richardson, 1908, p. 476–479). Kirk (1934, p. 450) suggested a lithologic and faunal subdivision of the El Paso into well-defined lower and upper units, termed the "*Piloceras-Calathium* beds" and the "*Taffia* beds," and a rather indefinite intervening unit, characterized mainly by *Ceratopea*. These subdivisions were further refined by Cloud and Barnes (1946, p. 67, 74) and were informally designated units A, B, and C. This usage is retained here.

DISTRIBUTION AND THICKNESS

In the Sierra Diablo region the El Paso Limestone is most prominently exposed on Beach Mountain, of which it forms the main bulk (pl. 2). Farther south and west it has been removed by pre-Hueco erosion, but to the north it emerges from beneath younger formations in small areas around the edges of the Baylor Mountains (pl. 1). A few of its uppermost beds may be exposed much farther north, at the base of a fault block in the salient of the Sierra Diablo northwest of the Figure Two Ranch (geologic section 9). The El Paso is also exposed in the interior of the Sierra Diablo, where it forms an inlier north of Cox Mountain, about 7 miles long and 2 miles wide, whose rocks are cut off by the Cox Mountain fault on the south and overlapped by the Hueco Limestone on the north.

The only complete section of the El Paso Limestone in the Sierra Diablo region is on the north side of Beach Mountain (geologic section 4, pl. 3 and p. 124–127), where it lies on Bliss Sandstone, is overlain by Montoya Dolomite, and is 1,115 feet thick. Elsewhere in the region its sequences are not continuous, and only basal, middle, or upper parts are exposed.

DIVISION A

Division A, lying on the Bliss Sandstone, is exposed mainly in Beach Mountain, but it appears in some places in the Baylor Mountains and forms the base of the sequence in the inlier near Cox Mountain. On the north side of Beach Mountain (geological section 4) division A is about 250 feet thick. It is separately represented on the geologic map (pl. 1) and structure sections (pl. 16).

In Beach Mountain and elsewhere division A includes two or three sandstone units, which crop out in prominent rounded yellowish or buff ledges. Individual sandstone layers are 5–30 feet thick. The sandstone is medium to fine grained and consists of well-rounded quartz grains and some feldspar grains, mainly with a dolomitic cement. Many of the layers are crossbedded and some are glauconitic.

Between the sandstone layers are units of gray to yellow limestone, in part dolomitic, some of which are strongly mottled and cherty, between which are partings and layers of marl and siltstone. Many of the limestone layers are sandy, some are glauconitic, and most of them contain abundant gastropods, cephalopod siphuncles, and other fossils.

DIVISION B

Division B of the El Paso Limestone is 813 feet thick on the north side of Beach Mountain (geologic section 4). Throughout most of Beach Mountain and the Baylor Mountains the division is a monotonous sequence of gray, brownish-gray, or brown dolomite, in beds a few inches to 3 feet thick, which stand in prominent ledges and steep cliffs. The dolomite is mostly fine grained to microgranular, and contains closely to widely spaced chert nodules of various sizes, as well as less regular siliceous masses. In the lower 100 feet some argillaceous and dolomitic limestone is interbedded. Many of the dolomitic layers contain dispersed sand grains and on the north side of Beach Mountain 60 or 70 feet of dolomite near the middle is very sandy. Some dolomite beds at about the same level are perceptibly petroliferous. Most of the fossils in the division are poorly preserved but some are silicified, and large collections have been made in some layers. Especially abundant and characteristic of the upper half of the division are opercula of the gastropod genus *Ceratopea*.

At the inlier within the Sierra Diablo north of Cox Mountain, most of the El Paso Limestone that is exposed belongs to division B, although the upper sandstone beds of division A emerge toward the east. The lower 350 to 400 feet of division B, exposed near the two county roads 3 miles east-northeast of Cox Mountain (western part of sec. 14 and eastern part of sec. 15, Block 45½) is largely limestone rather than dolomite as farther southeast. The limestone forms beds a few thick, with some 4-foot ledges. Many beds are mottled gray and yellow, and contain ropy brown chert; but a few beds are gray, aphanitic, and abundantly fossiliferous. A few more dolomitic argillaceous layers are interbedded, some of which contain a green clay mineral, and there are several layers of intraformational conglomerate.

Higher beds of division B, exposed farther northwest near the Edwards Ranch and beyond, are drab-gray or brown finely crystalline dolomite, more like the bulk of the division in the Beach Mountain area.

DIVISION C

At the top of the El Paso are the poorly resistant strata of division C, which form light-colored slopes and thin ledges between the darker cliffs and ledges of division B below and the Montoya Dolomite above. Division C is largely marly, nodular, gray, yellow, or buff limestone and dolomite, with some thin layers of more compact dolomite. Some of the beds are slightly sandy; a few of the more marly ones are greenish, probably from the presence of an iron-bearing clay mineral. On the north side of Beach Mountain (geologic section 4) division C is 50 feet thick. About the same thickness of similar strata occurs beneath the beds of Middle(?) Ordovician age in the Baylor Mountains to the northeast.

STRATIGRAPHIC RELATIONS

In the Beach Mountain section the uppermost beds of the El Paso Limestone, or division C, are followed by the Montoya Dolomite. Fossil evidence indicates that the top of the El Paso is of late Early Ordovician age and the base of the Montoya of early Late Ordovician age, or a little older, so that the two formations are separated by a disconformity. As indicated below, in the southeastern part of the Baylor Mountains the El Paso Limestone is overlain by a small thickness of beds of Middle(?) Ordovician age. These beds are seemingly conformable with division C of the El Paso Limestone, and the disconformity at the base of the Montoya Dolomite must pass above them.

FOSSILS AND AGE

Fossils can be observed in the El Paso Limestone in most exposures. In many places they are poorly preserved, especially in the middle part, or division B, but identifiable material can ordinarily be obtained in a few layers. Extensive collections have been made by various geologists at numerous levels in the formation on the north side of Beach Mountain (geologic section 4) and in the inlier within the Sierra Diablo northeast of Cox Mountain (X-1 and X-2). Fossils identified from these and other collections, and those which were observed in the field, are noted at appropriate places in the stratigraphic sections and fossil lists (p. 124–131, 133).

The sequence of fossils as observed on Beach Mountain and elsewhere is capable of zonation and indicates that the El Paso Limestone represents a wide span of Early Ordovician time. Cloud and Barnes (1946, p. 57–71) have compared the zones of the Sierra Diablo region with those in formations of the Ellenburger Group in central Texas and in formations of the Ozark uplift in Missouri, although they indicate that there is some uncertainty as to their precise equivalents.

The 250 feet of beds of division A is abundantly fossiliferous, except for the lower 70 feet of the Beach Mountain section. The division contains the cephalopods *Piloceras*, *Allopiloceras*, and *Kirkoceras*? (mostly represented only by siphuncles), various gastropods including *Ophileta*, *Hormotoma*, and *Lecanospira* and the brachiopods *Diaphelasma* and *Syntrophina*. These fossils indicate that the division is broadly equivalent to the Gorman Formation of central Texas and the Roubidoux Formation of Missouri.

The 800 feet or more of beds of division B contains more varied faunas, and has been divided on this basis by Cloud and Barnes into subunits B 1 and B 2.

Subunit B 1 (units 10–12, geologic section 4, and all the collections of X-1 and X-2) is broadly equivalent to the Honeycut Formation, or highest unit of the Ellenburger Group of central Texas, and to the Jefferson City Formation of Missouri. It is divisible into three zones (P. E. Cloud, Jr., written commun., 1954). A lower zone is characterized by the gastropods *Orospira* and *Barnesella*, the brachiopod *Xenelasma*, and the trilobite *Jeffersonia*. A somewhat higher zone contains the brachiopod *Archaeorthis* and *Jeffersonia*. A still higher zone contains a probable new species of *Heliocotoma?*. In addition, many beds in subunit B 1 contain the sponge *Calathium*.

Subunit B2 (units 2–9, geologic section 4) is probably younger than either the Honeycut or Jefferson City Formations of central Texas and Missouri, but older than the Black Rock Formation of Arkansas. It is characterized especially by opercula of the gastropod *Ceratopea* (Yochelson and Bridge, 1957, p. 293), which permit division into two main zones. The lower zone is characterized by a variety of *C. tennesseensis* Oder and by *C. keithi* Ulrich. A higher zone contains *C.* aff. *ankylosa* Cullison and *Lophonema*?.

Division C on the north side of Beach Mountain (unit 1, geologic section 4) contains a small *Maclurites*, other poorly preserved gastropods, the cephalopod *Buttsoceras*, and unidentified sponges. Cloud and Barnes state (1946, p. 352)—

Small *Maclurites* is common in high Lower Ordovician strata at other localities and *Buttsoceras* is known only from the Odenville Limestone of Alabama, so it is reasonably probable that unit C * * * is approximately equivalent to the Odenville Limestone of Alabama and correlative with some part of the Black Rock Formation of Arkansas * * *.

REGIONAL RELATIONS

The El Paso Limestone is exposed in the Hueco and Franklin Mountains west of the Sierra Diablo in Trans-Pecos Texas and also in many of the ranges of southern and southeastern New Mexico. In the Franklin Mountains (Kirk, 1934, p. 447–451; Cloud and Barnes, 1946, p. 72–75), where the formation is 1,590 feet thick, the same divisions as in the Sierra Diablo region are identiable; but the lower two differ much in lithology from their equivalents in the Sierra Diablo. Division A includes more dolomite than limestone, and its standstone layers are thinner and less conspicuous. Division B, on the contrary, is largely limestone, much of it gray and mottled, in contrast to its prevailing dolomite in the Beach and Baylor Mountains The northwestward transition in the division from dolomite to limestone apparently begins within the Sierra Diablo region itself, because limestone dominates the lower part in the inlier near Cox Mountain, and in the intervening Hueco Mountains the division is limestone like that in the Franklin Mountains. The increase in sandstone and dolomite in divisions A and B from the Franklin Mountains toward the Sierra Diablo may indicate an approach to a shoreline to the southeast, but the position of such a shore cannot be closely identified.

Farther north in the Caballo Mountains of New Mexico, the names Sierrite Limestone and Bat Cave Formation have been given to subdivisions of the El Paso (Kelley and Silver, 1952, p. 40–56). Detailed stratigraphic work by Flower (1958, p. 67–69) indicates that these subdivisions correspond broadly to divisions A and B of the Sierra Diablo and Franklin Mountains; but the El Paso is no more than 400 feet thick in the Caballo Mountains, and division C is missing at the top. Presumably the small thickness of the El Paso, and the absence of division C, is mainly due to truncation by the succeeding Montoya Dolomite. The Bat Cave, or upper unit of the Caballo Mountains, thickens southward toward the Franklin Mountains. The truncation has been verified by detailed stratigraphic studies by Howe (1959, p. 2289, 2292–2293), which demonstrate that the upper 245 feet of the El Paso at its type section in the Franklin Mountains is missing in the Organ Mountains 30 miles to the north.

Rocks of Early Ordovician age emerge again about 350 miles east of the Sierra Diablo, in the Llano uplift of central Texas, where they form the Ellenburger Group (Cloud and Barnes, 1946, p. 22–42). Drilling in the intervening West Texas basin indicates that rocks of this age are continuous beneath the surface, or nearly so, between central Texas and the Sierra Diablo (Galley, 1958, p. 401–406; Barnes and others, 1959, p. 25–42). As indicated by paleontologic data (see above), division A and the lower part of division B are broadly equivalent to the Gorman and Honeycut Formations of the Ellenburger Group. The Bliss Sandstone of the Sierra Diablo region is broadly equivalent to the basal formation of the group, the Tanyard, but apparently neither the upper part of division B nor division C of the El Paso Limestone is represented in central Texas.

BEDS OF MIDDLE(?) ORDOVICIAN AGE

In one area in the Sierra Diablo region, in the southeastern part of the Baylor Mountains, division C of the El Paso Limestone is overlain, apparently conformably, by strata of probable Middle Ordovician age. These strata were observed by the writer during his fieldwork, but are sketched only approximately on the geologic map (pl. 1); they have been studied further by C. C. Branson (written commun., 1950) and H. J. Howe (1959, p. 2289–2291), who have termed them the "Simpson (?) Formation.

The strata of Middle (?) Ordovician age extend along the southeast-facing escarpment of the Baylor Mountains for about 5 miles, between the El Paso and Montoya Formations. Howe ascribes them a thickness of 116 feet, but at least the lower 40 or 50 feet of the interval is equivalent to division C of the El Paso Limestone of the Beach Mountain area, so that they are probably nowhere more than 60 or 80 feet thick (geologic sections 6, 7, pl. 3 and p. 128–130).

The strata include two layers of medium-grained brown calcereous sandstone, between which are beds of shaly or silty limestone and marl, some of which are green. Sedimentary analyses of the sandstone indicate a textural resemblance to the St. Peter Sandstone of the northern interior region (Howe, 1959, p. 2289–2291) and a textural difference from the sandstone of the Cable Canyon Member of the Montoya, which also apparently occurs in parts of the Sierra Diablo region.

Few fossils have been observed in these strata, but a brachiopod was collected in the lower of the two sandstone beds by C. C. Branson, which was identified by G. A. Cooper (written commun. to Branson, 1949) as a probable *Desmorthis*, a genus which occurs high in the

Pogonip Group of Nevada and in the Joins and Oil Creek Formations of the Simpson Group of Oklahoma.

The strata of Middle(?) Ordovician age in the southeastern part of Beach Mountain are evidently the western featheredge of a unit which is much thicker and more extensive farther east, and which is missing farther west. In the West Texas basin drilling indicates the presence between the El Paso and Montoya Formations of as much as 2,000 feet of limestone, shale, and sandstone, which is of Middle Ordovician age and is equivalent to the Simpson Group of Oklahoma (Fillman and others, 1958, p. 122–124; Galley, 1958, p. 406–407). Middle Ordovician strata, 235 and 930 feet thick, have been reported in two deep wells in the Delaware and Apache Mountains, less than 20 miles east of the nearest outcrops of Ordovician rocks in the Sierra Diablo region (Maley, 1945, p. 280–281; M. E. Upson, in DeFord and others, 1951, p. 50–52) (Gulf Oil Corp., 1 M. A. Grisham, sec. 18, Block 99; Humble Oil & Refining Co., B-1 Reynolds Cattle Co., sec. 33, Block 62).

It is appropriate here to mention another reported occurrence of beds between the El Paso and Montoya in the Sierra Diablo region (King, P. B., 1934a, p. 1541–1542; Arick, 1935, p. 118–119). On the salient of the Sierra Diablo 1½ miles northwest of the Figure Two Ranch (center of southern part of sec. 9, Block 66, Twp. 5), the sandstone at the base of the Montoya Dolomite of geologic section 9 is bordered up to the dip to the northeast by a descending sequence of dark shale, cherty limestone, and finally by light-gray dolomite at the edge of the alluvium. Relations are obscured by slumping of blocks of the Montoya over strata farther down the slope. The questionable beds to the northeast, however, are like no Ordovician strata in the region; they are like the Mississippian, Devonian, and Silurian strata exposed not far away and are here interpreted and mapped as a downfaulted block of these strata (pl. 1). In a few ravines marly limestone is exposed in sequence below the Montoya on the upthrown side of the fault (unit 1, geologic section 9); although its age is undetermined, it is tentatively correlated with division C of the El Paso Limestone.

MONTOYA DOLOMITE

The type area of the Montoya Dolomite is in the Franklin Mountains north of El Paso, Tex., and the formation is named for Montoya station on the Santa Fe railroad west of the mountains (Richardson, 1908, p. 478–479; 1909, p. 4). A more specific type section of the formation has more recently been designated and measured, and the top redefined (Pray, 1958; Howe, 1959, p. 2321, fig. 24). At the time of the original work, the Montoya was also recognized in the Sierra Diablo region (Richardson, 1914, p. 4–5), with much the same character and extent as indicated by later investigations.

The Montoya has long been known to contain well-marked subdivisions in all its areas of exposure, and in the Caballo Mountains of New Mexico these subdivisions have been termed the Cable Canyon Sandstone, Upham Dolomite, Aleman Formation, and Cutter Formation (Kelley and Silver, 1952, p. 56–66). The Upham forms the lower cliff-making part of the Montoya, and the Aleman, the upper slope-making cherty part; the Cable Canyon is a basal sandy deposit, gradational into the Upham and not everywhere developed; and the Cutter is a unit transferred from the Fusselman Dolomite, of which it was formerly considered to be a lower member (Darton, 1928, p. 14). In the Sierra Diablo region the Upham and Aleman are certainly represented in the Montoya and also possibly the Cable Canyon, but the Cutter is apparently missing (Howe, 1958, p. 2328, fig. 29).

In many recent reports the Montoya has been classed as a group and its subdivisions as formations, but this is mainly a matter of personal preference. In the present report the subdivisions are classed as members of the Montoya Dolomite.

On Beach Mountain the Montoya Dolomite caps the El Paso Limestone in parts of the summit areas, and is also downfaulted along the eastern side (pl. 1 and upper view, pl. 2). It crops out at many places along the edges of the Baylor Mountains, generally forming the first ledges beneath the Hueco Limestone, although the Fusselman Dolomite intervenes in places. In the Sierra Diablo farther northwest it forms a small inlier in Victorio Canyon west of Victorio Peak, and is exposed in many of the fault blocks in the salient of the Sierra Diablo between the Figure Two Ranch and Apache Canyon.

The Montoya Dolomite is generally a cliff-making unit. Its lower beds form a wall-like escarpment rising above the weaker beds of the upper part of the El Paso, and surmounted by receding ledges of the higher beds. From a distance the formation appears darker colored than the underlying and overlying El Paso and Fusselman Formations, and its basal sandstone beds, where present, form a brown band on the mountain sides.

The Montoya Dolomite is 250 to 325 feet thick in the eastern Baylor Mountains (geologic sections 6, 7, pl. 3 and p. 128–130) and is somewhat thinner in the northeastern salient of the Sierra Diablo (geologic sections 9, 10). On Beach Mountain (geologic section 4) 416 feet of beds has been assigned to the Montoya, but the upper 110 feet might be part of the Fusselman Dolomite.

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CABLE CANYON(?) SANDSTONE MEMBER

In parts of the Sierra Diablo region, sandstone beds are prominent at the base of the Montoya, but their stratigraphic relations are complex. Most of the sandstone beds in the southeastern part of the Baylor Mountains are probably below the Montoya and are of Middle(?) Ordovician age, whereas those on Beach Mountain are gradational with the dolomite of the Upham Member and are more certainly part of the Montoya. Affinities of the sandstone beds in other parts of the region are less clear, and deserve further appraisal.

On the north side of Beach Mountain (geologic section 4), a single massive bed lies between division C of the El Paso Limestone and the dolomite of the Upham Member. It is a ledge-making pinkish sugary sandstone 35 feet thick, dolomitic throughout, and contains a few poorly preserved horn corals and brachiopods. Farther south on the mountain only the lower 10 feet is sandstone; the remainder is sandy dolomite. These beds resemble the Cable Canyon Sandstone as described in the Caballo Mountains, and like it, appear to be gradational with the Upham above, but precise correlation of such basal sandy deposits between distant areas is not assured.

In the Baylor Mountains, where several sandstone layers occur in the beds of Middle(?) Ordovician age, sandstone at the base of the Montoya itself is poorly developed, being no more than 10 feet thick in most places, and in some, missing altogether. On the salient of the Sierra Diablo 1½ miles northwest of the Figure Two Ranch (geologic section 9), the Upham Member is underlain by 55 feet of sandstone, of which only the lower half forms a strong ledge, the upper half being thinner bedded and with interbedded marly layers.

UPHAM MEMBER

The Upham Member is a prominent cliff-making unit, which is about 100 feet thick toward the south (geologic sections 4, 6) but somewhat thinner farther north (geologic section 9). For the most part it is a homogeneous light-gray or pinkish-gray fine-grained dolomite, forming massive beds as much as 5 feet thick that weather to dark-gray jagged surfaces. Some of the beds contain spherical chert nodules, and in the southeastern Baylor Mountains there is a very cherty layer 30 feet below the top. Few fossils are preserved in the dolomite, although silicified brachiopods and corals occur in places.

Parts of the member in the northeastern Baylor Mountains (geologic section 7) are of a different facies—a gray limestone mottled by anastomosing yellow dolomite and containing fairly abundant fossils. This facies forms the greater part of the member in the Hueco and Franklin Mountains farther west. Probably the homogeneous fine-grained dolomite facies of the member developed from the mottled limestone facies by dolomitization and recrystallization (Howe, 1959, p. 2298, 2299).

ALEMAN CHERTY MEMBER

The Aleman Cherty Member forms a succession of cherty ledges above the cliff-making Upham Member, and is 150 to 240 feet thick in the south (geologic sections 4, 6, 7) but about 110 feet in the north (geologic sections 9, 10). The Aleman Member is gray dolomite, in beds a few feet thick with interspersed thicker beds. Nearly all the beds are cherty, and chert makes up 30 or 40 percent of the volume of some of the beds. The silica content of the member is greater than that of any other unit in the Paleozoic sequence in the Sierra Diablo region, with the possible exception of the beds of Devonian age.

In some beds chert forms closely spaced layers a few inches thick that taper as long lenses; other beds are crowded with spherical chert nodules and irregularly knotted lenses. Brachiopods, corals, and other fossils in the dolomite are also commonly silicified, and project on weathered surfaces. Much of the silica in the Aleman was probably an original sedimentary constituent, perhaps derived from distant areas of volcanism (Howe, 1959, p. 2306), although the chert itself has been greatly rearranged during diagenesis of the original sediment, and later.

On the north side of Beach Mountain (geologic section 4) the 286 feet of strata preserved above the Upham Member is notably less cherty than in other sections. Two very cherty units, 40 and 25 feet thick, occur in the lower part, but the upper 110 feet is a massive cliff-making dolomite without chert. No fossils were observed in this unit, and although it is tentatively mapped with the Montoya and does not resemble the Fusselman of nearby areas, it is perhaps an unusual facies of the latter, or a remnant of the Cutter Member that is otherwise missing in the region.

At the inlier in Victorio Canyon in the central Sierra Diablo, about 100 feet of Montoya is exposed which consists of thin to thick beds of gray dolomite, the thinner beds crowded with chert layers and lenses. Both the lithologic features and the rather abundant fossils indicate that all these beds are part of the Aleman Member.

STRATIGRAPHIC RELATIONS

In the Sierra Diablo region the Aleman Cherty Member of the Montoya Dolomite is overlain by the Fusselman Dolomite. Where the Fusselman is of massive dolomite facies, the contact is abrupt; but in the few places where the Fusselman is of limestone facies, the contact is more obscure. Although paleontological data regarding the age of the Fusselman are rather meager, fossils of Silurian aspect have been observed here and there, in places not far above its base.

Farther northwest in Texas and in southern New Mexico, the Aleman Member is separated from the Fusselman Dolomite by the Cutter Member, about 165 feet thick, which contains a fauna of late Late Ordovician age (Kelley and Silver, 1952, p. 62–64; Howe, 1959, p. 2315–2326). Observations by the writer and by Howe (1959, p. 2319) indicate that this unit must be missing in the Sierra Diablo region. Here, the Aleman Member of the Montoya Dolomite is apparently separated from the Fusselman Dolomite by a disconformity, whose hiatus includes the time during which the Cutter Member was deposited farther northwest.

FOSSILS AND AGE

Fossils are rather plentiful in the Montoya Dolomite of the Sierra Diablo region, especially in the Aleman Cherty Member, although most are silicified and poorly preserved. Collections made during the present investigation are meager, but more extensive ones, which indicate a zonation of the sequence, were made by Howe (1959, p. 2328, fig. 29) in the Baylor Mountains.

In the Upham Member streptelasmid and halysitid corals and the brachiopod *Lepidocyclus* (formerly *Rhynchotrema*) were observed at various places in the homogeneous fine-grained dolomite facies. More abundant fossils occur in the mottled limestone facies in the northeastern Baylor Mountains (geologic section 7), where the sponge *Receptaculites*, halysitid and favositid corals, the brachiopod *Lepidocyclus*, the gastropod *Maclurites*, and large orthoceratid cephalopods were observed.

Near the top of the Upham Member and in the lower part of the Aleman Member (geologic section 6) Howe (1959, p. 2301, 2310–2314) has obtained an extensive brachiopod fauna which includes the genera *Lepidocyclus*, *Onniella*, *Thaerodonta*, *Plaesiomys*, *Rhynchotrema*, *Austinella*, and *Glyptorthis*. Higher in the Aleman he has observed a distinctive zone characterized by the coral *Paleophyllum thomi* (Hall).

From various localities in the Aleman Member the writer and his colleagues have collected the following, which were identified by P. E. Cloud, Jr., Helen Duncan, and Jean Berdan: streptelasmatid corals of the *Streptelasma foerstei* and *S. prolongatum* groups, *Foerstephyllum?*, *Paleophyllum thomi* (Hall), trepostomatous bryozoans, *Dinorthis* (*Plaesiomys*), "*Rafinesquina*," *Platystrophia*, *Lepidocyclus*, and *Hypsiptychia?*

Opinions have varied among paleontologists as to the age of the Montoya and related units in the Western States. According to the original determinations by Ulrich (in Richardson, 1909, p. 4), the Montoya contains faunas of two ages, one of Trenton (Galena) age in the Upham Member and the other of Richmond (Fernvale) age in the Aleman Member. On the other hand, Kirk (in Richardson, 1914, p. 4; Kirk, 1930, p. 464, 465) judged that the whole formation was of Late Ordovician age, although perhaps pre-Richmond. More recently available evidence has been reviewed by Howe (1959, p. 2301, 2302, 2315).

Perhaps the fauna in the Montoya that is most significant for correlation with the eastern Ordovician sequences is the assemblage of brachiopods which occurs in the upper part of the Upham Member and lower part of the Aleman Member. This faunal assemblage has close affinities with that of the Elgin Limestone Member of the lower part of the Maquoketa Shale of Iowa and may be correlative (Howe, 1959, p. 2301). Correlation of the Maquoketa with the type Cincinnatian (Upper Ordovician) of Ohio is subject to alternative interpretations; it may be entirely of Richmond age, or it may include equivalents of the Eden, Maysville, and Richmond. If the former interpretation is correct, both the Upham and Aleman Members of the Montoya are of Late Ordovician age; if the latter, the Upham Member includes beds of late Middle Ordovician (Trenton) age.

According to Howe, the fauna of the lower part of the Upham Member, including *Receptaculites* and *Maclurites*, "finds its closest relation with the Red River formation of southern Manitoba and its widespread correlatives" (1959, p. 2301), but the age of the Red River in terms of the eastern sequences has not been established. The higher brachiopod faunas of the Aleman member "possess a strong upper Maquoketa aspect" (1959, p. 2315). The fauna of the Cutter Member, which overlies the Aleman west of the Sierra Diablo, is of Late Ordovician and probably Richmond age (1959, p. 2326).

For purposes of the present report, it seems best to classify all the Montoya Dolomite as of Late Ordovician age, but with recognition that at least part of the Upham Member may be somewhat older.

REGIONAL RELATIONS

The Montoya Dolomite is exposed in the Hueco and Franklin Mountains northwest of the Sierra Diablo in Texas and in the mountains of southern New Mexico at least as far north as the Caballo Mountains and as far west as Silver City. Throughout this area the formation and its members are remarkably constant, except for minor regional variations and for the more drastic disappearance of the Cutter Member eastward in the Sierra Diablo. The regional aspects of the Montoya in west Texas and New Mexico have been reviewed by

Kelley and Silver (1952, p. 64–66) and have been studied in more detail by Howe (1959).

The Montoya Dolomite extends eastward beneath the surface from its outcrops in the Sierra Diablo and underlies that part of the West Texas basin southwest of a line between Lubbock and Edwards Counties, Tex. (Fillman and others, 1958, p. 90–93; Galley, 1958, p. 407–410). Except for a single small remnant (Barnes, Cloud, and Duncan, 1953), no rocks of Late Ordovician age are preserved in the outcrops of older Paleozoic rocks farther east, in the Llano uplift of central Texas.

SILURIAN

FUSSELMAN DOLOMITE

The Fusselman Dolomite was named for exposures near Fusselman Canyon in the Franklin Mountains north of El Paso, Tex. (Richardson, 1908, p. 479–480; 1909, p. 4). Later, a type section of the Fusselman was designated farther north in the Franklin Mountains, and the base of the formation was redefined (Pray, 1958). Existence of the Fusselman Dolomite in the Sierra Diablo region was not reported during the earlier investigations (Richardson, 1914) and was only discovered later (King, P. B., 1932).

DISTRIBUTION

In the Sierra Diablo region the Fusselman Dolomite crops out in more restricted areas than the earlier Paleozoic formations, as it has been more extensively removed by pre-Hueco erosion. It is exposed discontinuously beneath the Hueco along the eastern escarpment of the Baylor Mountains for several miles north and south of the eastern portal of Red Tank Canyon; it also occurs in many of the fault blocks in the salient of the Sierra Diablo between the Figure Two Ranch and Apache Canyon (pl. 1).

THICKNESS

The full thickness of the Fusselman Dolomite between the Montoya Dolomite below and the beds of Devonian age above is preserved in few of its exposures. In most places the eroded top of the Fusselman is overlain by Hueco Limestone, and where beds of Devonian age overlie the Fusselman, its base is concealed. One of the most prominent exposures of the Fusselman in the region is on the point of the mountains 1½ miles northwest of the Figure Two Ranch (geologic section 9, pl. 3 and p. 131–132), where it forms a wall-like ridge, bordered on the northeast by Montoya Dolomite and on the southwest by beds of Devonian and Mississippian age; however, the structure is obscure and the rocks dip steeply, so that their thickness is uncertain.

In the northeastern Baylor Mountains (geologic section 7) where the structure is plainer, the thickness of the Fusselman between the Montoya and beds of Devonian age is about 300 feet. At Apache Spring in the northern Sierra Diablo (geologic section 10), 420 feet of Fusselman occurs between the Montoya and the Hueco, but the beds of Devonian age and an unknown thickness of the upper part of the Fusselman have been removed by pre-Hueco erosion. The two sections indicate a northward thickening of the Fusselman, which is the reverse of relations in the Montoya.

LITHOLOGY

Throughout much of its extent the Fusselman is a monotonous body of massive white or light-gray crystalline dolomite, without chert. Dolomitization during diagenesis has destroyed or obscured much of its original structure. The greater part of the dolomite is now finely crystalline or sugary, with ghosts of fossils here and there, and with patches, vugs, and veinlets of coarsely crystalline calcite. Indistinct bedding planes divide it into layers a few feet to more than 5 feet thick, with some partings of thin-bedded hackly dolomite. The dolomite crops out in light-gray ragged bouldery surfaces, which contrast with the darker gray well-bedded ledges of the Montoya and Hueco Formations below and above.

At a few places the massive dolomite grades into another facies of darker gray well-bedded limestone and dolomitic limestone, containing chert and silicified fossils in many layers. This facies occurs in the Baylor Mountains near the eastern portal of Red Tank Canyon (sec. 4, Block 122) and at Apache Spring (northeastern part of sec. 7, Block 66, Twp. 5). Near Apache Spring the facies contains irregularly bedded reefy limestone bodies as much as 30 feet thick, formed largely of corals. The well-bedded limestone and dolomitic limestone beds somewhat resemble the upper beds of the Montoya Dolomite on which they lie, and when first observed during the present investigation, they were mapped with that formation. They are distinguishable from the Montoya because they overlie the full thickness of its Aleman Member, and because of their gradational relations with the dolomitic facies of the Fusselman. Both in the Baylor Mountains and at Apache Spring some thin to thick layers of light-gray dolomite are interbedded with the limestone; these layers thicken toward the areas of dolomite, so that one facies is replaced entirely by the other within less than a mile.

The dolomite and limestone facies of the Fusselman are probably reef and interreef deposits which were laid down contemporaneously on adjacent parts of the sea floor. Within the limits of exposure, gradation from one to the other takes place in varied directions, and the exposures are not extensive enough to indicate any general pattern. Similar gradations on a smaller scale have been observed in the Franklin Mountains (Pray, 1958, p. 36); they also resemble the gradations which have been reported between the Silurian Lone Mountain and Roberts Mountains Formations in Nevada (Winterer and Murphy, 1960).

STRATIGRAPHIC RELATIONS

The Fusselman Dolomite is overlain abruptly by chert, siliceous shale, and thin-bedded limestone of Devonian age. No indications of erosion were observed at the contact, but the two formations are probably disconformable and are separated by a hiatus that represents considerable parts of Silurian and Devonian time.

FOSSILS AND AGE

Fossils in the dolomitic facies of the Fusselman are mostly poorly preserved and difficult to identify, because of the prevailing recrystallization; better preserved fossils occur in the limestone facies, some of which are silicified.

At most localities in both the dolomite and the limestone, the common fossils are colonial corals of favositid and halysitid types, and various horn corals, but more varied assemblages were observed or collected in places. In dolomite in the upper part of the formation north of the mouth of Black John Canyon (center of western part of sec. 9, Block 66, Twp. 5), Josiah Bridge and J. Brookes Knight observed stromatoporoids, favositid corals, crinoid stems, pentamerid brachiopods, and trilobite fragments. On the ridge north of Apache Spring (northeastern part of sec. 7, Block 66, Twp. 5) in the limestone facies, the same geologists collected the trilobite *Dalmanites* from near the middle of the formation and stromatoporiods, favositid and halysitid corals, and brachiopods from higher and lower beds.

Information obtained during the present investigation is insufficient to determine closely the age of the Fusselman Dolomite in the Sierra Diablo region, and the fossil collections which were made are not now available for further study. The various corals could not be differentiated in the field from those in the Montoya Dolomite and would require more detailed study than has been given to them if they were to yield diagnostic evidence. However, the occurrence in the Fusselman of pentamerid brachiopods and *Dalmanites* suggests that the formation is partly or wholly of Silurian age.

REGIONAL RELATIONS

Like the underlying Paleozoic formations, the Fusselman Dolomite extends farther west in Trans-Pecos Texas and also occurs in many of the ranges of southern and southwestern New Mexico. It attains a maximum thickness of about 770 feet in its type area in the Franklin Mountains, and in New Mexico is a few hundred feet thick or less.

The Fusselman has been assigned a Middle Silurian, or Niagaran age (Richardson, 1909, p. 4; Darton, 1928, p. 14), but recent observations in New Mexico indicate that the formation as originally defined contains strata of more varied ages. In New Mexico two members in the Fusselman have long been recognized, but the lower, or Cutter Member, is now known to contain fossils of Late Ordovician age, and has been transferred to the Montoya (see above). In the restricted Fusselman fossils representing different ages of Middle Silurian and possibly Early Silurian time have been obtained, so that the formation may include two or more original depositional units, whose identity has been obscured by dolomitization (Flower, 1958, p. 72).

Rocks of Silurian age have been penetrated by drilling in the western part of the West Texas basin east of the Sierra Diablo, and part of them has been designated as Fusselman; but this part, however, interfingers with other units, and the stratigraphy of the whole is as yet uncertain (Fillman and others, 1958, p. 53–57).

DEVONIAN

BEDS OF DEVONIAN AGE

Overlying the Fusselman Dolomite in a few places in the Sierra Diablo region is a thin unit of chert, thin-bedded limestone, and shale of Devonian age. As the unit is scantily preserved in the Sierra Diablo, it is inappropriate to give it a new stratigraphic name based on that region; moreover, stratigraphic terminology of better preserved comparable beds in the Hueco and Franklin Mountains farther west has not been satisfactorily resolved. In this report the unit will therefore be referred to by the informal title of "beds of Devonian age."

DISTRIBUTION AND THICKNESS

Beds of Devonian age are preserved in two areas in the Sierra Diablo region (pl. 1). Their main occurrence is near Black John Canyon in the salient of the Sierra Diablo northwest of the Figure Two Ranch (secs. 9 and 12, Block 66, Twp. 5), where they form parts of many of the fault blocks in an area of several square miles. Relations are complex, not only because of the faulting during Cenozoic time, but also because of pre-Hueco deformation and the unconformity at the base of the Hueco, so that complete sections of the unit are preserved in few places. In the outermost fault block in the salient of the Sierra Diablo (northeast of base of geologic section 9), the full thickness of this unit between the Fusselman Dolomite on the northeast and the Barnett Shale on the southeast appears to be about 125 feet. Beds of

Devonian age are also preserved in a much smaller area in the Baylor Mountains to the south, on the southeastern spur of the high point of the mountains (unit 14, geologic section 7, pl. 3, sec. 11, Block 122), where 30–50 feet of the lower part of the unit intervenes between the underlying Fusselman and the overlying Hueco Limestone.

LITHOLOGY

Beds of Devonian age are characteristically siliceous. In large part they are bedded chert, mainly buff or brown, but partly white, gray, black, or dull green, in layers less than an inch to several inches thick; near the middle there are also some more massive beds of buff vitreous chert a foot or more thick. Some of the chert, especially in the lower part, is interbedded with dolomitic or argillaceous thin-bedded limestone, which itself contains many irregular chert nodules and lenses. In the upper part the chert is interbedded with, and grades into, siliceous shale, which is platy, black or brown, and bituminous. Conodonts, spicules, and spores are visible under a hand lens in many of the shales. These upper shaly beds are preserved only in the salient of the Sierra Diablo; the remnant in the Baylor Mountains (geologic section 7) consists only of the lower chert and limestone beds.

STRATIGRAPHIC RELATIONS

In most places the beds of Devonian age are overlain with angular unconformity by the Hueco Limestone, but the next higher unit of the normal sequence, the late Mississippian Barnett Shale, is preserved in the southeastern part of the salient of the Sierra Diablo. Exposures there are insufficient to determine its relations to the beds of Devonian age, but the known ages of the two units suggest that they are disconformable and are separated by a large hiatus.

FOSSILS AND AGE

Collections were made by W. H. Hass and others in 1938 from the beds of Devonian age in the lower course of Black John Canyon (southeastern part of sec. 9, Block 66, Twp. 5). The material collected is gray and brown shale and siltstone, presumably from the upper part of the unit. In this material W. H. Hass (written commun., 1959) has identified the following conodonts:

Ancyrodella sp.
Ancyrognathus euglyphea Stauffer
Bryantodus sp.
Hibbardella sp.
Hindeodella sp.
Icriodus sp.
Ligonodina sp.
Neoprioniodus alatus Hinde
Palmatolepis cf. *P. subrecta* Miller and Youngquist
Palmatolepis sp.
Polygnathus sp.

According to Hass—

Conodonts in this collection indicate that the rocks from which they came are early Late Devonian. This age determination is based chiefly on the presence of *Ancyrognathus euglyphea* and *Neoprioniodus alatus*. In the western New York section *Ancyrognathus euglyphea* had been found by me in the Pipe Creek member of the Hanover shale, and in Chadwick's type Letchworth shale, which Pepper, DeWitt, and Colton place in their West Falls formation. All of these formations fall into G. A. Cooper's Chemung stage of the Upper Devonian. I have also collected *A. euglyphea* from the basal beds of the Dunkirk shale near Hornell, New York. This formation is the basal member of Pepper and DeWitt's Perrysburg formation. *Neoprioniodus alatus* has a somewhat longer range. It appears to range from very high in the Middle Devonian into the highest beds of the Upper Devonian Hanover shale. The species is most common in authentic Upper Devonian rocks. The specimens identified as *Palmatolepis* cf. *P. subrecta* occur in the collection as molds. *P. subrecta* is commonly found associated with *Ancyrognathus euglyphea* in New York and elsewhere throughout the Interior States. Supporting evidence for a Devonian age is indicated by other specimens, which belong to the following genera: *Ancyrodella* whose known range is high Middle Devonian-Upper Devonian; *Icriodus*, Devonian; and *Palmatolepis*, Upper Devonian.

REGIONAL RELATIONS

Beds of Devonian age crop out in the Hueco and Franklin Mountains farther west in Trans-Pecos Texas and also in many of the ranges of southern and southwestern New Mexico.

The beds in New Mexico have long been termed the Percha Shale (Darton, 1928, p. 15–16), but later they were subdivided into various formations of Middle to Late Devonian age (Stevenson, 1945, p. 220). Other geologists (Kelley and Silver, 1952, p. 72–78) have judged that these formations are faunal zones and not mappable; hence, they have retained the name Percha for the whole unit.

In the Franklin Mountains north of El Paso, Tex., beds of Devonian age, lying between the Fusselman Dolomite and beds of Mississippian age, are about 175 feet thick, they have been termed the Canutillo Formation (Nelson, 1940, p. 1964; Cooper and others, 1942, p. 1749; King, P. B., King, R. E., and Knight, J. B., 1945, section A, sheet 2; Laudon and Bowsher, 1949, p. 46). Part of these beds may be equivalent to those in New Mexico; but they are not entirely comparable, and despite their small thickness their stratigraphy may be complex. The Canutillo of the Franklin Mountains includes an upper shale, a medial fossiliferous limestone, sandstone, and siltstone, and a lower chert. The upper shale has been correlated with the restricted Percha of New Mexico and the medial unit with the Oñate Formation of New Mexico (idem); hence, these parts are of late Middle and early Late Devonian age. The lower chert has yielded few or no fossils and its age is undetermined, except that it is older than the beds of Middle Devonian age and is younger than the Silurian Fusselman. A similar, but less fossiliferous, sequence occurs in the Hueco Mountains (King, P. B., King, R. E., and Knight, J. B., 1945, sections B to F, sheet 2; Loudon and Bowsher, 1949, p. 32–34).

In the Sierra Diablo the conodont-bearing beds are probably in the upper part of the unit here discussed. According to Hass, these beds are of early late Devonian age, hence probably equivalent to the middle or upper part of the Canutillo. They may also be equivalent to part of the Woodford Chert of Late Devonian and Early Mississippian age, which has been identified in the West Texas basin to the east (Fillman and others, 1958, p. 144–145) and in a drill hole between the Sierra Diablo and Hueco Mountains to the northwest (Lloyd, 1949, p. 50). However, the dominantly cherty beds which form the greater part of the unit in the Sierra Diablo are probably correlative with the lower chert of the Canutillo Formation in the Franklin Mountains and, like it, belong to some undetermined earlier part of the Devonian.

Correlation of the lower cherty beds in the Sierra Diablo and Franklin Mountains with the Caballos Novaculite of the Marathon region farther southeast has been suggested (King, P. B., and King, R. E., 1929, p. 912; King, P. B., 1932, p. 96); but this correlation has little precise meaning, as the Caballos is probably a composite unit, formed during a relatively long span of Devonian and possibly early Mississippian time (Berry and Neilsen, 1958, p. 2258–2259).

MISSISSIPPIAN

BARNETT SHALE

Beds of Mississippian age in the Sierra Diablo region were previously designated the Helms Formation (King, P. B., 1934a, p. 1542–1543; King, P. B., and Knight, J. B., 1944), for a unit whose type area is in the Hueco Mountains farther northwest in Trans-Pecos Texas. The beds in the Sierra Diablo are of the same general age as the typical Helms, but, as explained below, are of different facies and are more like the Barnett Formation, whose type area is in the Llano uplift of central Texas (Plummer and Moore, 1921, p. 24); the name Barnett is therefore used in this report.

DISTRIBUTION

In the Sierra Diablo region the Barnett Shale is exposed only on the southeast side of the salient of the Sierra Diablo northwest of the Figure Two Ranch (mainly in sec. 12, Block 66, Twp. 5; pl. 1). Its main occurrence is on the southwestern or upthrown side of the complex of fault blocks in the salient, but a small remnant is also preserved in the northeasternmost fault block of the salient (south-central part of sec. 9, Block 66, Twp. 5). Through most of its extent the Barnett is overlain by the Hueco Limestone, and much of its surface is covered by landslides, talus, and wash derived from that formation. It is thus exposed only intermittently, where ravines have cut through these surficial deposits.

LITHOLOGY AND THICKNESS

The Barnett is black, purplish, or dark-gray, carbonaceous shale, which contains small phosphatic and pyritic nodules and lenses and beds of earthy limestone. Most of the shale is barren of larger fossils, but limestone lenses contain cephalopods, fish teeth, and a few pelecypods and brachiopods. Fossils in the limestone lenses weather free and strew the surface of the outcrops.

The Barnett Shale is visible only in small outcrops, so that its full thickness cannot be determined. In the northeasternmost fault block of the salient about 75 feet is exposed, lying on beds of Devonian age and cut off by a fault above. About a mile to the southwest a large ravine exposes 135 feet of beds beneath the Hueco Limestone. (See geologic section 11, p. 133–134.)

STRATIGRAPHIC RELATIONS

Although the Barnett Shale is overlain unconformably by the Hueco Limestone in most places, it is bordered on the south by limestone and shale of Pennsylvanian age. The contact of the two units is not exposed, although small outcrops of each lie closely adjacent; presumably, however, the beds of Pennsylvanian age succeed the Barnett in normal stratigraphic order. As the Barnett is of Late Mississippian age and the limestone and shale are of Early Pennsylvania age at their base, the two stratigraphic units are probably conformable or are separated at most by only a small hiatus.

FOSSILS AND AGE

The principal occurrence of larger fossils in the Barnett Shale of the Sierra Diablo region is in the exposures described under geologic section 11. In 1931 J. Brookes Knight collected fossils from units 2, 3, and 4 of geologic section 11 (USGS 7019), and in 1936 obtained additional material, probably from the same locality (USGS 14945). From these collections, the following forms have been identified by Mackenzie Gordon, Jr., and E. L. Yochelson, who supplemented earlier identifications by G. H. Girty (written commun.; 1954, 1955):

	USGS Collection No.	
	7019	14945
Coelenterata:		
zaphrentoid coral, gen. undet	×	------
Brachiopoda:		
Composita sp	×	------
Leiorhynchus sp	×	×
Ambocoelia sp	×	------
Cleiothyridina? sp	------	×
Lamellibranchiata:		
Edmondia? sp	×	------
Posidoniella sp	×	------
Nuculana sp	×	×
Cypricardella sp	------	×
Gastropoda:		
Indeterminate specimen	------	×
Cephalopoda:		
Bactrites sp	×	×
orthoceratoid nautiloid	×	------
Girtyoceras sp	×	------
Neoglyphioceras cloudi (Miller and Youngquist)	×	×
Neoglyphioceras sp	------	×
Goniatites choctawensis Shumard	×	×
Goniatites crenistria Phillips	×	------
Pisces:		
Fish teeth and plates	×	×

From another collection from the same locality Miller and Furnish have identified the cephalopods *Goniatites* sp., *Girtyoceras* sp. cf. *G. mesleranum* (Girty), and *Lyrogoniatites* sp. cf. *L. newsomi* (Smith) (W. M. Furnish, written commun., 1959).

According to Gordon—

These collections are Mississippian in age (Meramec-Chester). *Goniatites choctawensis* and *Neoglyphioceras cloudi* are also known from the Barnett shale of north-central Texas and represent a zone that elsewhere crosses the Meramec-Chester boundary. A wide form of *G. crenistria* first described from British rocks is found in the upper part of the Moorefield Formation of Arkansas. *G. choctawensis* appears higher, in the Ruddell Shale and Batesville Sandstone. The two species of *Goniatites* are not generally found together, *G. crenistria* being an earlier form.

According to Furnish—

The lirate goniatitids are one of the indices for P_2 or upper Visean, world-wide. This now means upper Bollandian of northern England and lower Chesterian of the Midcontinent.

REGIONAL RELATIONS

From its type area in central Texas the Barnett Shale extends westward beneath the West Texas Basin, where it has been penetrated by drilling (Galley, 1958, p. 414–417). Throughout its extent it is a deposit of black shale facies, generally of middle to late Mississippian age, containing brachiopods (*Leiorhynchus*), various cephalopods, and other fossils characteristic of that facies. In its type area the Barnett is mainly of Meramec age and probably does not extend into the Chester (Cloud and Barnes, 1946, p. 59), but in the West Texas basin Fillman and others (1958, p. 16–17) state that similar shale—

varies in age from place to place in the subsurface so that its age is Kinderhook, Osage, Meramec, and Chester in the southern part of the Midland and Delaware basins and Central Basin platform. Northward the Barnett Shale grades laterally into limestone which comes into the section from the bottom, so that its age is progressively younger and younger until in northern Gaines County it is restricted to the Chester.

Presumably the shale exposed in the Sierra Diablo lies near the western edge of this broad sheet of deposit.

Farther northwest in Trans-Pecos Texas, in the Hueco Mountains and beyond, equivalent beds of middle to late Mississippian age are of different facies, and constitute the Helms Formation (Beede, 1920, p. 7–8; King, P. B., King, R. E. and Knight, J. B., 1945, sheet 2). The Helms consists of 300 to 500 feet of slabby limestone, gray and cherty below, changing to brown and sandy above, where much green shale is interbedded. It contains brachiopods, bryozoans, and crinoidal fragments of several faunas, the lower of which are of Meramec age and the higher of Chester age. Some geologists have restricted the name Helms to the Chester part of the sequence and have named the Meramec part the Rancheria Formation (Laudon and Bowsher, 1949, p. 17–30, 34), but it is doubtful whether these subdivisions represent more than faunal zones. The Helms is probably an equivalent on the outcrop of the limestones which interfinger northward with the Barnett in the West Texas basin, as described above. Presumably a similar interfingering between the Barnett and Helms facies occurs between the Sierra Diablo and Hueco Mountains, beneath the surface of the Diablo Plateau.

PENNSYLVANIAN

BEDS OF PENNSYLVANIAN AGE

Beds of Pennsylvanian age in the Sierra Diablo were previously termed Bend Formation and Magdalena Limestone (King, P. B., and Knight, J. B., 1944), the first name being derived from central Texas and the second from New Mexico. For the present, however, it seems best not to give them formal names. The beds which are exposed in the Sierra Diablo are only fragments of a larger sequence, and although they may be equivalent to parts of the Bend and Magdalena in their typical areas, the latter have much broader stratigraphic range. Moreover, relations between the so-called Bend and Magdalena within the Sierra Diablo itself, are in doubt as indicated below.

DISTRIBUTION

Beds of Pennsylvanian age are exposed along the lower part of the Sierra Diablo escarpment west and southwest of the Figure Two Ranch for a distance of about 3 miles, or from north of Mine Canyon to south of Marble Canyon (pls. 1, 14). However, its outcrops are interrupted for more than a mile in the middle, between Mine and Marble Canyons, where Hueco Limestone and Tertiary intrusive rocks extend to the base of the escarpment. Moreover, the Pennsylvanian rocks north of Mine Canyon, like the adjacent Barnett Shale, are extensively concealed by landslides and wash from the Hueco Limestone higher on the slope.

LOCAL FEATURES

The strata north of Mine Canyon (western part of sec. 16, Block 66, Twp. 5) are those previously called Bend Formation. Both sequence and structure are obscure because of poor exposures, but there is apparently a lower limestone and an upper shale, which dip generally southward and are truncated northward by the unconformity at the base of the Hueco Limestone.

The lower limestone is well exposed in several ravines near the foot of the escarpment on the downthrown side of a fault in the northwestern part of sec. 16, where about 35 feet of beds is visible. The limestone is fine grained to aphanitic, dark gray to black, and weathers variously buff, yellow brown, or blue gray. The beds are a foot or two to less than an inch thick, and some are separated by layers of platy, shaly limestone. The limestone is interbedded with units as much as 4 feet thick of brown or black bedded chert. It is only sparsely fossiliferous, but small collections have been obtained.

The upper shale is mainly exposed farther south, in the southwestern part of sec. 16, near some felsite intrusives that project as low knobs at the foot of the escarpment. The shale is best revealed just north of the portal of Mine Canyon, but because it is much decomposed at the surface, no more than 10 feet of beds is exposed at any one place. The shale is poorly consolidated, gray to black, carbonaceous, and richly fossiliferous. Large areas of its surface are strewn with fossils that were originally pyritized, but which have now weathered to limonite and have been separated from their matrix.

The beds of Pennsylvanian age south of Marble Canyon (east edge of sec. 21, Block 66, Twp. 5), like those north of Mine Canyon, form the basal part of the Sierra Diablo escarpment and are overlain unconformably by the Hueco Limestone. However, as this part is formed of thicker bedded strata than those farther north, it is much better exposed. Its tilted ledges beneath the flat-lying Hueco are plainly visibly from Texas Highway 54, nearly 2 miles distant to the east (upper view, pl. 10).

The Pennsylvanian rocks in this area are gray granular thick-bedded limestone that stands in prominent rounded ledges as much as 25 feet thick separated by thinner bedded limestone of much the same nature. Some of the layers contain moderately abundant fossils, but none of the limestone is cherty. The beds dip about 10° southward, each bed being truncated northward by the unconformity at the base of the Hueco, so that, although less than 100 feet is exposed at any one place, more than 170 feet of beds occurs in a distance of about half a mile along the scarp. (See geologic section 12.)

STRATIGRAPHIC RELATIONS

The Pennsylvanian rocks, like the other pre-Permian formations of the Sierra Diablo region, lie with angular unconformity beneath the Hueco Limestone. The strata are the youngest which are preserved beneath this unconformity at any exposure in the region, and probably lie in the trough of a syncline that was produced during the pre-Hueco deformation (fig. 2). As indicated below, the part of the Pennsylvanian sequence that is preserved in the Sierra Diablo is no younger than Middle Pennsylvanian age, and strata of later Pennsylvanian age are missing. These beds and the Hueco are thus separated by a considerable hiatus.

FOSSILS AND AGE

The Pennsylvanian rocks of the Sierra Diablo region are sparingly to abundantly fossiliferous, the most prolific part being the upper shale beds north of Mine Canyon, whose fossils have previously been discussed by Arick (1932, p. 485–486), Plummer and Scott (1937, p. 25), and Miller and Furnish (1940b). The fossil collections from these beds that are here reported on were identified by Mackenzie Gordon, Jr., and E. L. Yochelson, supplementing earlier identifications by G. H. Girty (written commun., 1954, 1955).

A few fossils were collected by J. Brookes Knight in 1931 from the lower limestone north of Mine Canyon, from exposures in the northwestern part of sec. 16, Block 66, Twp. 5 (USGS 7023). These consist of *Chonetes* sp., *Cleiothyridina* sp., and *Gastrioceras occidentale* (Miller and Faber). In addition, gastropods were observed in the limestone in the field, but they are not now represented in the collections. These fossils are too meager to indicate the stratigraphic position of the beds containing them, but the *Gastrioceras* also occurs in the upper shale beds, exposed nearby to the south.

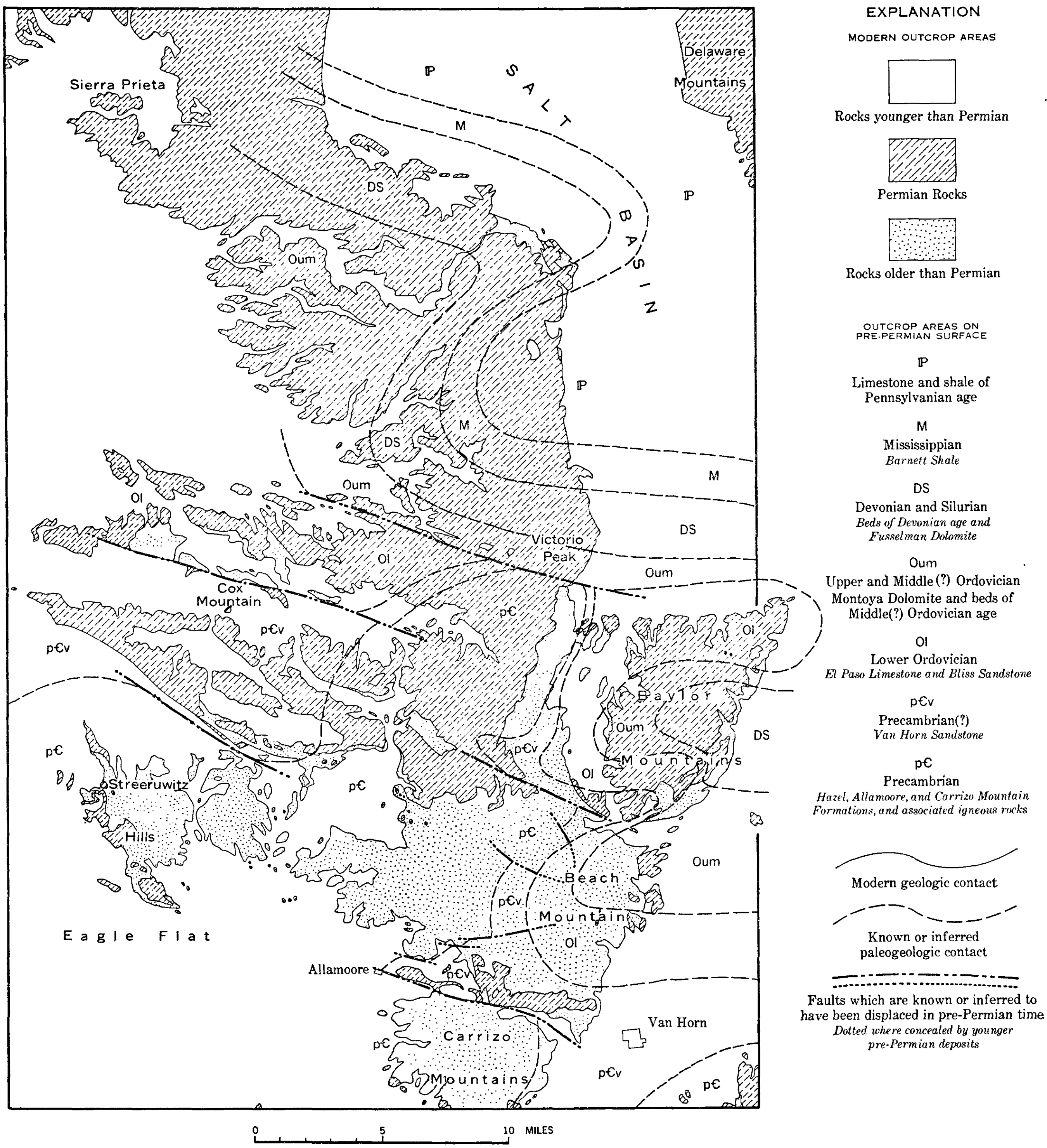


Figure 2.—Map of Sierra Diablo region showing paleogeology of the surface on which the Hueco Limestone (basal Permian) was deposited.

The upper shale beds north of Mine Canyon have yielded the following fossils.

	USGS Collection No.			
	7018	14944	8105	8106
Coelenterata:				
Chaetetes sp	×	----	----	----
Lophophyllidium sp	×	----	----	----
Zaphrentoid coral, gen. undet	----	×	----	----
Bryozoa:				
Stenoporoid bryozoan	×	×	----	----
Fistulipora sp	----	----	----	×
Brachiopoda:				
Composita sp	----	×	----	----
Productoid brachiopod indet	----	×	----	----
Lamellibranchiata:				
Nuculana arata (Hall)	×	×	×	----
Nuculana n. sp	×	×	×	×
Nucula cf *N.* (*Nuculopsis*) *girtyi* Schenk	----	×	×	----
Conocardium n. sp	×	×	×	×
Anthraconeilo sp	----	----	×	×
Gastropoda:				
Euphemites sp. indet	×	----	----	----
Knightites (*Retispira*) *bellireticulata* (Knight)	×	×	----	----
Cinclidonema cf. *C. texanum* Knight	×	----	----	----
Platyzona sp	×	----	----	----
Glabrocingulum n. sp	×	×	×	×
Straparollus aff. *S. savagei* Knight	----	×	×	×
Spirioscala sp	----	×	----	----
Gastropod n. gen	×	×	×	----
Gastropods indet	×	----	----	----
Cephalopoda:				
Bactrites sp	×	----	----	----
Dolorthoceras 3 spp	×	×	×	----
Cycloceras sp	----	----	----	×
Paralozoceras spp	×	×	×	----
Adnatoceras sp	×	----	----	----
Liroceras? sp	×	----	----	----
Stenopronorites sp	×	----	----	----
Boesites scotti Miller and Faber	×	----	----	----
Gastrioceras occidentale (Miller and Faber)	×	×	×	×
Diaboloceras varicostatum Miller and Furnish	×	×	×	×
Pseudoparalegoceras lenticulare (Plummer and Scott)	×	×	×	×
Glaphrites raymondi Plummer and Scott	×	×	×	×
Proshumardites primus (Plummer and Scott)	----	×	----	----
Pisces:				
Fish teeth	×	----	----	----

7018 (field loc. 12). Shale hills north of portal of Mine Canyon and west of felsite intrusive, in southwestern part of sec. 16, Block 66, Twp. 5. Collected by J. Brookes Knight, July 1931.

14944 (field label Pbs-1). Approximately the same locality as that of 7018. Collected J. Brookes Knight, 1936.

8105. Approximately the same locality as that of 7018. Collected by M. B. Arick for Humble Oil Co., February 1931.

8106. About a quarter of a mile north of the locality of the preceding collections, north of felsite intrusive. Collected by M. B. Arick for Humble Oil Co., February 1931.

In addition to the cephalopods listed above, Miller and Furnish (1940b) have described the species *Pseudoparalegoceras bellilineatum.*

The cephalopods of this fauna indicate that it is of Atoka age. These were correlated by Plummer and Scott (1937, p. 25) with those of their *Gastrioceras listeri* zone, which occurs a little below the top of the Smithwick Shale of the Llano uplift in central Texas, or in strata now considered to be late Atoka in age. However, Gordon (written commun., 1954) states: "This fauna is correlated with that in the lower part of the Atoka Formation in eastern Oklahoma and western Arkansas, particularly because of the occurrence of *Diaboloceras varicostatum* Miller and Furnish in both."

A small collection of fossils was made by J. Brookes Knight and the writer in 1931 from the limestone beds south of Marble Canyon, probably mainly from units 5 and 6 of geologic section 12 (USGS 7010A; field loc. 12). According to Gordon and Yochelson (written commun., 1954)—

> The Pennsylvanian age of the rocks is borne out by the fauna. Included are such forms as the corals *Caninia* and *Chaetetes*; the brachiopods *Chonetes, Dictyoclostus, Marginifera*? spp., *Echinoconchus, Rhipidomella, Girtyella*?, *Dielasma, Spirifer* cf. *S. rockymontanus* Marcou, *Punctospirifer, Phricodothyris perplexa* (McChesney), *Crurithyris, Cleiothyridina,* and *Composita subtilita* (Hall); and several pelecypods and gastropods.

Besides these fossils, Garner L. Wilde reports the occurrence in the rocks south of Marble Canyon of *Fusulina, Wedekindellina,* and *Fusulinella,* which indicate an early Des Moines age (Kepple and others, 1962, p. 20).

The corals and brachiopods of this fauna are not diagnostic of any particular zone in the Pennsylvanian, but some of them are more characteristic of the lower part than the upper part of the Pennsylvanian in nearby regions. *Chaetetes* and *Spirifer rockymontanus* are thus common in the lower division of the Pennsylvanian in the Hueco Mountains farther northwest in Trans-Pecos Texas (King, P. B., King, R. E., and Knight, J. B., 1945, sheet 2, sections G, H). The fusulinids reported by Wilde confirm this correlation.

REGIONAL RELATIONS

Pennsylvanian rocks are exposed in many mountain ranges northwest of the Sierra Diablo region in Trans-Pecos Texas and in New Mexico; they have also been penetrated by numerous wells in the West Texas basin to the northeast and east (Galley, 1958, p. 419–423). In most places the Pennsylvanian sequence is thicker and more complete than in the Sierra Diablo, and much is known of its stratigraphy (see, for example, Thompson, 1942, p. 27; Lloyd, 1949, p. 34–40). Because of the fragmentary representation of the Pennsylvanian rocks in the Sierra Diablo, it is inappropriate to summarize the regional stratigraphy of the Pennsylvanian in this report, but it is appropriate to speculate regarding the relation of this fragmentary sequence to the more complete sequences known elsewhere.

In the Sierra Diablo the sequence and relations of the different parts of the Pennsylvanian strata are uncertain, not only because of disconnected exposures, but because the rocks and fossils of the parts north of Mine Canyon and south of Marble Canyon are so different that few comparisons between them are possible. However, the strata in all exposures dip to the south, and those north of Mine Canyon are adjacent to exposures of the Mississippian Barnett Shale, so that they would seem to form the base of the unit and to lie beneath the strata south of Marble Canyon.

Comparison with the more complete section of the Magdalena Group in the Hueco Mountains farther northwest in Trans-Pecos Texas suggests another possible interpretation (King, P. B., King, R. E., and Knight, J. B., 1945, sheet 2). In that area the Magdalena Group, which is about 1,300 feet thick, forms three lithologic divisions which can be correlated on the basis of fusulinids and other contained fossils with the subdivisions of the standard Pennsylvanian section of the midcontinent region. The lower division, 500 feet thick, is thick-bedded coralline limestone and is approximately of Morrow and early Atoka age. The middle division, 300 feet thick, is marl, marly limestone, and shale and is approximately of late Atoka and early Des Moines age. The upper division, of variable thickness because of the unconformity at the top, is limestone and interbedded marl and is approximately of late Des Moines, Missouri, and early Virgil ages.

Lithologically, the lower limestone of the Magdalena Group in the Hueco Mountains closely resembles the beds south of Marble Canyon in the Sierra Diablo, and like them contains *Chaetetes* and *Spirifer rockymontanus*. This lower limestone lies directly on the Mississippian Helms Formation, with no intervening shale or thin-bedded cherty limestone like the beds north of Mine Canyon in the Sierra Diablo. The first shale in the Hueco Mountains section is that in the lower part of the middle division. Like the shale north of Mine Canyon in the Sierra Diablo, this is of Atoka age. The two shales might be equivalent, although that in the Hueco Mountains lacks the prolific cephalopods of the Sierra Diablo, and contains mainly a brachiopod fauna. If the two are equivalent, the true sequence of the Pennsylvanian limestone strata in the Sierra Diablo is the reverse of the sequence indicated by the field relations.

A possible alternative is that the thick-bedded coralline limestones and the cephalopod- or brachiopod-bearing shales of the lower part of the Pennsylvanian System in the west Texas-New Mexico region do not form persistent time-stratigraphic units of wide extent, but are facies that occur in different stratigraphic order from one mountain area to another.

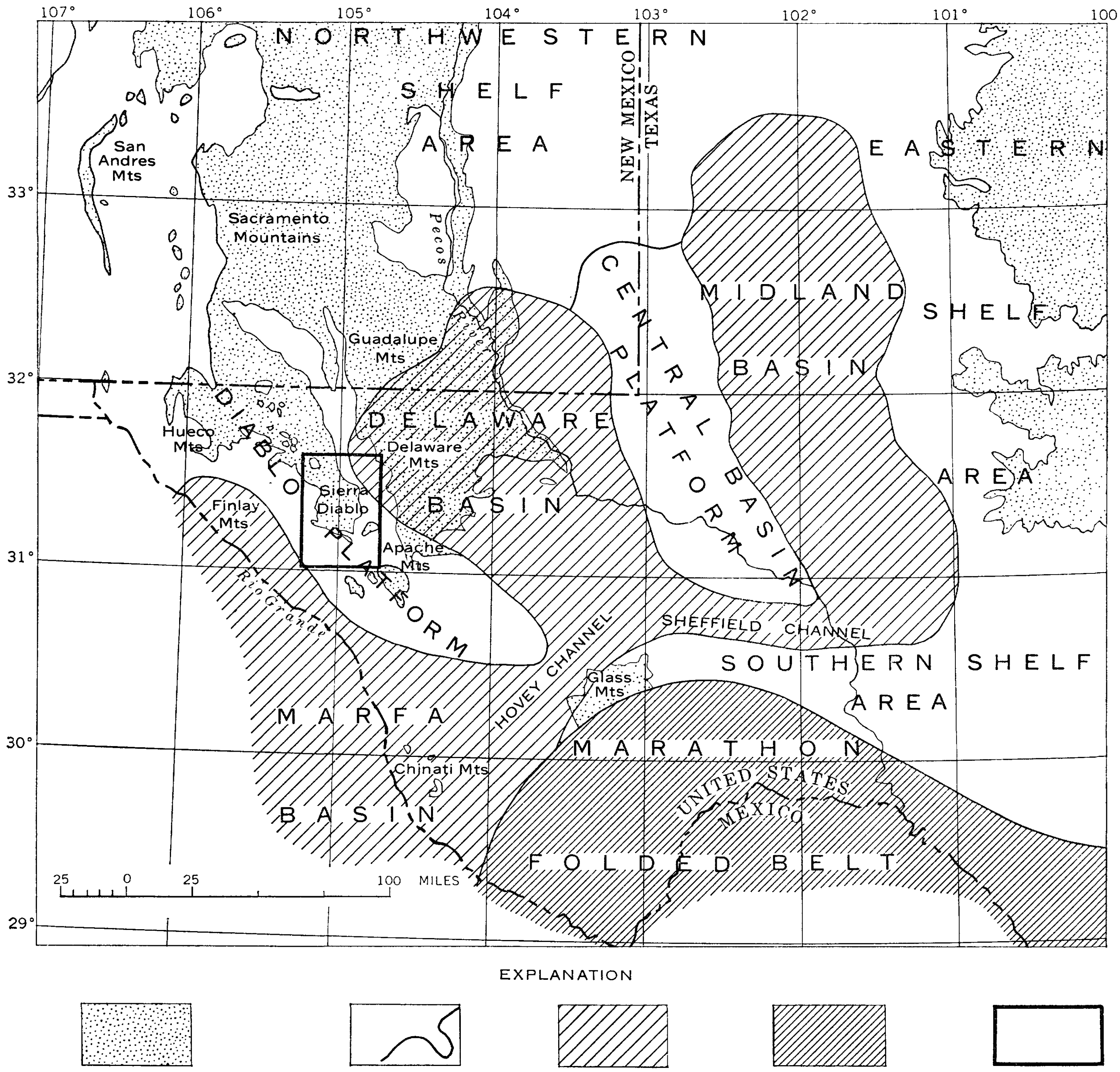
PERMIAN

Rocks of the Permian System occupy the largest surface area of any in the Sierra Diablo region. They are prominently exposed on the escarpments on the east, north, and south sides of the Sierra Diablo and form many square miles of its summits. They also occur in the adjacent Baylor Mountains, Beach Mountain, and the Carrizo Mountains, as well as in the Delaware and Wylie Mountains, across the Salt Basin in the northeast and southeast corners of the report area (pl. 1).

Because of the variability of the subdivisions of the Permian System in the Sierra Diablo region, it is difficult to ascribe a total thickness to the part preserved there. Several thousand feet is exposed nearly everywhere along the escarpments in the northeastern Sierra Diablo (pls. 4–8), the maximum being 2,128 feet on Victorio Peak. At the north end of the range near South Mesa, 2,140 feet is exposed, which includes strata higher than those on Victorio Peak. Smaller thicknesses of the lower part of the Permian are preserved in the southern Sierra Diablo, the Baylor Mountains, Beach Mountain, and the Carrizo Mountains. In the Wylie Mountains to the southeast the Permian sequence is 4,473 feet thick, but most of it is exposed only east of the report area. Permian strata exposed in the Delaware Mountains within the report area are 1,783 feet thick, but they are only part of the much thicker sequence of the Delaware and Guadalupe Mountains.

The Permian rocks of the Sierra Diablo region are largely limestone, dolomitic limestone, and dolomite but there are subordinate layers of shale, sandstone, and conglomerate. Their stratigraphy is the most complex of the rocks of any system in the region. They vary greatly, not only in thickness, but also in lithology and faunas. In some areas the whole Permian is a monotonous sequence of poorly fossiliferous dolomitic limestone, yet only a few miles away it may be interbedded richly fossiliferous massive limestone, thin-bedded limestone, and shale (pl. 4). Many of these variations are visible in three dimensions because the rocks are exposed not only on the escarpment faces, but in canyons behind the escarpments and in outlying mountains in front of them.

The complex variable stratigraphy of the Permian rocks was created by unequally subsiding tectonic units in the depositional area—the Delaware basin on the northeast and the Diablo platform on the southwest (fig. 3). Because of unequal subsidence, the basin gen-



Outcrops of Wolfcamp, Leonard, Guadalupe, and Ochoa Series (Permian), and their equivalents

Boundaries of provinces of Permian time

Basin areas

Deformed pre-Wolfcamp Paleozoic rocks of Marathon folded belt

Area covered by this report

FIGURE 3.—Map of parts of western Texas and southeastern New Mexico showing provinces of Permian time.

erally stood at greater depth than the platform; thus, the basin received mainly shaly and sandy deposits, the platform mainly stratified carbonate deposits; on the intervening basin margin grew extensive limestone reefs and banks which were the home of varied marine life. Because of unequal subsidence, many of the units on the platform are also separated by unconformities, along which the underlying strata have been eroded, and the overlying strata wedge out by overlap.

The Permian rocks of the Sierra Diablo region belong largely to the Wolfcamp and Leonard Series, the succeeding Guadalupe Series being represented merely by small remnants at the north end of the range. This situation contrasts with that in the Guadalupe Mountains, across the Salt Basin to the north, where only the upper part of the Leonard Series emerges from beneath a thick sequence of the Guadalupe Series, the latter being followed by part of the Ochoa Series (King, P. B., 1948, p. 7–100). The Permian section in the Sierra Diablo thus usefully supplements the more famous Permian section in the Guadalupe Mountains and extends the sequence to the base of the system.

Stratigraphic terminology of the Permian rocks in the Sierra Diablo region has varied with the work of successive geologists and has evolved with increasing knowledge. Because of the long span of the present investigation, the stratigraphic terminology used by the author and his colleagues is not the same in their successive publications. The following table compares the classification used in the present report with that in earlier reports.

The Permian rocks were investigated primarily by means of description and measurement of stratigraphic sections, mostly the work of J. Brookes Knight. The greater part of the fossils collected were on the lines of these stratigraphic sections. Details of the nature of the Permian rocks may be found in the descriptions of the sections at the end of the report. The sections are also illustrated on plates 5–8. Variations in the Permian rocks between the sections were observed during

Stratigraphic classification of Permian rocks in Sierra Diablo region

<table>
<tr><th>Richardson, 1914</th><th>Beede, 1920</th><th colspan="2">King, P. B., and King, R. E., 1929; King, R. E., 1931</th><th colspan="2">King, P. B., 1934b</th><th colspan="2">King, P. B., 1942; King, P. B., and Knight, J. B., 1944</th><th colspan="2">This report</th></tr>
<tr><td rowspan="3">Not observed</td><td rowspan="3">Word</td><td colspan="2" rowspan="3">Delaware Mountain Formation</td><td colspan="2" rowspan="3">Delaware Mountain Formation</td><td colspan="2">Goat Seep Limestone</td><td colspan="2">Goat Seep Limestone</td></tr>
<tr><td colspan="2">Sandstone tongue of Cherry Canyon Formation</td><td colspan="2">Sandstone tongue of Cherry Canyon Formation</td></tr>
<tr><td rowspan="4">Bone Spring Limestone</td><td>Cutoff Shaly Member</td><td colspan="2">Cutoff Shale</td></tr>
<tr><td rowspan="5">Hueco Limestone</td><td rowspan="3">Leonard</td><td rowspan="2">Leonard Formation</td><td>Victorio Peak Member</td><td rowspan="4">Bone Spring Limestone</td><td>Victorio Peak Massive Member (zone D)</td><td>Victorio Peak Gray Member</td><td colspan="2">Victorio Peak Limestone</td></tr>
<tr><td>Bone Canyon Member</td><td>(zone C)</td><td rowspan="2">Black limestone, etc.</td><td colspan="2" rowspan="2">Bone Spring Limestone</td></tr>
<tr><td rowspan="2">Hess Formation</td><td rowspan="3">Gym Formation</td><td>(zone B)</td></tr>
<tr><td rowspan="2">Manzano</td><td>(zone A)</td><td rowspan="2">Hueco Limestone</td><td>Limestone</td><td rowspan="2">Hueco Limestone</td><td>Main body of formation</td></tr>
<tr><td>Upper Wolfcamp Formation</td><td colspan="2">Basal beds</td><td>Basal clastic member</td><td>Powwow Member</td></tr>
</table>

field mapping, as shown on the geologic map (pl. 1) and in views of the escarpment faces and canyon walls, which are illustrated in the panoramas (pls. 10, 11, and upper 12) and in geologic sections $V-V'$ to $Z-Z'$ (pl. 4). The text which follows is a summary of these data.

PRESENTATION OF PALEONTOLOGIC DATA

Fossils were collected from the Permian rocks of the Sierra Diablo region during successive field seasons of the present investigation, and have been identified at different times by various paleontologists. Brachiopods of the earlier collections were identified by R. E. King (1931, p. 14–15), and fusulinids by C. O. Dunbar and J. W. Skinner (1937, p. 587–590). Later collections were identified by P. E. Cloud, Jr., E. L. Yochelson, and L. G. Henbest (written commun., 1954, 1955); additional identifications were made by R. M. Finks, A. R. Palmer, and I. G. Sohn. Fossils collected by other geologists from the Permian rocks of the region have been identified and described by G. H. Girty (1931), A. K. Miller and W. M. Furnish (Miller and Furnish, 1940a; Miller, 1945), C. O. Dunbar (1953), F. G. Stehli and G. A. Cooper (Stehli, 1954; Cooper and Stehli, 1955), E. L. Yochelson (1956, 1960), and others.

Identifications of Permian fossils collected during both earlier and later phases of the investigation are listed on pages 134–170, in the texts of the stratigraphic sections, or in appropriate geographic order where not collected in measured sections. Stratigraphic position of most of the collections is indicated on the plotted stratigraphic sections (pls. 5–8) and their geographic position on the index map of the region (pl. 9).

Because many revisions of the fossil terminology and taxonomy have been made between the times of the earlier and later investigations, the names used for the same fossils are likely to vary from one collection to another. Although it has not been feasible to revise the earlier identifications to agree with the later, the earlier identifications are of historical interest; some of the earlier collections, for example, contain type specimens of genera or species. All collections marked "REK" and "D & S" on pages 134–170 are therefore listed in the form in which they were originally presented, with the understanding that they would require review to harmonize them with the collections marked "USGS" or "F."

To provide a sampling of the whole fauna of the different Permian formations in the Sierra Diablo region, based on a single taxonomic standard, the later fossil identifications have also been assembled in a set of tables (tables 3–9).

The fossils listed in these tables represent only part of those which have been collected and identified during the present investigation and do not include those yielded from other investigations. In each table the fossils are shown according to the formations in which they occur, and in the order in which they are given in the stratigraphic sections and fossil lists (p. 134–170). It has not proved feasible to introduce any further refinements in zonation. However, the fossils of the Hueco Limestone occur in several well-marked facies, shown separately in tables 3–5—the calcitic limestone of the southern and southwestern part of the Sierra Diablo region, the marl and calcitic limestone of the northeastern part, and the main body of the formation of the northeastern part, containing only foraminifers. The fauna of the Bone Spring Limestone, although not divisible into zones or facies, is so extensive that it has been subdivided according to taxonomic groups into tables 5–7. The faunas of the Victorio Peak and Goat Seep Limestones are shown in tables 8 and 9, respectively.

HUECO LIMESTONE

The lowest Permian formation of the Sierra Diablo region is the Hueco Limestone, whose type area is in the Hueco Mountains farther northwest in Trans-Pecos Texas. As indicated above, the Hueco as now defined includes only part of the beds originally so named by Richardson (1904, p. 32–38; 1908, p. 480–482), or the part which contains the Hueco fauna as understood by Girty. This part is a carbonate facies of the Wolfcamp Series, which is extensive in northwestern Trans-Pecos Texas and adjacent areas. In both the Hueco Mountains and the Sierra Diablo, the Hueco lies unconformably on Pennsylvanian and earlier rocks. In the Hueco Mountains its top is poorly defined, because of uncertainty as to what strata, if any, are preserved above it; in the Sierra Diablo the Hueco is overlain by the Bone Spring Limestone of the Leonard Series, at least in part unconformably.

OUTCROP

The Hueco Limestone is extensively exposed in the southern half of the report area (pl. 1). It forms most of the surface of the Sierra Diablo south of the Victorio flexure and stands in ledges or cliffs at the edges of the bordering escarpments. It also forms much of the bulk of the Baylor and Wylie Mountains to the east and southeast, and is preserved in smaller outliers in Beach Mountain, the Carrizo Mountains, and the Streeruwitz Hills. North of the Victorio flexure in the Sierra Diablo, the Hueco stands at a lower level than farther south, and is extensively covered by younger Permian formations. Here it projects as a bench on the lower part of the escarpment between Victorio Peak and Apache Canyon; within the range it emerges only in

Victorio and Apache Canyons and in the uplift on the south side of the Sierra Prieta intrusive. The Hueco Limestone doubtless extends northwestward beneath the surface from the Sierra Diablo and joins the type Hueco in the Hueco Mountains.

THICKNESS

The thickness of the Hueco Limestone varies remarkably. The gross pattern of the variations is not entirely clear, as in many places the full thickness of the formation is not preserved; where preserved, it appears to be greatest in the platform area to the south and southwest and thinnest near the edge of the basin area to the northeast.

The Hueco is about 1,400 feet thick in the Wylie Mountains (geologic section 13) and 1,100 feet or more thick in the head of Apache Canyon (geologic sections 37–40). At the lower end of Apache Canyon it thins to a few hundred feet (geologic sections 36, 37). Along the Sierra Diablo escarpment between Apache Canyon and Victorio Peak, the thickness averages 500 feet, but it is thicker than 900 feet in places and thinner than 400 feet in others (geologic sections 27–34). At several places in the northern Baylor Mountains it wedges out entirely, so that the succeeding Bone Spring Limestone directly overlies the earlier rocks.

Many of the variations in thickness of the Hueco are caused by overlap of the formation against its unconformable basal surface and by truncation of its top before the Bone Spring was deposited over it. These relations, or combinations of both, are well displayed in Apache Canyon and parts of the Baylor Mountains. There is also a possibility, difficult to assess, that different thicknesses of Hueco Limestone were deposited from place to place.

LITHOLOGY AND SUBDIVISIONS

In the Sierra Diablo region the Hueco Limestone includes a thick main body of bedded calcitic and dolomitic limestone and thinner basal beds, the Powwow Member.

The type Powwow Member is in the Hueco Mountains, where it forms a basal lens of conglomerate and red beds a few miles long (King, P. B., and King, R. E., 1929, p. 911; King, P. B., King, R. E., and Knight, J. B., 1945). The beds termed Powwow Member in the Sierra Diablo region (King, P. B., and Flawn, P. T., 1953, p. 34–36; 98–99; Hay-Roe, 1957; Twiss, 1959)[3] are more extensive and varied. They everywhere underlie the main body of the formation except at a few places on the higher parts of the pre-Hueco surface where they wedge out by overlap. The Powwow Member of the Sierra Diablo region is formed of varicolored coarse to fine clastic rocks, which become coarser downward and southward, and pass upward and northward into marl and thin beds of limestone that are conformable with the main body of the formation. All the Powwow strata are poorly resistant to erosion and form slopes between the ledges above and below, on which exposures are likely to occur only in ravines; in places the Powwow has been mapped principally by its topographic expression. As in other transgressive deposits, fossils occur only in the more marly or limy beds above the base; these fossils are like those in the main body of the formation which succeeds it, and their facies vary in the same manner as those of the fossils of the overlying strata.

The main body of the Hueco Limestone is not divisible into units except in local areas, but its lithology and faunas vary significantly from place to place (fig. 4). Toward the south and southwest it is a thin- to thick-bedded gray calcitic limestone with a well-defined but rather restricted invertebrate assemblage. Farther northeast, as in the Baylor Mountains and the central and northern Sierra Diablo, much of the main body is a thin-beded dolomitic limestone, containing few fossils other than fusulinids. However, in the same area the basal Powwow member contains invertebrate fossils much more varied than those farther southwest. This fossil assemblage extends in places into the main body and occupies all of it near Victorio Peak; here it occurs in thin- to thick-bedded calcitic limestone, unlike the prevailing dolomitic limestone of the vicinity.

The calcitic southern and southwestern facies was deposited on the platform of Hueco time. The other two facies to the northeast were deposited nearer the basin of Hueco time. However, the facies of the Hueco seem to be little related to the Victorio flexure, which markedly influenced the distribution of facies in the succeeding Bone Spring deposits.

SOUTHERN PART OF REPORT AREA

In the southern part of the report area the Powwow Member is thick and coarsely clastic at most places; the main body of the formation is of the calcitic southern and southwestern facies. The full sequence of the Hueco is exposed in the Wylie Mountains (geologic section 13, pl. 5), but only partial sections of the lower part are preserved farther west where, in places, the eroded top of the formation is overlain by Cretaceous strata. Among the better exposed sections to the west are those on Threemile Mountain northwest of Van Horn (geologic sec. 15, pl. 5) and on the butte northwest of Eagle Flat section house at the south end of the Streeruwitz Hills (geologic section 20, pl. 6).

[3] Hay-Roe and Twiss class the Powwow as a formation separate from the Hueco Limestone, which they restrict to the main body of the formation of present terminology.

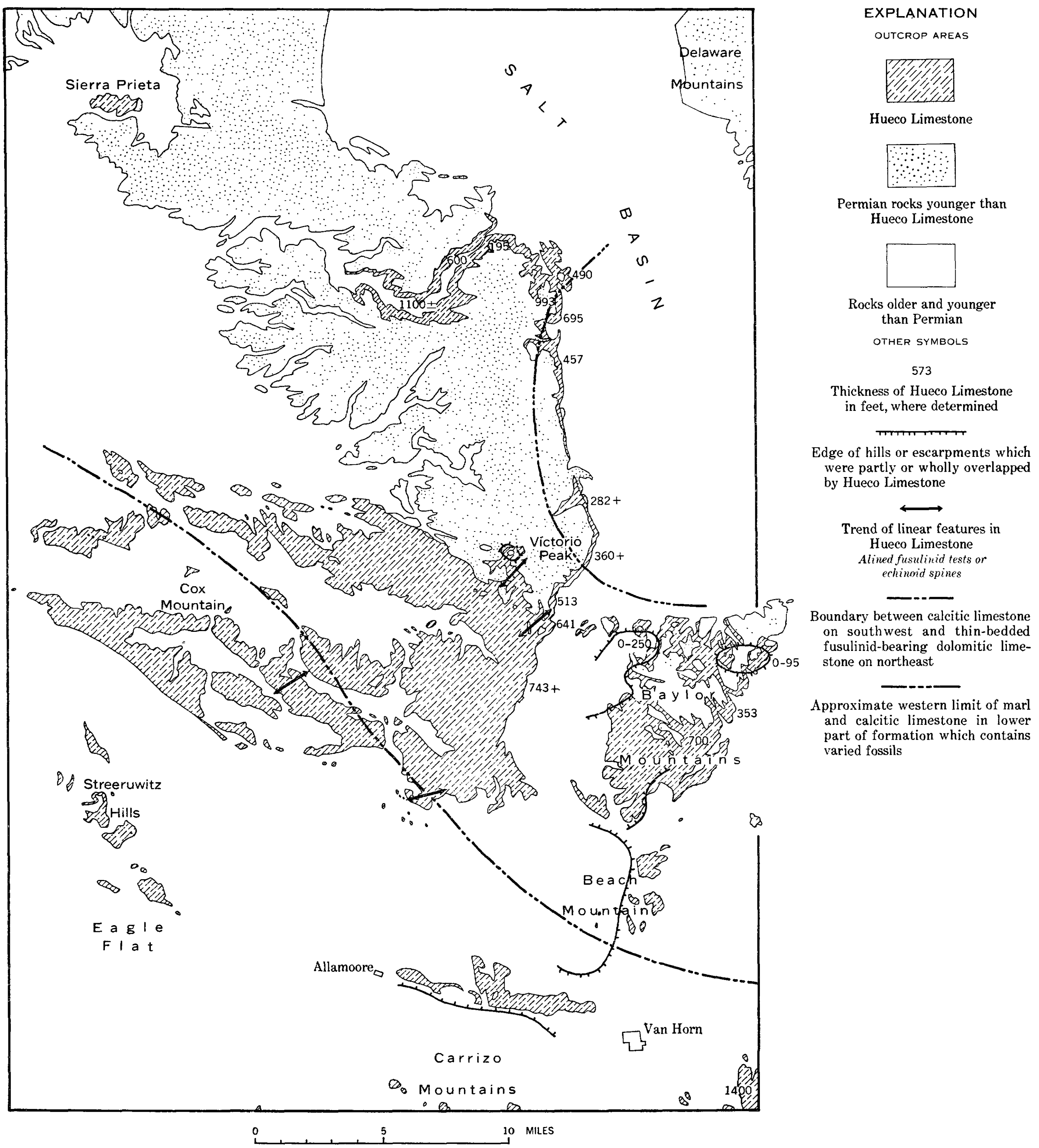


FIGURE 4.—Map of Sierra Diablo region showing paleotectonics of Hueco Limestone.

In the southern part of the report area the Powwow Member lies mainly on various Precambrian and Precambrian(?) formations, although on Beach Mountain it extends onto Ordovician rocks. Its basal surface was moderately irregular, as shown by large variations in thickness of the member within short distances and by variations in the character and volume of the coarser clastic constituents. In the Wylie and Carrizo Mountains these variations indicate a basal topography with a relief of several hundred feet (Flawn, in King, P. B., and Flawn, P. T., 1953, p. 34–35, 43; Hay-Roe, 1957; Twiss, 1959). In the Carrizo Mountains, Powwow deposits were laid against a north-facing scarp along the Hillside fault. North of the fault the Powwow is as much as 250 feet thick and overlies the Van Horn Sandstone, but it contains abundant angular fragments of the metarhyolite that intrudes the Carrizo Mountain Formation south of the fault. These fragments decrease in abundance and coarseness northward, where they are intermingled with fragments from other sources (King, in King, P. B., and Flawn, P. T., 1953, p. 99). The Ordovician carbonate rocks of Beach Mountain must have projected as an erosion remnant on the pre-Hueco surface. At Threemile Mountain the basal 70 feet of the Powwow is a lenticular mass of limestone pebbles and cobbles of the El Paso Limestone, evidently derived from talus of an ancestral Beach Mountain, not far to the north.

Aside from the breccia and conglomerate derived from earlier rocks, much of the Powwow in the southern area is bedded coarse sandstone, partly arkosic, of vermilion-red, purple, brown, or yellow hues. Some of this sandstone was assigned to the Van Horn by earlier geologists (Richardson, 1914, p. 4; Baker, 1927, p. 9), but its true age is indicated not only by its more varied nature, but by its unconformable relations below and conformable relations above.

The coarsely clastic and varicolored parts of the Powwow are succeeded at most places by more calcareous strata, mainly gray or yellow calcareous shale or marl, but they include thin intercalated limestone beds. These strata are fossiliferous—the fossils weathering free on the surface in places—and they have yielded large collections at Threemile Mountain and in the Streeruwitz Hills.

The overlying main body of the formation is stratified limestone in thin to thick beds, mainly gray and calcitic, but with some more dolomitic layers, and with many poorly resistant marly partings; a few of the beds contain small chert concretions. The main body characteristically forms ledges and slopes. The limestone beds contain an abundant but restricted invertebrate fauna that includes minute staffellid foraminifers, echinoid spines and plates, and a few brachiopods. The marly layers contain mollusks, particularly poorly preserved bellerophontoid gastropods. Fusulinids are lacking in most places, although a few stray forms have been discovered. They are abundant about 500 feet above the base in the Wylie Mountains, at a level higher than any strata preserved farther west, as at Threemile Mountain and Eagle Flat.

Farther north this calcitic limestone changes into more dolomitic fusulinid-bearing limestone. In exposures on the east side of Beach Mountain (geologic section 16), both the main body of the Hueco and the Powwow Member are dolomitic, but the same fossil assemblage occurs as farther south, here nearly destroyed by dolomitization. Along the south-facing escarpment of the Sierra Diablo, dolomitic layers come in gradually eastward, by interbedding and intertonguing, and fusulinids increase correspondingly. On the escarpment above the Hazel mine (geologic section 25, pl. 6) the main body of the Hueco is largely thin-bedded dolomitic limestone, which is different from the limestone farther south and west and contains many fusulinids. The boundary between the calcitic and dolomitic facies of the main body of the Hueco is traceable northwestward from the Old Circle Ranch (geologic section 24, pl. 6) across low exposures in the southern part of the Sierra Diablo.

BAYLOR MOUNTAINS

In the Baylor Mountains the Hueco Limestone lies with angular and erosional unconformity on older Paleozoic rocks, mainly the El Paso, Montoya, and Fusselman Formations, and is separated from the Bone Spring Limestone above by a less evident unconformity (fig. 5). The Hueco varies greatly in thickness in different parts of the mountains, by overlap along the unconformity at the base and by truncation along the unconformity at the top.

Striking features of the basal unconformity are hills of older Paleozoic rocks, against and over which the Hueco was deposited (fig. 4). The pre-Hueco hills seem to be most extensive in the northern part of the mountains, near the Victorio flexure, but the west edge of another hill is well exposed at the "unconformity locality" in the southern part (sec. 3, Block 65, Twp. 7) (fig. 5*A*). The edges of some of the hills were steep scarps as much as 200 feet high, near which the basal Hueco contains breccia lenses formed of coarse fragments of the adjacent older rocks. The Hueco was draped over the hills of older rocks, and its strata slope away from them with initial dips, some as steep as 15°.

Draping of the Hueco over the hills of older rocks may account for some of the truncation of its upper surface. At the beginning of Bone Spring time the

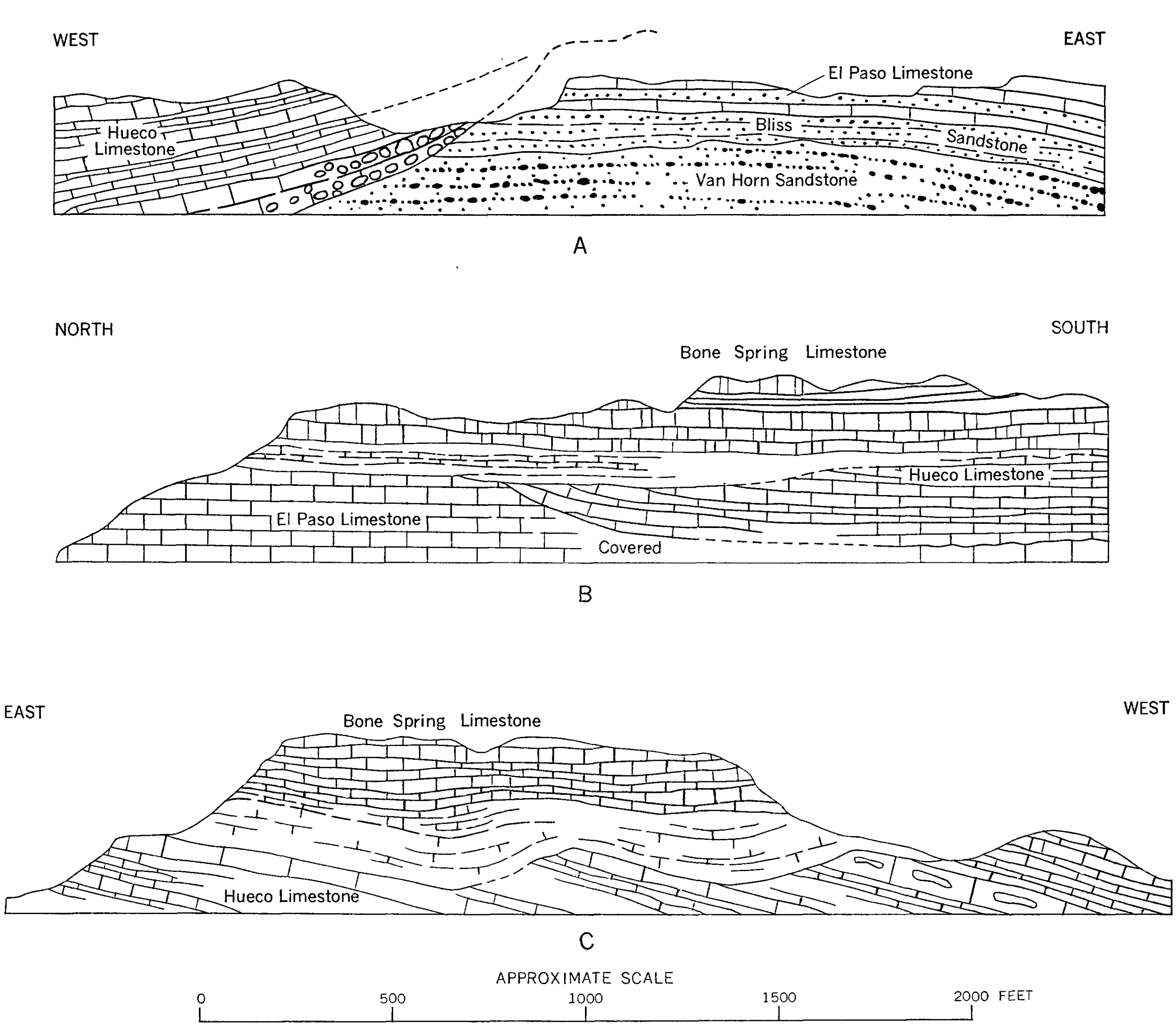


FIGURE 5.—Detailed sections showing unconformities below and above Hueco Limestone in Baylor Mountains. *A*, South end of mountains ("unconformity locality," northwestern part of sec. 23, Block 65, Twp. 7) showing unconformity at base of Hueco and one between Van Horn sandstone (Precambrian?) and Bliss Sandstone (Ordovician). *B*, Northwestern part of mountains (southwestern part of sec. 43, Block 65, Twp. 6) showing unconformities below and above Hueco. *C*, Outlying hill northwest of mountains, west of Texas Highway 54 (center of sec. 9, Block 66, Twp. 6) showing unconformity at top of Hueco.

higher standing parts of the Hueco, over the buried hills, were eroded more than the lower. The most prominent exposure of an angular unconformity between the Hueco and Bone Spring is on a hill in the northwestern Baylor Mountains west of Texas Highway 54 (summit 4410, sec. 9, Block 66, Twp. 6) (fig. 5*C*), where the Bone Spring overlies Hueco strata that dip 7° west or southwest; inclination of the Hueco was probably a primary slope off a hill of El Paso Limestone that is exposed east of the highway.

The Powwow Member is thin in the Baylor Mountains and is missing entirely near the buried hills in the northern part. It is thickest to the southeast, but even here does not exceed 100 feet. Where the Powwow occurs, it is red, buff, and yellow marl and shale interbedded with conglomerate layers containing pebbles of the older Paleozoic carbonate rocks.

The main body of the Hueco Limestone in the Baylor Mountains is largely thin-bedded aphanitic dolomitic limestone, containing few fossils other than molds of small fusulinids. Although few of the limestone beds are thick or massive, the whole unit stands in steep slopes or cliffs. The main body is as much as 700 feet thick along Red Tank Canyon and elsewhere in the southern part of the mountains, but farther north both it and the underlying Powwow thin out. In the northern part of the mountains the Hueco is a dolomitic limestone no more than a few hundred feet thick (geologic sections 18 and 19, pl. 5), and at a few places it is missing entirely on tops of the hills of the underlying rocks (fig. 5*B*; section *Z–Z′*, pl. 4).

CENTRAL SIERRA DIABLO

On the east-facing escarpment of the Sierra Diablo, the Hueco forms a bench or line of cliffs which is at the top to the south of the Victorio flexure, but which descends to the base to the north (pl. 10). The Hueco is also exposed behind the escarpment in Victorio Canyon.

In the central Sierra Diablo the uncomforable base of the Hueco emerges only toward the south and north. South of the Victorio flexure the Hueco lies on red sandstone of the Precambrian Hazel Formation, but it overlies a hill of steeply dipping Montoya Dolomite in Victorio Canyon (section *X–X′*, pl. 4). Where the base is exposed again from Marble Canyon northward, the Hueco lies on higher Paleozoic formations, including rocks of Pennsylvanian age.

The Powwow Member at the base is generally somewhat more than a hundred feet thick, but it is as much as 250 feet thick at a locality south of Victorio Peak (geologic section 27, pl. 6) and another three-quarters of a mile south of Marble Canyon, both probably in local valleys on the pre-Hueco surface. At the east foot of Victorio Peak (geologic section 29, pls. 6, 7), 134 feet is exposed, but the base is not visible. The lower part of the Powwow is clastic, varicolored, and conglomeratic. Conglomerate fragments were derived from the Hazel Formation, the Van Horn Sandstone, and various older Paleozoic formations. The associated sandstone and shale beds are arkosic and red, yellow, or gray. The upper part is yellow or gray marl and shale interbedded with thin layers of limestone, and in places is abundantly fossiliferous. Large collections of invertebrate fossils have been obtained from this part of the Powwow Member near the portals of Victorio, Marble, and Mine Canyons.

The overlying main body of the Hueco is more than 600 feet thick at Bat Cave south of the Victorio flexure (geologic section 26, pl. 6), where the top is not preserved, and about 800 feet thick south of Black John Canyon (geologic section 34, pl. 7), but it is much thinner at nearby localities. At Marble Canyon (geologic section 32, pl. 7) it is 357 feet thick, and at the east base of Victorio Peak (geologic section 29, pls. 6, 7), about 200 feet.

Most of the main body, and especially its upper part, is thin-bedded dark-gray aphanitic dolomitic limestone containing few fossils other than fusulinids, most of which are preserved as molds. Near Marble and Mine Canyons (geologic sections 32 and 33, pl. 7), however, the lower 120–150 feet is thick-bedded blue-gray calcitic limestone, with some intervening thinner beds, which contain fusulinids and other fossils similar to those in the Powwow Member beneath. At the east base of Victorio Peak (geologic section 29, pls. 6, 7), where the main body is exceptionally thin, it is fossiliferous throughout and is all calcitic limestone in thin to thick beds. The thin beds are dark gray to black, with wavy bedding surfaces, irregular chert nodules, and partings of marl. The thick beds are light gray and cherty and are lenticular or moundlike; some are brecciated. At the top is an especially thick lens or reef body (the "Křiž lens" of Dunbar, 1953, p. 802), a quarter of a mile across and 115 feet thick at the apex. It is mostly massive gray limestone containing sponges, corals, massive bryozoans, and a few other fossils, but it is brecciated at its edges. The succeeding Bone Spring beds overlap the lens.

APACHE CANYON AREA

At the lower end of Apache Canyon the Powwow Member is thin or missing, and the overlying main body of the formation is less than 200 feet thick (geologic section 36, pl. 8). The Hueco dips southwestward at an angle of a few degrees up the canyon, but its top, overlain unconformably by Bone Spring Limestone, rises a thousand feet in the same direction (pl. 11; section *U–U′*, pl. 4). The Hueco thus forms as much as the lower half of the walls and the canyon in its middle and upper course, but the beds exposed are younger and higher than those at the lower end. The whole of the formation is not exposed-in the upper part of the canyon, but matching of units in different sections suggests that it is more than 1,100 feet thick.

Three subdivisions of the Hueco Limestone are recognizable in the canyon, designated as divisions A, B, and C in geologic sections 37, 38, 39, and 40 (pl. 8). Division A at the base is about 400 feet thick; it is thick-bedded dolomitic limestone, weathering brown and craggy, and contains some interbedded thinner layers. Division B, about 250 feet thick, is light-gray to dark-gray calcitic limestone, resembling the southwestern facies of the formation, which forms ledges that are lighter gray and less massive than those of the divisions below and above. Division C is preserved only in the headwaters of the canyon, where it is about 400 feet thick; it is thick-bedded dolomitic limestone like division A. In places it contains thin interbedded layers of porcelaneous dolomite that weather white and splintery. All the divisions contain abundant fusulinids, but other fossils are scarce. The three subdivisions are local units that have no counterparts elsewhere in the Sierra Diablo region; they have probably been produced by intertonguing of the northeastern and southwestern facies of the formation.

Northwest of the head of Apache Canyon the Hueco is exposed in an uplift on the south side of the Sierra Prieta, over an area of a few square miles. About 550 feet of beds emerge, whose base is cut off by the igneous rock (geologic section 42, pl. 8). Most of the limestone is dolomitic and resembles the upper part of the Hueco in the head of Apache Canyon.

FOSSILS AND CORRELATION

Smaller foraminifers occur in nearly all parts of the Hueco Limestone, but the larger foraminifers, the fusulinids, are vastly more abundant in the northeastern part of the region (table 2). In the marl and calcitic limestone of the lower part in the northeastern sections, fusulinids are associated with varied fossil of other phyla, but in the dolomitic limestone of the upper part they crowd the layers, almost to the exclusion of other fossils. In the calcitic limestone of the southern and southwestern area, fusulinids are strangely rare, except for a zone about 500 feet above the base in the Wylie Mountains and small staffellids which are common in many layers.

The fusulinid fauna of the Hueco Limestone in the Sierra Diablo region is notable for the abundance of small species (Dunbar and Skinner, 1937, p. 589), especially *Parafusulina linearis* (Dunbar and Skinner), *Pseudofusulina emaciata* (Beede), *P. powwowensis* (Dunbar and Skinner), *Schubertella kingi* Dunbar and Skinner, and *Schwagerina bellula* Dunbar and Skinner. This assemblage furnishes a ready field criterion for distinguishing the Hueco from the overlying Bone Spring, with its perceptibly larger forms of fusulinids. In some layers of the Hueco the small species are associated with species of the larger, more robust genus *Pseudoschwagerina*. The characteristic fusulinids of the Hueco seem to range throughout the formation and have been observed low in some sections, high in others (table 2); no zonation within the formation is apparent from the available data.

The remaining fossil groups, as noted in the stratigraphic descriptions, are markedly differentiated into southwestern and northeastern facies that correspond to lithologic differences between the strata in the two areas.

The fauna of the southwestern facies is well-defined but little varied, and is remarkably alike at all localities (table 3). The most abundant brachiopods are the productoids *Dictyoclostus wolfcampensis* (King), *D.* (n. subgen.) cf. *D. hessensis* (King), and the nonproductid *Composita*, particularly *C. subtilita* (Hall). *Hustedia* was observed at many places in the field, but it is scantily represented in the collections. *Dielasma* is abundant at a few localities, but rare elsewhere. Mollusca, especially gastropods and pelecypods, are numerically as abundant as the brachiopods, but are equally restricted as to kind. The most widely distributed gastropods are bellerophontaceans, mainly preserved as steinkerns (Yochelson, 1960, p. 216). Less abundant are species of *Omphalotrochus*, *Straparollus* (*Euomphalus*), and *Meekospira.* The pelecypods include species of *Allorisma*, *Aviculipinna*, and *Septimyalina.* Fragments of the scaphopod *Plagioglypta* occur at many localities. Of the remaining fossil groups perhaps the most abundant are echinoids, but these are preserved only as detached spines and plates that are probably specifically indeterminate by modern standards. The only other fossils of interest are dasycladacean algae, which occur at a locality on the south-facing escarpment of the Sierra Diablo southwest of the former McAdoo Ranch (geologic section 22, pl. 6); these probably lived in an environment of very shallow tropical to subtropical waters (P. E. Cloud, written commun., 1954).

Fossils in the marl and calcitic limestone of the lower part of the Hueco in the northeastern part of the region show a much greater diversity, especially among the brachiopods (table 4). *Dictyoclostus wolfcampensis* (King) and species of *Composita* occur here as farther southwest, but they are overshadowed by other genera and species, including *Dictyoclostus* (*Chaoiella*) aff. *D. boliviensis* (d'Orbigny), *Buxtonia* (*Kochiproductus*) *victorioensis* King, species of *Linoproductus*, "*Marginifera*" (*Kozlowskia*) *capaci* (d'Orbigny), "*Marginifera*" aff. "*M.*" *lasallensis* (Worthen), "*Marginifera*" (*Kozlowskia*) cf. "*M.*" *wabashensis* (Norwood and Pratten), and a fine-spined species of *Waagenoconcha.* Mollusks are numerically and taxonomically less abundant, and include much the same assemblage as in the southwestern area, with the addition of a few orthoceratid cephalopods. Corals occur at many localities, and bryozoans are abundant at a few, especially in the Powwow Member near the mouths of Marble and Mine Canyons.

REGIONAL RELATIONS OF FAUNA

All the fusulinid species of the Hueco Limestone occur in beds of Wolfcamp age throughout a wide region in the Southwestern States. However, according to L. G. Henbest (written commun., 1955), most of them characterize more particularly bed 14 and higher parts of the Wolfcamp at its type section in the Glass Mountains, and he suggests that the highest fusulinid-bearing layers in the Hueco Limestone of the Sierra Diablo

TABLE 2.—*Foraminifera identified from Hueco*

[Identifications by L. G. Henbest. Explanation of symbols: ×, genus or species present; var, variety of species present; cfr, specimen

	Distribution of fossils in stratigraphic section,														
	26—Bat Cave					Sheep Peak area				27—Second section south of Victorio Peak	Victorio flexure				
	F 2690	F 2693	F 2714	F 2703	F 2719	F 2712	F 2701	F 2695	F 2704	F 9823	F 9810	F 9807	F 9811	F 2718	F 9806
Foraminifera:															
Bradyinid sp											×				
Climacamina spp					×			×		×			×		×
Endothyra sp	×								?	?	×				
Geinitzina sp			×				×	×			×			×	
Geinitzina or *Spandelina* sp										×					
Millerellid sp	×													×	
Osagia [1] *incrustata* Twenhofel	×														
Ozawainella huecoensis Dunbar and Skinner															
sp	?											?		?	
Parafusulina linearis (Dunbar and Skinner)	×	var	var			cfr		?		aff	×		×		
spp												?			
Paraschwagerina gigantea (White)															
Pseudofusulina emaciata (Beede)											×				
fraklinensis (Dunbar and Skinner)															
gracilitatis (Dunbar and Skinner) var															
huecoensis (Dunbar and Skinner)															
powwowensis (Dunbar and Skinner)	×	?										aff		aff	cfr
uddeni (Dunbar and Skinner)										?					
sp				?			?					×	?	×	×
Pseudoschwagerina beedei Dunbar and Skinner	×						×				×				
?*Pseudoschwagerina beedei* Dunbar and Skinner						×									
Pseudoschwagerina? *laxissima* (Dunbar and Skinner)															
Pseudoschwagerina texana Dunbar and Skinner			×					var							
var. *ultima* Dunbar and Skinner															
uddeni (Beede and Knicker)															
sp															
Schubertella kingi Dunbar and Skinner		?	?	×	×			×	?	?	?	×	×		
sp							×								?
Schwagerina bellula Dunbar and Skinner		?		×				×					?		
?*Schwagerina bellula* Dunbar and Skinner	×					×									
Schwagerina kawkinsi Dunbar and Skinner															
Schwagerina? *hessensis* Dunbar and Skinner															
Schwagerina knighti Dunbar and Skinner															
sp					×				×			×	?	?	
Spandelina sp	×							×		×	×				
Spandelinoides sp							×								
Spandelinid sp												×			×
Staffella lacunosa Dunbar and Skinner															
sp	×			×							×		×	×	
Tetrataxis sp	×							×		×	×	×		×	×
Textulariidae	×														
Tolypamminid sp	×														
Trepeilopsis sp	×														
Triticites subventricosus Dunbar and Skinner					aff		×		aff						
ventricosus (Meek and Hayden) var															
victorioensis Dunbar and Skinner															
spp								×							

[1] *Osagia* is a consortium or an alternative association of incrusting algae and tubiform, sedentary foraminifers of the subfamily Cornuspirinae.

region may be younger than any beds preserved in the type Wolfcamp.

Differentiation of the Hueco faunas into a northeastern and southwestern facies may represent a transition from a fauna like that of the type Wolfcamp into one like that of the type Hueco, although available collections from the Sierra Diablo region are not so varied as those from either of these units in their type areas. Presumably the differentiation expresses a change from a depositional environment of shale, marl, and limestone in the basin area to one of dominant limestone in the platform area. However, the differences are mainly in relative abundance of species and groups rather than in the gross assemblages. Thus, R. E. King (1931, p. 14) has noted the identity of many brachiopod species of the northeastern facies to those in the type Wolfcamp, but some of the brachiopods of this facies, such as *Buxtonia* (*Kochiproductus*) *victorioensis* King and *Dictyoclostus* (*Chaoiella*) aff. *D. boliviensis* (d'Orbigny), also occur in the lower part of the Hueco near Powwow Canyon in the Hueco Mountains.

Many of the brachiopods and gastropods of the Hueco fauna are very similar to, or specifically identical with, those in the upper part of the Cisco Group and in the Wichita Group of central Texas. Brachiopods in the Camp Creek Shale Member of the Pueblo Formation are like those in the Hueco, and *Dictyoclostus* (*Chaoiella*) aff. *D. boliviensis* (d'Orbigny) is abundant there.

Limestone in central and northern Sierra Diablo

compared with the species listed; aff, specimen related to species but probably different; ?, specimen doubtfully assigned to genus or species]

locality, and collection number indicated

29b—Victorio Peak							30—Victorio Canyon		31—North of Victorio Canyon				32—Marble Canyon	37—First section in Apache Canyon	38—Second section in Apache Canyon				39—Third section in Apache Canyon		41—Apache Tank	42—Sierra Prieta
F 2700	F 2689	F 2707	F 2715	F 2687	F 2721	F 2706	F 2694	F 2717	F 2699	F 2722	F 2708	F 2702	F 2718 B	F 9826	F 3805	F 9830	F 9831	F 9832	F 9829	F 9828	F 9805	F 9838
										×			×							×		
		×						×				×	×				×			×		×
		×						×					×		×							
	×	×			×			×					×			×			×	×		×
													?									
							×	×														
×		×			var	×	var	×	×	var	×					×	var	var				
		×						×														
													×									
																	?			×		
			×		×																	
																	?					
								×					× var									
						×	×			?		?	×				×					
																					aff	
											×			×	?							
		×										×								cfr		
		×	×	×							×							×				
			×					×								×						
													×									
													×					?				
						×					×											
				×	×			×			×	×	×	×	×	var	×		×	?		
							×		?												?	
		?		×			?			?				?				?				
		×				×																
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										×											?	
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		×																	×	×		×
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		×										×						×	×			
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										aff												
															?							
			×																			
								?							×			×				

On the other hand, the Hueco gastropods resemble those at somewhat higher levels in the central Texas section. The Hueco species of *Straparollus* (*Euomphalus*) and *Naticopsis* occur in the Grape Creek Limestone Member of the Clyde Formation, and those of *Omphalotrochus* extend as high as the Lueders Limestone.

Faunas like those in the Hueco also extend well to the west of Texas; for example, Williams (in Gilluly and others, 1954, p. 39–41) has compared the Hueco fauna with that of the Colina Limestone of the Naco Group in southern Arizona.

STRATIGRAPHIC RELATIONS

As indicated above, the Hueco Limestone lies unconformably on all the earlier rocks of the sequence throughout the Sierra Diablo region (fig. 2). During the latter part of Pennsylvanian time these rocks were broadly folded, locally faulted, and greatly eroded. Erosion penetrated deepest in the more uplifted area to the south and southwest, where the Hueco was deposited on the Precambrian and Precambrian(?) formations. Earlier Paleozoic formations (the El Paso, Montoya, and Fusselman Formations) were preserved from pre-Hueco erosion in synclinal areas in Beach Mountain and the Baylor Mountains. Later Paleozoic formations (the Barnett Shale and Pennsylvanian rocks) were similarly preserved in a deeper synclinal area in the northeastern Sierra Diablo. In many places erosion progressed so far that the Hueco was deposited on a nearly level surface, but in others it was laid

TABLE 3.—*Fossils identified from Hueco Limestone of southern calcitic limestone facies*

[Identifications by P. E. Cloud, Jr., Helen Duncan, R. M. Finks, L. G. Henbest, and E. L. Yochelson. Explanation of symbols.—Under Foraminifera: ×, species or genus present; ?, specimen doubtfully assigned to genus or species. Under other biological groups: A, abundant; C, common; X, present; R, rare]

Distribution of fossils in stratigraphic section, locality, and collection number indicator

	13—Wylie Mountains		15—Threemile Mountain		Near Threemile Mountain		20—Eagle Flat		20—Streeruwitz Hills			22—McAdoo Ranch	Near Sheep Peak
	7005	7005x	14430	6937 14437 F 2718c F 9812	14438 F 9813	14426	7028	7008	7003 7003a 14431 F 9808	7003b	14432 F 9809	7013 7013a 7013b	14424
Foraminifera:													
Bradyina sp									?		?		
Ozawainella sp				×							×		
Schubertella kingi Dunbar and Skinner										?			
Schubertella sp					×								
Schwagerina knighti Dunbar and Skinner									×				
Spandelinids					×				×		×		
Staffella sp				×	×						×		
Triticites or *Pseudofusulina* sp									×				
Porifera:													
Wewokella (*Talpaspongia*) *clavata* (R. H. King)				×							A		
Sponge indet				×									
Coelenterata:													
Syringopora sp				×									
Horn coral indet									C	R			
Compound coral indet				×									
Echinodermata:													
Echinoid spines and plates	R			C		×			R	A	R		
Bryozoa:													
Fenestella sp				×			R						
Fistulipora sp				×						×			
Polypora sp		×		R			R			×			
Rhombopora sp							×						
Septopora sp									×	×			
Streblotrypa sp										R			
Bryozoans indet., encrusting, massive, and fenestrate types			×	R	R								
Brachiopoda:													
Cleiothyridina sp							×			C			
Composita cf. *C. subtilita* (Hall)	R		×	A		×		R	C	A	A		R
sp		×			R		A		R				
Crurithyris? sp				C						R			
Dictyoclostus (n. subgen.) cf. *D. hessensis* (King)	×				C								
wolfcampensis (King)	A		A	A	×	R	A	×	R	A	C		
Dielasma aff. *D. bovidens* (Morton)			×	×			×						
spp				A			R		C	R			
Hustedia mormoni (Marcov)				C									
sp									×				
Meekella? sp				×									
Wellerella sp										×			
Lamellibranchiata:													
Allorisma? sp				×					×				
Aviculopecten sp	×			×									
Aviculopinna sp				×									
Myalinid indet				×			×			×			
Nucula sp										R			
Parallelodontid indet													C
Pseudomonotis sp				×			R		×				
Septimyalina sp				×									
Gastropoda:													
Bellerophon huecoensis Yochelson										×			
parvicristatus Yochelson				R			R						A
Bellerophontid indet	C		A	C	C		×	×	A	R	×	×	
Euconospira cf. *E. missouriensis* (Swallow)				×			R			×			
Knightites (*Retispira*) sp								×	×				
(*Knightites*) sp							×						
Loxonematacean indet				×			A						
Meekospira sp				R									C
Murchisonid indet													×
Naticopsis spp				×			×	×		R			R
Omphalotrochus obtusispira (Shumard)			×	C		×			×				
sp	×	×			R			×					
Peruvispira sp													R
Stegocoelia? sp				×	×								C
Straparollus (*Euomphalus*) *cornudanus* (Shumard)			C	A	C		A	×		A	A	×	A
Sublitid indet				×	×								
Worthenia sp													R
Scaphopoda:													
Plagioglypta? sp			×	C			C		×	C			
Cephalopoda:													
Nautiloid indet										×			
Arthropoda:													
Ostracodes indet				×									
Plants:													
Mizzia? sp												×	
Dasycladacean algae indet												×	
Plant fragments									×				

TABLE 4.—*Fossils identified from Hueco Limestone, from marl and calcitic limestone in lower part, in northeastern Sierra Diablo (exclusive of Foraminifera)*

[Identifications by P. E. Cloud, Jr., Helen Duncan, R. M. Finks, and E. L. Yochelson. Explanation of symbols: A, abundant; C, common; ×, present; R, rare]

Distribution of fossils in stratigraphic section, locality, and collection number indicated														
Number	27—Second section south of Victorio Peak	Victorio flexure	29—Victorio Peak				30—Victorio Canyon	31—North of Victorio Canyon	32—Marble Canyon		33—Mine Canyon			34—South of Black John Canyon
	14452	14429	8553	8554	8555	8556	8557	8558	8551	8550 7050	7001a 7004 8552	7004a	7001	7056
Porifera:														
Heliospongia vokesi R. H. King		×												
Steriedictyum orthoplectum Finks											×			
Coelenterata:														
Campophyllum sp											C			
Caninia? sp	×													
Chaetetes sp													×	
Clisiophyllum sp												×		
Lithostrotian sp											R			
Lophophyllum sp					R	C				×		×		
Syringopora sp			×											
cf. *Waagenophyllum texanum* Heritsch				×										
Horn coral indet		C												
Echinodermata:														
Crinoid stems, plates, or calyces		R			×					×	A	C		
Echinoid spines and plates		×								×	C	R	×	
Bryozoa:														
Anisotrypa sp											×	C		
Cystodictya sp					×						R	C		
Fenestella spp										R	×			
Fistulipora sp										×	C	C		
Goniocladia sp					×									
Meekopora sp											C			
Polypora sp											C	C		
Rhomboporoid indet		C												
Septopora sp										×	A	R		
Stenopora sp							R	R			A	R		
Brachiopoda:														
Aulosteges? sp	×													
Avonia (n. subgen.) cf. *A. boulei* (Kozlowski)						C	×							
Avonia sp							×							
Buxtonia (*Kochiproductus*) *victorioensis* King					A		C	×			×			
Chonetes cf. *C. consanguineus* Girty					C									
Chonetes sp		×	×			×	A	A		R				
Cleiothyridina sp										R		×		
Composita sp	R				R		×			A	C	R		×
Crurithyris sp							×			C				
Derbyia sp					C		×		×			×		
Dictyoclostus (*Chaoiella*) aff. *D. boliviensis* (d'Orbigny)					A					C	C	C	R	
(n. subgen.) cf. *D. hessensis* (King)	×	R			A	C				C	R	×	R	
wolfcampensis (King)	R		R				C			C	×	C		
sp											R			
Dielasma sp												×		
Enteletes aff. *E. wordensis* King					C						×			
Glossothyropsis sp	×													
Hustedia sp					×						C	×	×	
Isogramma sp										R				
Linoproductus cf. *L. cora* (d'Orbigny)			C				A	R						
Linoproductus? (cf. *Cancrinella*) sp														×
Linoproductus sp	×				A				C	×	×			×
"*Marginifera*" (*Kozlowskia*) *capaci* (d'Orbigny)										×	C			
n. spp. aff. "*M.*" *lasallensis* (Worthen)	×						×							
cf. "*M.*" *wabashensis* (Norwood and Pratten)					A						C	A		
"*Marginifera*"? sp					×	×								
Neospirifer spp	×				R	R							×	
Productid indet						×		×			×		×	
Punctospirifer sp		×												
Rhipidomella sp					A	×					R	R		
Rhynchopora sp											R			
Schizophoria sp										R	×			
Spirifer sp					C									
"*Spiriferina*" sp					×									
Squamularia sp							×			×	C	C		
Waagenococnha sp	×				A									
Lamellibranchiata:														
Allorisma sp							R							
Aviculopecten? sp					×		R			×	×			
Aviculopinna sp. and *Aviculopinna*? sp					×		×							
Conocardium sp					×									
Cypricardinia sp												×		
Edmondia sp			×											
Myalinid indet							×							
"*Nucula*" sp							×							
Parallelodontid indet							×							
Pseudomonotis sp							×							
Septimyalina? sp										×				

TABLE 4.—*Fossils indentified from Hucco Limestone, from marl and calcitic limestone in lower part, in northeastern Sierra Diablo (exclusive of Foraminifera)*—Continued

[Identifications by P. E. Cloud, Jr., Helen Duncan, R. M. Finks, and E. L. Yochelson. Explanation of symbols: A, abundant; C, common; X, present; R, rare]

Number	Distribution of fossils in stratigraphic section, locality, and collection number indicated													
	27—Second section south of Victorio Peak	Victorio flexure	29—Victorio Peak				30—Victorio Canyon	31—North of Victorio Canyon	32—Marble Canyon		33—Mine Canyon			34—South of Black John Canyon
	14452	14429	8553	8554	8555	8556	8557	8558	8551	8550 7050	7001a 7004 8552	7004a	7001	7056
Gastropoda:														
Amphiscapha cf. *A. muricata* (Knight)										R				
"*Anomphalus*" sp		R												
Bellerophontid indet		R					X			R				
"*Donaldina*" sp							X							
Euconispira cf. E. *missouriensis* (Shumard)							X							
Loxonematia indet											X			
Murchisonid indet		X					X							
Naticopsis sp							X			X	X			
Omphalotrochus obtusispira (Shumard)										X	X			
sp				X		X								
Pharkidonotus sp										X				
Platyceras sp												X		
Pleurotomarian n. gen		X					X							
Pseudozygopleuroid n. gen							X							
Straparollus (*Euomphalus*) sp		X												
Cephalopoda:														
Orthoceratid indet						X				X				
Annelida:														
Spirorbis sp	C													
Arthropoda:														
Trilobite indet										X	X			

over hills and valleys with a relief of several hundred feet.

Similar pre-Permian deformation and erosion occurred in the Hueco Mountains farther northwest (King, P. B., King, R. E., and Knight, J. B., 1945), and it may correspond approximately to the climax of deformation in the Ouachita fold belt of the Marathon area to the southeast (King, P. B., 1937, p. 134–136). However, in many of the ranges of southern New Mexico the sequence is nearly complete from the Pennsylvanian into the Permian, and any unconformity between them is slight or local. Conformable relations between Pennsylvanian and Permian strata are also indicated by drilling in the West Texas basin to the east. In the part of Texas and New Mexico northwest of the Ouachita fold belt, pre-Permian deformation and erosion was probably greatest in the positive areas and was slight or lacking in the negative areas.

The top of the Hueco, where preserved, is likewise an unconformity. In the southwestern part of the Sierra Diablo region, the Hueco is overlain by Cretaceous rocks, and has been variably truncated by pre-Cretaceous erosion. Farther north the Bone Spring Limestone is preserved, and also lies unconformably on the Hueco—certainly in many places, and perhaps everywhere. The unconformity is most evident along the edges of the basin of Bone Spring time, in Apache Canyon, on the Victorio flexure south of Victorio Peak, and in the northern Baylor Mountains, where Hueco strata are angularly truncated. Here also, as described below, the Bone Spring overlaps the Hueco surface and passes into marginal reefs, banks, and pebble beds, the latter containing fusulinids reworked from the Hueco. Field evidence is less conclusive for an unconformity between the Hueco and Bone Spring elsewhere, as in the segment of the Sierra Diablo scarp between Victorio Peak and Apache Canyon; but the large variations in thickness of the Hueco in this segment may have been caused partly by erosion of its top. Very likely the unconformity at the top of the Hueco fades out into the basin area, like the one at the base, but its disappearance may be northeast of any outcrops in the Sierra Diablo region.

BONE SPRING LIMESTONE

The second formation of the Permian System in the Sierra Diablo region is the Bone Spring Limestone, named for exposures in Bone Canyon below Bone Spring, in the Guadalupe Mountains north of the Sierra Diablo (Blanchard and Davis, 1929, p. 961).

The type Bone Spring, and that farther south in the Guadalupe and Delaware Mountains, is "black limestone" (the "basal black limestone" of Girty, 1908, p. 10), but in previous reports the term Bone Spring has been applied also to rocks of other sorts, laid down in different environments, the gray Victorio Peak Limestone (King, P. B., and King, R. E., 1929, p. 922) and the Cutoff Shale (King, P. B., 1942, p. 569–570); it has thus been used for all strata of Leonard age in the northern Trans-Pecos Region.

However, the term Leonard Series is adequate to express time-stratigraphic relations in northern Trans-Pecos Texas. Moreover, the Victorio Peak Limestone and Cutoff Shale are thick persistent units with their own special characters in the shelf and platform areas. It is therefore appropriate to restrict the Bone Spring to deposits primarily of basin facies like those at the type locality and to class the Victorio Peak Limestone and Cutoff Shale as other formations of the Leonard Series. In the Delaware basin area, represented by exposures in the Delaware Mountains in the northeast corner of the report area, the Bone Spring occupies the whole of the Leonard interval; but in the Sierra Diablo it occupies only the lower part and is succeeded by the Victorio Peak and Cutoff, of later Leonard age. The Bone Spring Limestone of the Sierra Diablo region has its own assemblage of marginal deposits, different from those of the units above.

OUTCROP

The Bone Spring Limestone, as thus restricted, crops out at midheight on the east-facing escarpment of the Sierra Diablo from near Victorio Peak northward past Apache Canyon, where it is a little less than a thousand feet thick (pl. 1). Most of it is black limestone that characteristically forms a smoothly rounded slope between the bench of Hueco Limestone below and the cliff of Victorio Peak Limestone above, but the slope is interrupted by ledges in the lower part (pl. 10). Similar rocks are preserved in a large outlier in the northern Baylor Mountains, and form the lower part of the west-facing escarpment of the Delaware Mountains, as in the northeast corner of the report area. Marginal deposits of the Bone Spring, mainly thinner and including ledge-making limestone reefs and banks, are exposed on the Sierra Diablo escarpment near Mine and Marble Canyons and south of Victorio Peak, as well as in the central Baylor Mountains, but they are best shown in cross section on the walls of Apache and Victorio Canyons behind the escarpment.

LITHOLOGY AND FACIES

The dominant rock of the Bone Spring is "black limestone" which, in the type area in the Guadalupe Mountains, is a fine-grained impure limestone in beds a few inches thick, colored dark gray or black by bituminous material (King, P. B., 1948, p. 14–15). Elsewhere—in the Delaware Mountains, the Sierra Diablo, and the Baylor Mountains—the facies called black limestone is more varied, as it includes both thinner and thicker black limestone beds and thinly fissile black or brown siliceous shale. Layers of the black limestone dip irregularly, especially near the marginal areas. Irregularly dipping layers are extensive and well exposed in the Guadalupe Mountains (King, P. B., 1948, p. 15–16; Newell and others, 1953, p. 86–88), and occur also in the Sierra Diablo region.

In the Delaware Mountains in the northeastern part of the report area, well out in the basin of Bone Spring time, the exposed part of the formation is all black limestone; but the lower part of the black limestone in the Sierra Diablo is interbedded with various lighter gray, more clastic or more dolomitic layers, which are mainly tongues of the marginal deposits.

In the Sierra Diablo region black limestone deposits of the basin area are bordered by marginal deposits toward the southwest, whose position coincides with the Babb and Victorio flexures that cross the northern and central parts of the range (fig. 6). Both flexures are downbent northeastward toward the basin and were probably in process of growth during Bone Spring deposition, although they were much accentuated later. One marginal belt extends east-southeastward across Apache Canyon to the front of the mountains near Mine and Marble Canyons and parallels the upper end of the Babb flexure. Along it, the black limestone deposits pass abruptly into limestone reefs which overlap and wedge out against the sloping surface of the Hueco limestone. At the southeast end of the belt the reefs either terminate or bend southwestward beneath a cover of Victorio Peak Limestone to join the marginal deposits along the Victorio flexure. The marginal belt along the Victorio flexure is exposed across the central Sierra Diablo, east-southeastward to the front of the mountains south of Victorio Peak, and reappears in the northern Baylor Mountains. Along it, black limestone interfingers up the dip with thickening limestone banks, which are truncated by erosion at their upper ends and do not wedge out against the older rocks of the flexure.

On the platform at the upper end of the northern marginal belt, at the head of Apache Canyon, the Victorio Peak Limestone is separated from the Hueco Limestone by only a thin wedge of strata, and the area received no deposits during most of Bone Spring time. On the platform at the upper end of the southern marginal belt, in the southern Sierra Diablo and the central Baylor Mountains, Bone Spring Limestone extends over the Hueco a mile or so south of the Victorio flexure. The Bone Spring must have wedged out eventually farther south, because in the Wylie Mountains the Victorio Peak Limestone lies directly on the Hueco.

SIERRA DIABLO ESCARPMENT

Bone Spring Limestone is exposed along the northeastern segment of the Sierra Diablo escarpment from

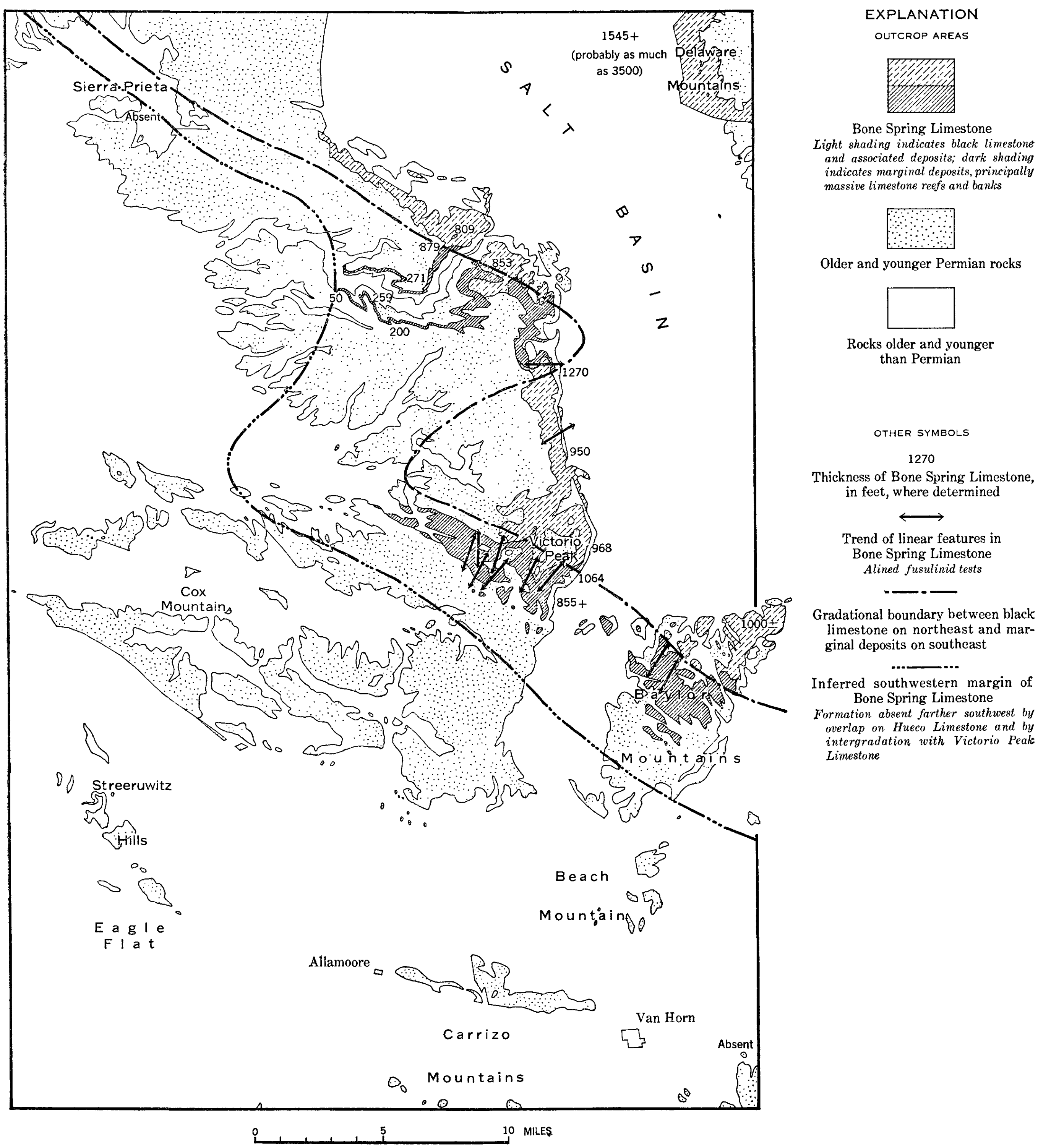

FIGURE 6.—Map of Sierra Diablo region showing paleotectonics of Bone Spring Limestone.

south of Victorio Peak nearly to Babb Canyon, where it passes beneath the surface. In this segment the Bone Spring is mainly black limestone, except for the marginal deposits on the Victorio flexure at the south end and for an interruption of several miles by the reef body near Mine and Marble Canyons. Stehli (1954, p. 273) proposed that the black limestone north of the reef body was deposited in an open basin and that to the south in a deep lagoon behind the reef, but the rocks of the two areas are identical lithologically and faunally and are not likely to have been deposited in different environments.

Most of the Bone Spring in this segment is dark-gray or black dense thin-bedded limestone, which weathers platy, light gray, buff, or brown, and is carved into rounded slopes. Much of it is siliceous or argillaceous; analysis of one specimen indicates 23.65 percent organic insoluble material (King, P. B., 1948, p. 14, specimen 3). Most of the beds are a few inches thick, but some are thicker, others paper thin; parts are featureless within the beds, others very thinly laminated. Some beds contain chert in long thin layers or lenses. Interbedded with the limestone, in places in thick units, is brown platy or papery siliceous shale, which grades locally into stony shale or bedded chert. These limestone and shale beds are nearly unfossiliferous, but some contain spicules, brachiopod shells, and more obscure organic markings. Further details of the nature of the black limestone have been given by Stehli (1954, p. 278).

In many places bedding in the black limestone dips irregularly, at a steeper angle than that of the formations above or below. Irregular bedding on a small scale in the lower part was observed in ravines between Victorio and Marble Canyons, where channels in limestones are filled by limestone of slightly different character, and where some beds are contorted, broken by minor thrusts, and truncated by beds above. Irregular bedding on a larger scale occurs near the marginal belts. In Apache Canyon (geologic sections, 36, 37, and 38, pl. 8) black limestone beds dip away from marginal reefs at angles of 12° to 25° northeastward; at the head of Marble Canyon (geologic section 32, pl. 7) they dip at a lower angle southward. Exposures are generally insufficient to determine the gross pattern or origin of these structures. In part at least they resulted from primary deposition on the slopes of the higher-standing reefs and other marginal deposits; some were probably acentuated by slumping or sliding of the newly deposited sediments.

Interbedded with the black limestone, especially in the lower part of the Bone Spring, are layers of lighter gray thicker bedded limestone, which project as ledges. Many are tongues of the reefs and banks of the marginal belts, and increase toward them in number and thickness. At Victorio Peak and Marble Canyon (geologic sections 29 and 32, pl. 7) they extend as high as 400 feet above the base of the Bone Spring; but farther away from the marginal belts, as near Victorio Canyon (geologic sections 36 and 37, pl. 8), they occupy a smaller interval. In places a hundred feet or so of ledge-making beds succeeds the ledge-making Hueco Limestone, with few partings of black limestone, so that the boundary between the Bone Spring and Hueco is topographically indistinct. However, the rocks above and below the boundary differ in both texture and fossils.

Individual ledge-making beds are a few feet to more than 150 feet thick. Some are well bedded and persist for miles along the outcrop, others pinch or swell within short distances, changing from bedded to massive, and a few are lenses of small extent. The ledge-making beds are partly calcitic but mostly dolomitic, are fine to coarse grained, and in places brecciated. Many beds are crowded with brachiopod and mollusk shells, some of which are silicified, but others contain little else than fusulinids and crinoid columns.

Most of the ledge-making beds are bioclastic and are formed of fossil shells and fragments. Part of the organic material accumulated in place, in patch reefs or more extensive layers; in these Stehli (1954, p. 278) has observed shells still in position of growth. Part was redeposited from growth areas elsewhere, mainly in shallower water, and was spread over the black limestone deposits in broad sheets, or as local banks or windrows. Two special kinds of bioclastic deposits deserve notice.

A little above the base of the Bone Spring in Black John Canyon (section 35; USGS 6938, 7055), northwest of the portal of Apache Canyon (USGS 14439), and in the Baylor Mountains as described below, are "molluscan ledges," which are very local lenses packed with molluscan shells. Gastropods dominate, but there are also pelecypods and cephalopods, as well as a few scaphopods, pteropods, and chitons. P. E. Cloud, Jr., and E. L. Yochelson (written commun., 1954) state—

> Fossils from these beds were silicified and have been prepared for study by etching with hydrochloric acid. The residues contain great quantities of shell fragments compared to the complete specimens recovered. The rock resembles the present-day coquinas in concentration of shell fragments.

These shells are not in position of growth, and were probably removed from their growth areas by waves and currents, which redeposited them in banks on the sea floor (compare Yochelson, 1956, p. 190).

Fusulinids collected at many localities within a hundred feet of the base of the Bone Spring are either Wolfcamp (Hueco) species, or a mixture of Wolfcamp with Leonard (Bone Spring) species, whereas the associated larger fossils are of Leonard affinity. Collections of this kind were made at Victorio Peak (geologic section 29b, F 2716), Victorio Cañyon (geologic section 30, F 2723), and northwest of the portal of Apache Canyon (F 9815, 9816, 9817). (See p. 151–153, 161–162.) Petrographic study of specimens from these and other localities by Henbest demonstrates that the anomalous association of Wolfcamp and Leonard fusulinids results from redeposition of the Wolfcamp fusulinids in younger sediments. Typical is the following report on specimens from about 70 feet above the base of the Bone Spring on Victorio Peak (geologic section 29b, unit 16, F 2716) by L. G. Henbest (written commun., 1955).

These specimens include two kinds of fusulinid-bearing limestone, which will for convenience be termed types 1 and 2.

Type 1 is a calcarenite that consists of well-sorted subspherical grains 0.15 to 0.45 mm in diameter. The grains are highly rounded fragments of lithified fusulinids, echinoderm ossicles, and very fine grained limestone. Each grain is coated with a layer of clear calcite 15 to 20 microns thick. This clear coating has no oolitic structure, and contrasts with the well-graded matrix, which consists of calcareous fine silt. In the sample the grains are as closely packed as they can lie.

Most of the grains are fusulinid fossils. The high degree of rounding indicates that these were either: (a) filled with sediment and lithified before they were eroded, rounded, and redeposited, or (b) impregnated and lithified during abrasion. The latter is indicated because the chamber filling is silt and detritus, whereas before breakage the interior volutions of fusulinid shells are ordinarily inaccessible to silt and are generally filled with crystalline calcite. Further support to this alternative is given by the weathered, corroded conditions of the shells, and the presence of a coating of chemically precipitated or nonoolitic type.

The fusulinid detritus consists of species of *Schwagerina*, *Pseudofusulina*, and perhaps other genera of Schwagerininae. These appear to be Hueco fusulinids. No Bone Spring species were recognized, but the preservation is so fragmentary that certain Bone Spring species could occur without recognizing them as such.

Type 2 consists of unsorted partly silicified angular to rounded detritus, containing an extraordinary variety of well-preserved shells of fusulinids and other foraminifers. Indistinct particles of limestone of a different facies are also present, as well as a few coated sand grains like those of type 1 lithology.

In this faunal aggregate part of the species are typical of the upper part of the Hueco Limestone in the Sierra Diablo, and to some extent of the uppermost beds of the type section at Wolfcamp, notably: *Pseudoschwagerina gerontica*, *P. texana* var. or *Pseudofusulina huecoensis* var., *Parafusulina linearis*, *Schubertella kingi*, and part of the smaller foraminifers. On the contrary, *Parafusulina schucherti*, *P. diabloensis*, other parafusulinid species, and *Schwagerina gumbeli* are characteristic of the Bone Spring. The exact range of none of these forms can be stated with finality, but the evidence is clear lithologically and biologically that this fauna is a depositional aggregate, in which Hueco fossils have been redeposited with early Bone Spring fossils.

NORTHERN MARGINAL BELT

The northern marginal belt of the Bone Spring Limestone emerges from younger Permian rocks on the west wall of Apache Canyon, and is exposed thence east-southeastward for 5 miles to the front of the Sierra Diablo near Mine Canyon. Marginal deposits of the belt were laid on an eroded surface of the Hueco Limestone, which is low and flat along the mountain front, but which rises southwestward nearly a thousand feet in Apache Canyon.

The marginal belt is well exposed in cross section on the northwest wall of Apache Canyon (pl. 11; section *V–V′*, pl. 4). Here the Bone Spring Limestone thins southwestward from 880 feet (geologic sections 37 and 38, pl. 8) to a few hundred feet (geologic sections 40, 41, pl. 8), mainly by overlap on the rising surface of the Hueco but partly by intergradation of the upper beds with the Victorio Peak Limestone. The thick body of Bone Spring in the northeastern part of the canyon is mainly black limestone, but it passes southwestward into marginal deposits. No more than a few hundred feet of marginal deposits occur at any locality, although they have a vertical range as great as the slope of the underlying Hueco.

At about midpoint in the canyon (geologic section 39, pl. 8) the Bone Spring includes a massive unit of saccharoidal dolomitic limestone that stands in massive dark ledges and a thinner underlying unit of cherty and marly limestone. The massive unit contains little else than fusulinids, but fossils are more varied in the unit below and many are silicified. Tongues of the massive unit extend with primary dip into the lower part of the black limestone farther northeast. The black limestone itself has steep primary dips, and includes many lenses or lumps of massive gray limestone, some of which are crowded with sponges, bryozoans, and other fossils. Probably these lenses were patch reefs that grew along the edge of the overlapping Bone Spring deposits. In this part of the canyon the unconformable basal surface is generally overlain by 25 feet or so of ledge-making dolomitic limestone, which is not obviously conglomeratic but which may have been reworked in part from the Hueco beneath. In places it contains not only indigenous fusulinids but fusulinids of Wolfcamp type that were redeposited from the Hueco.

In the southwestern part of the canyon, where the top of the Hueco stands high, it is separated from the Victorio Peak Limestone by thin-bedded slope-making dolomitic limestone, generally a few hundred feet thick but thinning to less than 50 feet in the westernmost exposure (sec. 15, Block 32). This unit is mapped as Bone Spring, although it is equivalent to only a little of the upper part of the formation in the northeastern sections. At Apache Tank (geologic section 41, pl. 8) the limestone of the unit, which is interbedded with pink and yellow marl, overlies a conglomerate of limestone pebbles and cobbles that was probably derived from the Hueco.

Southeast of Apache Canyon the marginal deposits form an escarpment nearly a thousand feet high, from which the strata in front have mostly been eroded (section *V–V′*, pl. 4). The rocks of the escarpment are a reef of dolomitic limestone, parts of which are very massive, parts thick bedded with a primary dip to the northeast. Within the reef, much of the original organic structure has been destroyed by dolomitization and recrystallization, but in places obscure traces of crinoid columns, bryozoans, sponges, and algae are visible, as well as better layered streaks or lenses of bioclastic debris.

The intertonguing of the reef mass with the black limestone is preserved at a few places, as on the spur that extends north to Apache Peak. Here, outer ends of the reef tongues and isolated patch reefs embedded in the black limestone are not so dolomitized as the main reef and preserve better their original nature. Many contain a profusion of sponges, massive bryozoans, crinoid columns, thick-shelled productids and other brachiopods, as well as cobbles and pebbles that are at least partly of algal origin.

Near Mine Canyon the reef extends to the edge of the Sierra Diablo escarpment, and any further extension to the southeast has been downfaulted. Probably it did not continue much farther in this direction, because dips in the reef and associated black limestone change from northeast near Black John Canyon, to east near Cave Peak, to south at the head of Marble Canyon (section *W–W′*, pl. 4). By coincidence, this change in dip is near the large igneous stocks at Cave Peak and Marble Canyon, but the stocks disturbed the strata very little during their intrusion. The dips were not produced by the intrusions, but are primary features of the reef. On the escarpment face at the head of Marble Canyon, intertonguing of the reef front southward with black limestone is well exposed, and presumably the reef continued thence southwestward under a cover of younger Victorio Peak Limestone (fig. 6).

SOUTHERN MARGINAL BELT

The southern marginal belt of the Bone Spring Limestone extends east-southeastward like the northern and is exposed for 8 miles along the Victorio flexure, emerging from alluvium on the west and projecting to the Sierra Diablo escarpment on the east. Best exposures are on the escarpment south of Victorio Peak and in Victorio Canyon (upper view, pl. 10; sections *X–X′* and *Y–Y′*, pl. 4); exposures farther west are less informative as the relief is lower.

In the southern marginal belt, as in the northern, both the surface of the Hueco Limestone and the strata of the Bone Spring slope northeastward, the former descending more than a thousand feet and the latter dipping 5° to 20°. Part of this slope is primary, as in the northern belt, but the slope was much accentuated by later movements on the Victorio flexure. The surface of the Hueco Limestone was much eroded before the Bone Spring was laid over it, as indicated by variations in thickness of the formation, by angular discordance between it and the Bone Spring, and by pebble beds in the Bone Spring; Bone Spring strata, however, do not overlap the Hueco as they do in Apache Canyon.

The Bone Spring Limestone on Victorio Peak (geologic section 29a, pl. 6) north of the flexure is 970 feet thick, but at midpoint on the flexure (geologic section 28, pl. 6) it has thickened to 1,050 feet, despite loss of much of its upper part by intergradation with the Victorio Peak Limestone. At the top of the flexure (geologic section 27, pl. 6) 850 feet of the formation is preserved, although the Victorio Peak is missing. Southward thickening of the Bone Spring is caused by swelling of each layer as it changes into marginal facies, so that the thick sequence in the south is equivalent only to the lower part of the thinner sequence in the north.

These relations are well shown in cross section south of Victorio Peak and in Victorio Canyon (sections *X–X′* and *V–V′*, pl. 4). On the east slope of Victorio Peak and in the lower course of Victorio Canyon, a 100-foot bed of gray limestone forms a prominent ledge about 300 feet above the base of the formation. This bed is traceable to the upper end of the flexure, where its thickness and its distance above the base of the Bone Spring have doubled. To the north, beds below and above the ledge are mainly black limestone, but to the south, thick units of cliff-making dolomitic limestone wedge in. These have been interpreted as reefs (King, P. B., 1962, p. 630), but "although the deposits are largely made up of organic debris, there is little evidence for more than occasional wave-resistant structures" (Stehli, 1954, p. 274). Between the wedges the black limestone changes into green clay shale and yellow nodular limestone, both containing many fossils, some of which weather free. Some beds are formed of closely packed fusulinid shells, which in places include both indigenous species and species reworked from the Hueco.

In the southernmost exposures many beds between the lower wedges are conglomerate, derived in part from erosion of the Hueco Limestone farther south. The conglomerate is formed of well-rounded limestone pebbles of various colors and textures, ¼ inch to 1 inch in diameter, which lie in a matrix of dolomitic or marly limestone. Both matrix and pebbles contain fusulinids and other fossils.

One wedge of massive dolomitic limestone directly overlies the Hueco and thickens southward like the rest, extending a mile or two beyond succeeding parts of the Bone Spring and the upper end of the Victorio flexure to form remnants on the crest of the Sierra Diablo. This basal dolomitic limestone is more massive than the Hueco Limestone on which it rests, and it weathers more jagged. Unlike the Hueco, it contains large fusulinids and other fossil shells in places, some of which are silicified.

BAYLOR MOUNTAINS

The Bone Spring Limestone forms most of the northern part of the Baylor Mountains and resembles that in the Sierra Diablo. The downfaulted eastern extension of the Victorio flexure crosses the northeast corner of the mountains, where Bone Spring strata dip 10° to 30° north-northeastward with the Victorio Peak Limestone at the top, but both flexure and earlier structures are obscured by closely spaced northwest-trending faults of Cenozoic age (section *Z–Z′*, pl. 4). The full sequence of the Bone Spring is exposed only toward the northeast, where it is probably about a thousand feet thick, but only the lower part could be measured (geologic section 18, pl. 5).

Most of the formation in the northeastern part of the mountains is black limestone, which includes the usual thin-bedded dark-gray or black limestone and platy siliceous shale. However, the uppermost 500 feet forms beds as much as several feet thick and contains many chert nodules. Southward, as on the Victorio flexure in the Sierra Diablo, part of the black limestone gives place to shale, calcareous marl, and earthy limestone. These rocks contain abundant fossils, many of which weather free.

The black limestone contains layers of lighter gray thick-bedded or massive limestone, but most of them are very lenticular. One group of lenticular layers 300 or 400 feet above the base of the Bone Spring is more persistent than the rest, although the layers wedge out and nearly disappear in places, and in others coalesce into a prominent ledge several hundred feet thick. Not far above these layers at one locality (geologic section 18; USGS 6983, 14475) is a "molluscan ledge" like those in the northeastern Sierra Diablo.

Southward in the Baylor Mountains, as farther west on the Victorio flexure, a massive dolomitic limestone wedges in at the base of the Bone Spring and caps the Hueco over much of the central part of the mountains (section *Z–Z′*, pl. 4). Higher wedges are preserved near the high point of the mountains (BM 5568), which slope northward with primary dip into the black limestone. Some of them are dolomitic, others calcitic; some are fine grained, others coarse and bioclastic with abundant silicified fossils.

FOSSILS AND CORRELATION

Fossils are preserved in varying abundance in the different kinds of rocks of the Bone Spring Limestone, but all its fossils make a varied assemblage (tables 5–7). Fossils are scarce in most of the black limestone, probably because of an original poverty of life; they are poorly preserved in the reefs and banks, because of subsequent dolomitization and recrystallization. They are most abundant and best preserved in the ledge-making beds and lenses of gray limestone that are interbedded in the lower part of the black limestone. Fusulinids and other foraminifers occur here in varied associations. On the other hand, the kinds of larger invertebrates vary greatly in proportion from bed to bed and place to place, owing to either environmental differences in the growth areas or sorting of the shells during transportation and redeposition. Variations from these causes overshadow any faunal zonation within the formation, if such exists.

FAUNAL ASSEMBLAGES

Fusulinids of the Bone Spring Limestone include such characteristic species as *Parafusulina diabloensis* Dunbar and Skinner, *P. imlayi* Dunbar, and *P. schucherti* Dunbar and Skinner. Earlier collections from the Sierra Diablo did not yield *Schwagerina hessensis* Dunbar and Skinner, *S. gumbeli* Dunbar and Skinner, or *S. crassitectoria* Dunbar and Skinner, which are characteristic of the lower part of the Leonard Series of the Glass Mountains, and it was thought that the lower Leonard might be missing here (Dunbar and Skinner, 1937, p. 589). However, all these species have been discovered later in the Sierra Diablo (Dunbar, 1953, p. 804–809; L. G. Henbest, written commun., 1955), and the supposed hiatus must not exist. Similarly, *Parafusulina fountaini* Dunbar and Skinner and *Pseudofusulina setum* (Dunbar and Skinner), which were supposed to characterize the younger Victorio Peak Limestone, are now known to occur more sparingly in the Bone Spring.

At many places, mostly within a hundred feet of the base of the Bone Spring Limestone, fusulinids of Wolfcamp (Hueco) type are mingled with those of Leonard (Bone Spring) type but, as stated above, studies by Henbest (written commun., 1955) indicate that the Wolfcamp fusulinids have been redeposited from earlier strata. All the specimens of *Pseudoschwagerina* which have been identified from the lower part of the Bone

TABLE 5.—*Fossils identified from Bone Spring Limestone, Baylor Mountains and northeastern Sierra Diablo (Foraminifera)*
[Identifications by L. G. Henbest. Explanation of symbols: ×, genus or species present; var, variety of species present; aff, specimen related to species but probably different; ?, specimen doubtfully assigned to genus or species]

Distribution of fossils in stratigraphic section, locality, and collection number indicated

	19—Northwestern Baylor Mts.	27—Second section south of Victorio Peak		Victorio flexure		29b—Victorio Peak		30—Victorio Canyon	31—North of Victorio Canyon	Northwest of Apache Canyon			37—First section in Apache Canyon	38—Second section in Apache Canyon			39—Third section in Apache Canyon
	F 2720	F 3806 (=14453)	F 9827 (=14454)	F 2692 (=8543)	F 2713 (=8542)	F 2716 (=8562)	F 2710 (=8561)	F 2723 (=8539)	F 2705 (=8540)	F 9817 (=14443)	F 9816 (=14442)	F 9815 (=14441)	F 9819 (=14447)	F 9833	F 9834 (=14406)	F 9835	F 9824
Foraminifera:																	
Indigenous and probably indigenous genera and species:																	
Boultonia rawi Lee						aff											
Bradyina sp																	?
Clincacimmina sp	×			×		×				×							
Endothyra sp					×					×					×		
Geinitzina sp		×	×		×	×		×		×		×	×		×		?
Millerellid sp					×												
Ozawainella sp						×		?							×		
Parafusulina attenuata Dunbar and Skinner			?														
attenuata-P. bakeri series	×																
bösei Dunbar and Skinner							aff										
diabloensis Dunbar and Skinner					×	×						×			×		
?*Parafusulina diabloensis* Dunbar and Skinner								×								×	
Parafusulina fountaini Dunbar and Skinner									var					×	×		
imlayi Dunbar	var			×	var		×								?		
linearis (Dunbar and Skinner)																	var
lineata Dunbar and Skinner													aff				
schucherti Dnnbar and Skinner	×		?	×		×		×					×	×			
spp	?		×	×		×	?		?	?		?	×			×	
Pseudofusulina setum (Dunbar and Skinner)	×			var					×								
Quinqueloculina sp								?							×		
?*Schwagerina compacta* (White)		×															
Schwagerina? *franklinensis* Dunbar and Skinner													×				
Schwagerina gumbeli Dunbar and Skinner													×		×		
?*Schwagerina gumbeli* Dunbar and Skinner						×		×									
pseudoregularis Dunbar and Skinner						×											
Spandelina sp		×	×			×						?					
Spandelinoides sp		×		×	×												
Staffella sp	×	?	×				?	×							?		
Textulariidae		×	×														
Tetrataxis spp	×	×	×			×		×		×				×			
Genera and species redeposited from Hueco limestone:																	
?*Parafusulina gracilitatis* (Dunbar and Skinner)										×							
Parafusvlina linearis? (Dunbar and Skinner)						× var				× var	×	×					
Paraschwagerina sp		×															
Pseudofusulina powwowensis (Dunbar and Skinner)								?		×	×	×					
Pseudoschwagerina gerontica Dunbar and Skinner						var											
Pseudoschwagerina? *laxissima* (Dunbar and Skinner)		?															
Pseudoschwagerina texana Dunbar and Skinner						?				?	×						
uddeni (Beede and Knicker)		×	×														
Schubertella kingi Dunbar and Skinner		×				×		×	var			×					
Schwagerina bellula Dunbar and Skinner								aff		var		aff					

Spring are probably of this origin, except the oddly shaped *Pseudoschwagerina stanislavi* Dunbar, which is indigenous to the Bone Spring and is seemingly a late variant of the genus (Dunbar, 1953, p. 809–812).

The remaining groups of invertebrates of the Bone Spring Limestone form two contrasting assemblages, with few forms in common. The most widely distributed assemblage is dominated by brachiopods, the other occurs in the "molluscan ledges."

A typical collection dominated by brachiopods, from the lower part of the Bone Spring in the Victorio Peak area, is summarized as follows by Stehli (1954, p. 280):

An interesting feature of this and other collecting localities is the complete imbalance of the organic assemblage. There are ten times as many brachiopod individuals as all others combined. Second in importance are the bryozoans, which occur in large numbers and include both stony forms and delicate fenestellids. Pelecypods are next in variety but are very low in numbers of individuals. Crinoid debris is abundant. Corals are present in moderate numbers. Gastropods are of limited variety, but there are moderate numbers of individuals. Cephal-

TABLE 6.—*Fossils identified from Bone Spring Limestone, Baylor Mountains, and northeastern Sierra Diablo (Porifera, Coelenterata, Echinodermata, Bryozoa, and Brachiopoda)*

[Identifications by P. E. Cloud, Jr., Helen Duncan, and R. M. Finks. Explanation of symbols: X, present; C, common; A, abundant; R, rare]

	Distribution of fossils in stratigraphic section, locality, and collection number indicated																		
	17—High point of Baylor Mountains	Near High point of Baylor Mountains		18—Northeastern Baylor Mountains			19—Northwestern Baylor Mountains		27—Second section south of Victorio Peak	Victorio flexure			29b—Victorio Peak		30—Victorio Canyon	31—North of Victorio Canyon	32—Marble Canyon	35—Black John Canyon	Northwest of Apache Canyon
	7048	7053	7009	7000a	7000	6983-14475 Molluscan ledge	7002a	7002b	14454	8544	8543	8542	8562	8561	8539	8540	7010	7055-6938 Molluscan ledge	14439 Molluscan ledge
Porifera:																			
Girtyocoelia dunbari R. H. King							X				X								
Fissispongia n. sp							X				X			X					
N. gen. aff. *Fissispongia*							X												
Heliospongia vokesi R. H. King									X		X		X						
Anthracosycon uriforme Finks																		X	
Stereodictyum orthoplectum Finks											X								
Stioderma coscinum Finks																		X	
Lyssacina incertae sedis														X					
Sponge spicules	X													X			A		X
Coelenterata:																			
Amplexus sp						X													
Aulopora sp																		X	
Cladochonus sp								X				R	X					R	
Lonsdaleia? sp													C		A	X		X	
Lophophyllum sp		X				R		C			C								
Triplophyllum sp												X	X						
Horn corals indet									X					X	A				
Colonial corals indet									X				R					X	
Echinodermata:																			
Crinoid calyces and stems indet											X				X			X	
Echinoid spines and plates indet								X										X	X
Bryozoa:																			
Acanthocladia sp	X					C												X	
Batostomella sp								X											
Chainodictya? sp													C						
Cystodictya sp						R						X	R						
Domopora? sp													R						
Fenestella sp						X								C	X				
Fistulipora sp	C	R	X		A	C	X	R			R		C	C	A	X	A		
Meekopora sp						R													
Polypora sp	X					R									X				
Rhombopora sp						R									X				
Septopora sp						X							X	R				X	X
Stenopora sp						C													
Striatopora sp			X			X		X					X	X				R	

Brachiopoda:																			
Aulosteges? sp											X								
Avonia spp						R				X				R		X			
Buxtonia (*Kochiproductus*) *victorioensis* King	R					R			X	A				X					
Chonetes consanguineus Girty														R					
(*Chonetinella*) *victorianus* Girty								C					R	R	X				
spp	X	C				C				C					X			X	
Composita sp	X					X	C												X
Crurithyris sp								R						X					
Derbyia sp												C		R					
Dictyoclostus (*Chaoiella*) *guadalupensis* (Girty)	R	C							C										
Dielasma sp								R									X		
Enteletes cf. *E. dumblei* Girty						C		A			C	A	X			R			
sp							R		X	X				X	X		C		
Hemiptychina sp								X											
Hustedia hessensis King															R				
mormoni (Marcou)						R		X					X	X			C		
sp	X										R					X			
Isogramma sp											X								X
Leptodus sp			X			X		X		X		R		X			X	X	
Linoproductus (*Cancrinella*) spp	X	X																	
"*Marginifera*" (*Kozlowskia*) aff "*M.*" *capaci* (d'Orbigny)													X		A				
cf. "*M.*" *sublaevis* King													X						
(*Kozlowskia*) aff "*M.*" *wabashensis* (Norwood & Pratten)														R					
cf. "*M.*" walcottiana Girty									A					R					
spp	X	C		C										R					
"*Martinia*" sp	X																		
Meekella difficilis Girty						C						A							
sp	X				C			X						X	X	X	X		
Neospirifer sp		C					X	X				R							
Orthotetacean indet	X					C		X		X									
Productids indet		X	X				X				R	R		X	X	X	X	X	X
Prorichthofenia sp				X	C		C									R	C		
Rhipidomella sp		X	X			C		R		X		A		X					
Scacchinella sp														X					
"*Spirifer*" sp	X					R													
Spiriferina sp. and "*Spiriferina*" sp												R		X					
Squamularia sp. and *Squamularia*? sp						R	C										C		
Stenocisma cf. *S. inequalis* (Girty)									X										
sp	X	X								R									
Streptorhynchus sp												R			X				
Wellerella spp					C	X	R	R			R	X		R					

TABLE 7.—*Fossils identified from Bone Spring Limestone, Baylor Mountains and northeastern Sierra Diablo (Amphineura Conconchia, Lamellibranchiata, Scaphopoda, Gastropoda, Cephalopoda, Annelida, Arthropoda and Alga)*

[Identifications by W. M. Furnish, A. K. Miller, I. G. Sohn, and E. L. Yochelson. Explanation of symbols: A, abundant; C, common; ×, present; R, rare]

Distribution of fossils in stratigraphic section, locality, and collection number indicated

	17—High point of Baylor Mountains	Near high point of Baylor Mountains		18—Northeastern Baylor Mountains			19—Northwestern Baylor Mountains		27—Second section south of Victorio Peak	Victorio flexure			29b—Victorio Peak		30—Victorio Canyon	31—North of Victorio Canyon	32—Marble Canyon	35—Black John Canyon	Northwest of Apache Canyon
	7048	7053	7009	700a	7000	6983–14475 Molluscan ledge	7002a	7002b	14454	8544	8543	8542	8562	8561	8539	8540	7010	7055–6938 Molluscan ledge	14439 Molluscan ledge
Amphineura:																			
"*Gryphochiton*" sp						R												C	
Coniconchia(?):																			
Hyolithes sp																		×	
Lamellibranchiata:																			
Acanthopecten sp						×		×		×				×					
Anthraconeilo sp																		×	
Astartella nasuta Girty						A												C	
Aviculopecten sp						×													
"*Cypricardinia*" sp			×															R	
Edmondia sp						C													
Myalinid indet						R													×
Nucula sp						C												A	
Nuculoid indet	×		×															C	×
Nuculana spp						×												A	C
Paleoneilo sp						×													R
Parallelodon spp						C	×	×										C	C
Pectenoid indet		×					×												×
Permophorus sp						×												×	R
Pseudomonotis sp						×	×												
Pteria? sp			×			C												×	R
Schizodus sp						C													
Solenomya sp						×													
Streblopteria sp						C												×	
Pelecypods indet																			R
Scaphopoda:																			
Dentalium sp							×												
"*Laevidentalium*" sp																		R	
Plagioglypta sp	×			R		R												R	C
Gastropoda:																			
Anomphalus sp						×		×		×								R	R
Apachella sp	×		×											×	×			×	×
Babylonites sp	×					×				×			×					R	
Bellerophon deflectus Chronic						×		×	×									R	
sp							×											×	C
Bellerophontid indet		C																×	
Cinclidonema sp																		×	
Discotropis girtyi Yochelson																		×	
Donaldina? sp								×										R	×
Euconospira pulchra Batten														×	×				
Euphemites cf. *E. imperator* Yochelson	×																		×
cf. *E. kingi* Yochelson	×						×												
sp	×		×															×	R
Glabrocingulum sp			×								×			×				R	
Glyptospira sp						×												×	
Knightites (*Retispira*) sp	×					C												×	×
Lamellospira conica Batten														×					
cf. *Loxonema* sp						×												R	
Murchisonid indet																			×
Naticopsis sp						×												×	R
Orthonema sp						×												R	
Peruvispira sp																		×	×
Pharkidonotus sp																			×
Platyceras sp								×					×			×			
Pleurotomarian indet			×		×	×				×								×	
Pseudozygopleuran indet					×			×										×	×

Shewdagonia? sp														×				×	
Stegocoelia? sp						×		×										×	R
Straparollus (*Euomphalus*) *glabribasis* Yochelson													×		×				
cf *S.* (*E.*) *kaibabensis* Chronic								×											
"*Strobeus*" spp						×												R	×
Sublitid indet						×												×	×
Trachydomia sp						×		×											
"Trachydomia" sp						×		×			×								×
Warthia waageni Yochelson				×	×													×	R
"*Worthenia*" sp						×					×							×	R
Cephalopoda:																			
Cooperoceras? sp																			×
Metacoceras mammiferum Miller																			×
megapora Miller																			×
spp																			×
Michelinoceras spp																			×
Mooreoceras sp																			×
Propinacoceras knighti Miller and Furnish																			×
Pseudorthoceras sp																		C	×
Ammonite indet						R		×											
Coiled nautiloid indet					×													R	
Orthoceratoid indet						R												A	C
Annelida:																			
Spirorbis sp													×						
Arthropoda:																			
Anisopyge sp																		R	R
Bairdia spp																		×	
Bairdiocypris? sp																		×	
Delaria? sp	×					R													
Healdia spp																		×	
Hollinella sp. or spp																		×	
Kellettina sp																		×	
Roundyella? sp																		×	
Alga:																			
Solenoporoid indet													×						

opods are very rare. Sponges and arthropods are represented by rare fragmentary material. Fusulinids are abundant.

Distinctive brachiopods of the assemblage are *Dictyoclostus* (*Chaoiella*) *guadalupensis* (Girty), *Buxtonia* (*Kochiproductus*) *victorioensis* King, *Chonetes* (*Chonetinella*) *victorianus* Girty, species of *Enteletes*, *Wellerella*, and *Stenocisma*, and a small species of *Avonia*. Many layers also contain *Meekella*, *Leptodus*, and *Prorichthofenia*, adapted to life on a firm substratum, probably in a reef environment. Collections from some beds contain many productids, whereas others are dominated by *Enteletes* and other nonproductids; but these differences are not stratigraphically significant. Many of the brachiopod species of the assemblage have been described by R. E. King (1931), some by Stehli (1954, p. 289–357).

Bryozoans are varied, but most of the genera at any locality are represented by only a few specimens, except for fistuliporoids, which form abundant large masses in some layers. Sponges are abundant in places, most of the identifiable ones being *Heliospongia* or *Defordia*-like forms. Spicules have been recovered in many insoluable residues and indicate a greater abundance of sponges than would be inferred from the larger specimens that have been collected. Horn corals of lonsdaleoid type and colonial corals occur here and there.

In the brachiopod-dominated assemblage mollusks are notable mainly for their paucity of number and variety, in contrast to the assemblage in the "molluscan ledges."

The assemblage in the "molluscan ledges" is dominated by mollusks, almost to the exclusion of other phyla. Brachiopods are represented by only a few specimens; sponges, corals, bryozoans, and crinoid debris are uncommon. The mollusks are mainly gastropods and pelecypods, the first dominating the ledge northwest of Apache Canyon (USGS 14439), the second, the ledge at Black John Canyon (USGS 7055, 6938); cephalopods, scaphopods and chitons are less abundant. According to Yochelson (1956, p. 189)—

Pelecypods are abundant, comprising well over half of the fossils recovered at the locality [at Black John Canyon]. Of these, *Nucula*, *Nuculana*, and *Astartella* are the commonest types, and parallelodontids are fourth in abundance. Most of the other pelecypod genera are represented by only a few specimens.

Gastropods are varied, being represented by nearly 20 genera. High-spired forms of several unrelated genera are somewhat more common than gastropods of other shapes; however, there is no striking difference in numbers of individuals among the several genera. No large gastropods occur, and few of medium size are present.

Cephalopods from the ledge northwest of Apache Canyon include the ammonite *Propinacoceras knighti* Miller and Furnish, four genera of coiled nautiloids, and the straight-shelled genus *Pseudorthoceras* (Miller and Furnish, 1940a, p. 42–44; Miller, 1945).

The fauna of the "molluscan ledge" in the northeastern part of the Baylor Mountains (USGS 6983, 14475) is transitional between the molluscan and brachiopod assemblages. Although it includes abundant pelecypods, these are associated with *Meekella*, *Enteletes*, *Prorichthofenia*, and other brachiopods, as well as massive bryozoans. A collection from near the high point of the Baylor Mountains (USGS 7009) is of similar transitional character, as it contains nearly equal numbers of brachiopods and mollusks.

CORRELATION

Bone Spring faunas differ from those of the underlying Hueco, and have many affinities with the higher faunas of the Guadalupe Series. They include the earliest of the large fusulinids which characterize the zone of *Parafusulina*, as well as the peculiarly adapted brachiopods *Leptodus* and *Prorichthofenia*. These and other distinctive features of the Bone Spring fauna characterize the Leonard Series in the West Texas Region.

From the stratigraphic position of the Bone Spring Limestone in the Sierra Diablo, between the Hueco Limestone and Victorio Peak Limestone, it would seem to be equivalent to the lower part of the type Leonard Series of the Glass Mountains, and there is some confirmation of this in the fossils. Thus, a group of schwagerinid species by which Dunbar and Skinner (1937, p. 586) characterized the lower part of the type Leonard occurs also in the Bone Spring. R. E. King (1931, p. 14) found that most of the brachiopod species in his collections from the Bone Spring occur in the type Leonard. Also, most of his collections ascribed to the "Hess limestone" were from basal ledges of the Bone Spring as now defined; he found that many brachiopod species from it occur in the Hess Limestone of the Glass Mountains, now known to be a facies of the lower Leonard. According to Stehli (1954, p. 276)—

It must be noted that in the Sierra Diablo the lower Bone Spring contains a few forms which in the Glass Mountains are seemingly restricted to the Wolfcamp, and a possibility exists that these rocks are somewhat older than the Leonardian in the Glass Mountains.

STRATIGRAPHIC RELATIONS

Throughout the Sierra Diablo region the varied deposits of the Bone Spring Limestone are overlain conformably by the light-gray thick-bedded Victorio Peak Limestone.

The Victorio Peak Limestone also intergrades extensively with the upper part of the black limestone of the Bone Spring, both by intertonguing and by abrupt passage from light-gray into black strata in units several hundred feet thick. Intergradation of the two formations is prominently exposed on the south slope of Victorio Peak, on the escarpment just north of Victorio Canyon, and in Apache Canyon (sections *U-U′*, *V-V′*, *W-W′*, and *Y-Y′*, pl. 4). At all such places gray limestone changes to black northeastward, toward the basin area. Well out in the basin area, in the Delaware Mountains in the northeast corner of the report area, black limestone extends to the top of the Leonard interval and probably includes equivalents of the Victorio Peak (fig. 7).

However, the Victorio Peak Limestone does not replace the whole Bone Spring Limestone away from the basin area. In the marginal belts it overlies thick-bedded gray limestone layers of different character, which were laid down as reefs or banks during Bone Spring time. In the platform areas these lower strata wedge out, and the Victorio Peak lies with hiatus on the Hueco Limestone.

VICTORIO PEAK LIMESTONE

The Victorio Peak Limestone is named for Victorio Peak (King, P. B., and King, R. E., 1929, p. 922), the prominent detached summit about midway along the east-facing escarpment of the Sierra Diablo (upper view, pl. 10). The Victorio Peak is a formation of later Leonard age which is thick and extensive around the margins of the basin area in the Guadalupe Mountains, the Sierra Diablo, and the Wylie Mountains.

The Victorio Peak Limestone forms the summits of the Sierra Diablo north of the Victorio flexure (pl. 14), breaking off on the east-facing escarpment into prominent light-gray cliffs that surmount slopes carved from the Bone Spring Limestone (lower view, pl. 10). North of the Babb flexure it descends to the edge of the Salt Basin, where it forms a low bench capped by younger formations that extends northward beyond the report area (upper view, pl. 12; section *B-B′*, pl. 16). A small remnant of the Victorio Peak is preserved at the northeast corner of the Baylor Mountains, and a large outlier forms the eastern slope of the Wylie Mountains (geologic section 13; Hay-Roe, 1957).

The Victorio Peak Limestone is overlain by higher Permian formations at the north end of the Sierra Diablo and in the Wylie Mountains. On the Babb flexure at the north end of the Sierra Diablo its full thickness is 975 feet; in the Wylie Mountains it is about 1,600 feet but includes undifferentiated beds of Guadalupe age at the top. Elsewhere in the Sierra Diablo, the Victorio Peak Limestone is the highest Permian formation and its full sequence is undetermined; here 500 to 1,000 feet of beds are commonly preserved. On the south slope of Victorio Peak it is nearly 1,500 feet thick, but the lower half intergrades with black limestone in the northern part of the mountain. Even allowing for erosion after Permian time, the formation thus varies much in thickness from place to place, probably mainly by intertonguing with the Bone Spring Limestone beneath.

NORTHEASTERN CALCITIC FACIES

Along the east-facing escarpment of the Sierra Diablo, the Victorio Peak is a light-gray thick-bedded limestone, mainly calcitic but slightly dolomitic in part, which stands in sheer cliffs that in places are remarkably fluted and pinnacled. Beds are a few feet or tens of feet thick, and in places are irregularly inclined at low angles in different directions. Near Apache Peak and Apache Canyon, where the gray limestone extensively intergrades northeastward with the black limestone of the Bone Spring, long tongues of gray limestone extend into the black and descend several hundred feet from the main body toward their outer ends (section *U-U′*, pl. 4). The calcitic limestone of the Victorio Peak is probably mainly a bank deposit (King, P. B., 1948, p. 27), although it may contain some small reef masses along its northeastern margin.

In places the Victorio Peak Limestone is separable into lithologically distinct subdivisions, but these are of local extent. Between Victorio Canyon and Mine Canyon the lower 250 feet is massive gray limestone, with indistinct bedding planes, that stands in a prominent cliff. Above is thinner-bedded gray limestone, with much interbedded buff marl, sandy and cherty limestone, and platy siliceous limestone. Many of these upper beds are fossiliferous, and contain productids, other brachiopods, sponges, and crinoid stems, some of which are silicified.

On the Babb flexure (geologic section 43, pl. 8) the Victorio Peak is separable into three divisions. The thick lower division is gray thick-bedded dolomitic limestone, in part cherty, which weathers gray brown and splits along closely spaced joints. About halfway up is a thin layer of fine-grained sandstone. The middle division, 100 feet thick, is thin-bedded dolomitic limestone, which weathers white and porcelaneous and forms a persistent light-colored slope. The upper division, 50–65 feet thick, is dark-gray calcitic fossiliferous limestone, which is overlain by the Cutoff shale. The three divisions of this area are significant, because they are nearly identical with divisions of the Victorio Peak Limestone in the Guadalupe Mountains to the north (King, P. B., 1948, p. 17), and assist in correlation of the formation between the two areas.

SOUTHWESTERN DOLOMITIC FACIES

West of the front of the Sierra Diablo the dominantly calcitic thick-bedded fossiliferous limestone of the Victorio Peak changes to dolomitic thin-bedded poorly fossiliferous limestone. One facies gives place to the other in about a mile along a well-defined boundary that extends north-northwest across the mountains from Victorio Canyon to a little east of Sierra Prieta (fig. 7).

The dolomitic limestone includes white 6-inch to 1-foot layers with crinkled laminae that weather to jagged surfaces and dull-gray thicker layers. Analysis of a typical specimen from near the Slaughter Ranch by K. J. Murata (written commun., 1940) indicates a content of 50.25 percent $CaCO_3$, 38.75 percent $MgCO_3$, and 1.34 percent insoluable material; the carbonate fraction is close to the composition of the mineral dolomite. Most of the dolomitic limestone beds are probably unfossiliferous, but some contain ghosts of fusulinids, crinoid stems, and bellerophontids.

The Victorio Peak Limestone of the small remnant in the Baylor Mountains and the larger body in the Wylie Mountains is of the same dolomitic facies as that in the western Sierra Diablo.

The thin-bedded dolomitic limestone of this facies of the Victorio Peak somewhat resembles the dolomitic limestone beds of the underlying Hueco in the northeastern Sierra Diablo; it closely resembles Permian limestones of other ages elsewhere in the West Texas region that have been interpreted as back-reef or lagoonal deposits—the Hess Limestone Member of the Leonard Formation and Gilliam Limestone of the Glass Mountains and the Carlsbad Limestone of former usage of the Guadalupe Mountains. The dolomitic limestone of the Victorio Peak was laid down on platform areas, which were probably separated from the basin area by low banks of the calcitic limestone facies.

FOSSILS

Nearly all the fossils that have been collected from the Victorio Peak Limestone are from the calcitic facies, on the rim of the Sierra Diablo escarpment or near the Babb flexure (table 8). The fauna indicated by these collections is less extensive than that of the Bone Spring Limestone, but it is less known because of poorer preservation and the relative inaccessibility of the outcrops. For these reasons the faunal makeup also differs much from one collection to another, but probably no collection approaches the whole biota of its locality.

Fusulinids are dominated by large parafusulinids and pseudofusulinids, such as *Parafusulina fountaini* Dunbar and Skinner and *Pseudofusulina setum* (Dunbar and Skinner). The somewhat smaller *Parafusulina diabloensis* Dunbar and Skinner and *P. schucherti* Dunbar and Skinner occur also, although they are more characteristic of the Bone Spring beneath.

Sponges which occur at many places are mostly *Defordia*-like forms and are probably a significant feature of the whole fauna in bulk (Finks, 1960, p. 28–32). Corals are less common. Dasycladacean algae, mostly *Macroporella*, are abundant at one locality, and indicate an environment of shallow tropical to subtropical water.

The fauna is dominated by brachiopods, and especially by productids, such as *Buxtonia* (*Kochiproductus*) *victorioensis* King.[4] Of the nonproductids, perhaps the most abundant genera are *Enteletes* and *Neospirifer*. Bryozoans are mostly rare, but massive fistuliporoids occur here and there, and at one place numerous *Batostomella*. Mollusks are likewise uncommon and are mostly moderate- to large-sized gastropods.

STRATIGRAPHIC RELATIONS

The top of the Victorio Peak Limestone is not preserved in most of the Sierra Diablo region, but north of the Babb flexure it is followed by the Cutoff Shale. Over the wide area in which the contact between the two units is exposed, thick-bedded calcitic limestone of the Victorio Peak is overlain by thin-bedded shaly limestone of the Cutoff, and although the two rocks are not interbedded, they appear to be conformable. In the Wylie Mountains southeast of the report area the Cutoff Shale is not recognizable, and beds mapped as Victorio Peak are succeeded by the Seven Rivers Limestone of Guadalupe age (Hay-Roe, 1957). The equivalent of the top of the Victorio Peak Limestone of other areas however, must lie within the dolomitic limestone beds beneath, as parafusulinids of Guadalupe type are reported from their upper part.

CUTOFF SHALE

The Cutoff Shale is named for Cutoff Mountain (King, P. B., 1942, p. 569–570), in the Guadalupe Mountains near the Texas-New Mexico boundary. Like the Victorio Peak Limestone, the unit is characteristic

[4] Earlier identifications by R. E. King in the Sierra Diablo and by G. H. Girty in the Guadalupe Mountains suggested that a common brachiopod species of the Victorio Peak Limestone is *Dictyodostus* (called "*Productus*") *ivesi*. However, according to P. E. Cloud, Jr., (written commun., 1960):

"The brachiopod that R. E. King figured as *Productus ivesi* in his Glass Mountains memoir (and of which I have the figured specimens before me) is a Leonard species that somewhat resembles *Dictyoclostus bassi* of the Kaibab Limestone, but which is not present in any Sierra Diablo collection examined by me.

"I have also studied Newberry's three cotype specimens of *Productus ivesi*, which are presumably also from the Kaibab, and regard them as unidentifiable productids. Possibly they are small specimens of *Dictyoclostus bassi* and perhaps they are the same as *D. hessensis*, but there is no way to tell, and *D. ivesi*, unhappily, must be relegated to the limbo. I can only guess that the Sierra Diablo specimens identified by R. E. King as *D. ivesi* represent the same species I have referred to *D.* cf. *hessensis*."

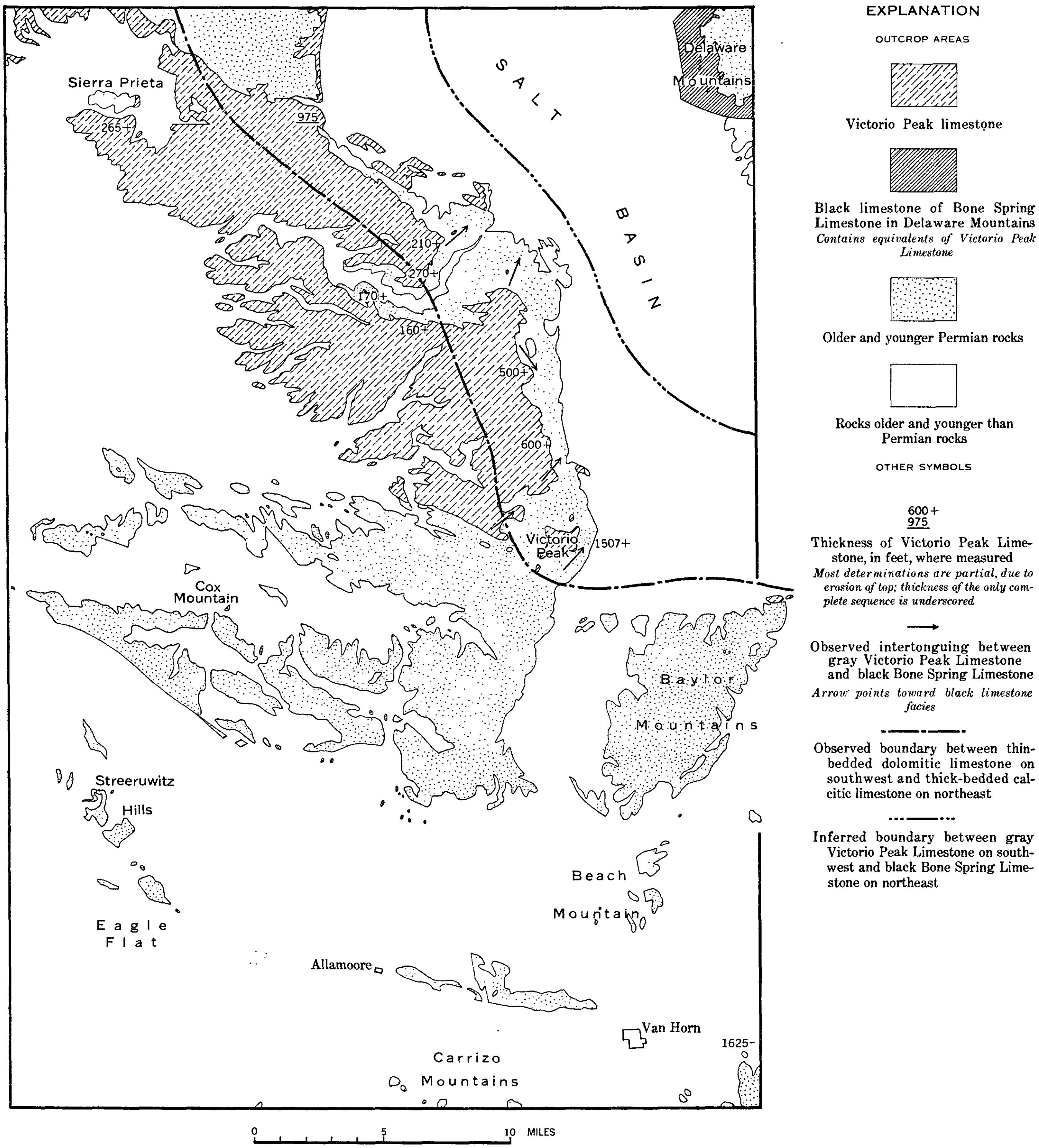

FIGURE 7.—Map of Sierra Diablo region showing paleotectonics of Victorio Peak Limestone.

TABLE 8.—***Fossils identified from Victorio Peak Limestone in central and northern Sierra Diablo***

[Identifications by P. E. Cloud, Jr., Helen Duncan, R. M. Finks, L. G. Henbest, and E. L. Yochelson. Explanation of symbols.—Under Foraminifera: ×, species or genus present; var, variety of species present; aff, specimen related to species but probably different; ?, specimen doubtfully assigned to genus or species. Under other biological groups: A, abundant; C, common; ×, present; R, rare]

	Distribution of fossils in stratigraphic section, locality, and collection number indicated															
	29a—Victorio Peak	31—North of Victorio Canyon	32—Marble Canyon	Northeastern Sierra Diablo				37—First section in Apache Canyon	38—Second section in Apache Canyon	39—Third section in Apache Canyon	40—South Mesa		Southeast of South Mesa			
	8545	8546	7011 14444	7006	14470 F 9837	14445 F 9818	F 9820 14448 F 9821 14449	14461	F 9836	F 9825	8534 F 2691	8535 F 2698	8536	8537 F 2709	8541	8547
Foraminifera:																
Climacammina sp							×			×						
Endothyra sp							×					×				
Geinitzina sp							×			×		×		?		
Parafusulina bakeri Dunbar and Skinner												? var				
Parafusulina? *bosei* var. *attenuata* Dunbar and Skinner							aff									
Parafusulina diabloensis Dunbar and Skinner							×									
cfr. *diabloensis* Dunbar and Skinner or *Pseudofusulina*										×						
fountaini Dunbar and Skinner											×					
?*Parafusulina fountaini* Dunbar and Skinner										var						
Parafusulina linearis (Dunbar and Skinner)										var						
schucherti Dunbar and Skinner							×									
sp					×				×							
or *Pseudofusulina* sp														×		
Pseudofusulina setum (Dunbar and Skinner)							?				?			×		
Schubertella kingi Dunbar and Skinner							×			var						
Schubertellid or millerellid sp												×				
Spandelinoides sp							×									
Tetrataxis sp							×									
Porifera:																
Actinocoelia meandrina Finks			×		×											
Defordia densa Finks			×		×											
Jereina cylindrica Finks								×								
Stioderma coscinum Finks			×													
Sponge indet		×		×												
Coelenterata:																
Lophophyllid indet												×				
Horn coral indet	×				R			×			R					
Echinodermata:																
Crinoid stems indet			C	C	×											
"*Echinocrinus*" sp		×														
Bryozoa:																
"*Batostomella*" sp												C				
Fenestrate indet	C				×											
Fistulipora sp	×			×	A							×				
Phyllopora sp		×														
Rhombopora sp				×												
Septopora sp				×												
"*Stenopora*" sp											R					
Bryozoans indet	×															
Brachiopoda:																
Avonia sp. ("*Avonia*" sp., *Avonia* small sp.)	×			×	R									×		
Buxtonia (*Kochiproductus*) *victorioensis* King	C		C								C				R	
(*Kochiproductus*) sp		C			C								×	R		
Chonetes sp	×			×	C									R		
(*Chonetinella*) sp												C				
Composita sp					×							×				
Derbyia sp				×												
Dictyoclostus (*Chaoiella*) *guadalupensis* (Girty)					C			×								
"*Dictyoclostus*" aff. *D. semistriatus* (Meek)											×					
Dielasma sp					×											
Enteletes dumblei Girty					C											×
sp				R		C		×						×		
Hustedia mormoni (Marcou)					R											
sp				×								R				
Leptodus sp				×	×							×				
"*Marginifera*" spp	A				R			×				C		×		
Meekella sp				×	R								C			
Meekella? or *Geyerella*? sp					×											
Neospirifer cf. *N. pseudocameratus* (Girty)											C					
spp			R	×	C											
Productid indet	C		×	×												
Prorichthofenia sp	×												C			
Rhipidomella sp	×			×	C			×				×		×		
Rhynchopora sp					×											

TABLE 8.—*Fossils indentified from Victorio Peak Limestone in central and northern Sierra Diablo*—Continued

Distribution of fossils in stratigraphic section, locality, and collection number indicated

	29a—Victorio Peak	31—North of Victorio Canyon	32—Marble Canyon	Northeastern Sierra Diablo				37—First section in Apache Canyon	38—Second section in Apache Canyon	39—Third section in Apache Canyon	40–South Mesa		Southeast of South Mesa			
	8545	8546	7011 14444	7006	14470 F 9837	14445 F 9818	F 9820 14448 F 9821 14449	14461	F 9836	F 9825	8534 F 2691	8535 F 2698	8536	8537 F 2709	8541	8547
Brachiopoda—Continued																
"Spirifer" sp				×		×						×	×			
Squamularia sp												×				
Stenocisma cf. *S. inequalis* (Girty)				×	C											
Streptorhynchus sp					×											
Wellerella cf. *W. elegans* (Girty)	R				R											
Lamellibranchiata:																
Acanthopecten sp				×												
Astartella? sp														×		
Parallelodontid indet				×												
Streblopteria sp	×			×												
Gastropoda:																
Babylonites sp					×							×				
Bellerophontid indet		×														
Callitomaria? sp		C														
Discotropis cf. *D. girtyi* Yochelson								×								
Euphemites exquisitus Yochelson								×								
Knightites (*Retispira*) sp								×								
Meekospira sp		×												×		
Loxonematid indet		×														
Stegocoelia? sp		×														
Warthia cf. *W. waageni* Yochelson		R														
Gastropod indet					×									×		
Scaphopoda:																
Plagioglypta sp		×												×		
Cephalopoda:																
Ammonite indet		×														
Arthropoda:																
Anisopyge? sp					×											
Vertebrata:																
Tooth of Helodus or Orodus type				×												
Alga (dasycladacean):																
Macroporella sp						A										

of the platform areas where it was probably once extensive, although it is now exposed only in the western part of the Guadalupe Mountains (King, P. B., 1948, p. 18; Boyd, 1958, p. 13–14) and north of the Sierra Diablo. Its equivalents in the basin area are uncertain; the beds there that were once tentatively assigned to the Cutoff (King, P. B., 1948, p. 16) are here classed as a member of the Brushy Canyon Formation.

LITHOLOGIC FEATURES

In the report area the Cutoff Shale is preserved only north of the Babb flexure and northeast of Sierra Prieta, from whence it extends northward for about 12 miles, (pl. 1). Here it surmounts the ledges of Victorio Peak Limestone and forms rolling hills, or lower slopes of mesas that are capped by Goat Seep Limestone. The Cutoff of this area is 250–275 feet thick, or somewhat thicker than in the Guadalupe Mountains.

The Cutoff of the Sierra Diablo region is interbedded thin-bedded or platy gray to black limestone, brown siliceous or sandy shale, and thin-bedded fine-grained sandstone. The limestone layers weather into light-gray or buff hackly fragments. At South Mesa thicker beds of black limestone occur near the middle, and north of North Mesa the top bed is a granular dolomitic limestone containing crinoid stems and small limestone pebbles. The Cutoff contains very few fossils. It much resembles the black limestone facies of the Bone Spring Limestone and probably formed during a brief incursion of basin deposits over the platform area (Stehli, 1954, p. 275).

North of South Mesa, shale and limestone beds of the Cutoff are separated by thin layers of earthy gypsum in which coarser crystals are embedded. The shale and limestone beds are turned up and broken, suggesting growth of the gypsum between them. The gypsum occurs only in the Cutoff Shale and not in formations below or above it; but it forms no definite layers so that the term "Dos Alamos gypsum member" that was once applied to it (King, P. B., and King, R. E., 1929, p. 922) is unwarranted. Mohr (1929) believed that the gypsum was introduced by circulating ground water from the gypsiferous deposits of the Salt Basin, but the gypsum is more likely an original constituent of the Cutoff that has been reconstituted and disordered by modern processes of weathering.

FOSSILS

The Cutoff Shale is very meagerly fossiliferous, and it has yielded no well-defined fauna. Most of the layers contain only a few brachiopods or other shells; where shells are abundant, they are apt to be of a single genus. During field investigations in the Sierra Diablo and the Guadalupe Mountains, the writer and his colleagues observed or collected the brachiopods *Squamularia*, *Chonetes*, and *Composita*, and poorly preserved mollusks. A somewhat larger collection of brachiopods was made near Bone Spring in the Guadalupe Mountains from strata of Cutoff type (King, P. B., 1948, p. 24); but these strata are not physically connected with the type Cutoff, and their precise relations to it are unknown.

A similar meager fossil assemblage has been observed by Boyd (1958, p. 59–60) in the Cutoff Shale of the central Guadalupe Mountains in New Mexico. Here, *Chonetes* and several genera of gastropods are the most common shells, but one locality yielded nautiloids and the ammonites *Pseudogastrioceras* sp. and *Perrinites hilli* (Smith). From the same area parafusulinids have been collected at several localities and have been identified as of Guadalupe type (Warren, 1955, p. 12; Boyd, 1958, p. 60–61). A possible similar occurrence is a collection of Dunbar and Skinner (1937, p. 725, loc. 140) near Dos Alamos north of the Sierra Diablo, from "cherty beds in basal part of Delaware Mountain sandstone a few feet above the Bone Spring [Victorio Peak(?)] Formation," which contains *Parafusulina rothi* Dunbar and Skinner.

AGE

The Cutoff Shale has been interpreted as a unit of late Leonard age (King, P. B., 1948, p. 18; Newell and others, 1953, p. 22–23; Boyd, 1958, p. 60–61), but some geologists (Warren, 1955, p. 12) have suggested that it is of Guadalupe age.

Most of the scanty fauna of the Cutoff is not a diagnostic of either series; although the ammonite *Perrinites* suggests a Leonard age, and the fusulinids are reported to suggest a Guadalupe age. This situation should be expected in beds lying near a boundary between series which contain similar and gradational faunas. Thus, much of the basis for judging the proper classification of the Cutoff must be in physical evidence, and especially in correlation of the sequence in the platform area with that in the basin, where the Leonard and Guadalupe Series are more clearly differentiated.

One reason for the original assignment of the Cutoff Shale to the Leonard Series was that its southern edge in the Guadalupe Mountains is eroded and is overlain by the Brushy Canyon Formation of early Guadalupe age. Elsewhere in that area it is overlain by the sandstone tongue of the Cherry Canyon Formation of middle Guadalupe age. Although there is little indication of erosion at the contact, there was apparently a hiatus. North of the Sierra Diablo the upper surface of the Cutoff is eroded and is overlain by the sandstone tongue of the Cherry Canyon Formation.

Correlation of the Cutoff Shale with the sequence in the basin area is uncertain. It was originally suggested (King, P. B., 1948, p. 16) that its equivalent is in shaly strata between the black limestone of the Bone Spring and the sandstone of the Brushy Canyon (the Pipeline Shale Member of the Brushy Canyon Formation of this report), but this correlation now appears less likely. Alternatively, Newell and others (1953, p. 23, fig. 10) proposed that the Cutoff is equivalent to shaly beds below the uppermost black limestone of the Bone Spring in the Delaware Mountains (geologic section 44, unit 10), and they imply that this uppermost black limestone is younger than the Cutoff. Their proposal, although interesting, involves tracing of beds across the very confused rocks of the Bone Spring flexure, where tracing by the writer (King, P. B., 1948, p. 17) has yielded different results. Correlation of the Cutoff with the Brushy Canyon Formation or higher units of the Guadalupe Series (Warren, 1955, p. 12) has little basis in known field relations.

In summary, faunal evidence as to the classification of the Cutoff Shale is equivocal; physical evidence, however, indicates that it is more likely a part of the Leonard Series than the Guadalupe Series, although its precise equivalent in the Leonard sequence of the basin area is undetermined.

STRATIGRAPHIC RELATIONS

In the Sierra Diablo region the Cutoff Shale is overlain unconformably by the sandstone tongue of the Cherry Canyon Formation. On South Mesa a medium-grained sandstone bed of variable thickness at the base of the sandstone tongue lies on an eroded surface of the Cutoff. On North Mesa the sandstone tongue nearly or completely wedges out on the unconformity. This unconformity is probably the boundary between the Leonard and Guadalupe Series; it also may express a hiatus during which the Brushy Canyon Formation was deposited in the basin area to the east during early Guadalupe time.

BRUSHY CANYON FORMATION

The Brushy Canyon Formation is missing in the Sierra Diablo and the area north of it, but it occurs in the Delaware Mountains to the east, as in the northeast corner of the report area (pl. 1) (geologic section 44, pl. 8). The Brushy Canyon, a formation of the basin area, overlaps the edges of the basin (King, 1948, p. 28–32). It is the basal formation of the Guadalupe Series.

The most prominently exposed parts of the Brushy Canyon Formation are thick beds of relatively coarse sandstone, which are separated by units of thinner bedded finer grained sandstone and sandy shale. The formation is about 1,000 feet thick, but its top is not exposed within the report area in the Delaware Mountains and is only preserved farther east.

At the base of the Brushy Canyon Formation in the Delaware Mountains is a persistent unit, 30–150 feet thick (geologic section 44, unit 12), of black platy shale and shaly sandstone, interbedded with layers of limestone and sandstone. This unit lies with abrupt contact on black limestone of the Bone Spring and is overlain with gradational contact by the Brushy Canyon. It was tentatively correlated with the Cutoff Shale of the platform area (King, P. B., 1948, p. 16), but although it lies in the same general stratigraphic position, it now seems unlikely that the two units could be equivalent. A rather abundant brachiopod fauna in parts of the shaly unit has affinities with both Leonard and Guadalupe faunas (King, P. B., 1948, p. 24). The unit also contains large species of *Parafusulina* and species of the ammonites *Waagenoceras* and *Medlicottia* (Newell and others, 1953, p. 23), which are more clearly of Guadalupe affinity.

Both physical relations and fossils indicate that the shaly unit is more closely related to the Brushy Canyon Formation above than to the Bone Spring Limestone beneath. It is therefore termed the Pipeline Shale Member, following Warren (1955, p. 11), and is classed as a basal member of the Brushy Canyon Formation.

SANDSTONE TONGUE OF CHERRY CANYON FORMATION

The Cutoff Shale of the northern part of the report area is followed by the sandstone tongue of the Cherry Canyon Formation (King, P. B., 1942, p. 588), which forms the upper part of the slope of South Mesa, and other summits farther north that are capped by Goat Seep Limestone (pl. 1).

On South Mesa the unit is 150–190 feet thick, and most of it is buff fine-grained thin-bedded sandstone. At the base, however, is a more massive layer of brown medium-grained sandstone that contains poorly preserved fusulinids, as well as shale and limestone pebbles derived from the underlying Cutoff. The layer rests on a channeled surface of the Cutoff Shale, and its thickness varies within short distances from 5 to 40 feet. On North Mesa, north of the report area, the sandstone tongue is not exposed; it is either missing by overlap on the Cutoff, or is very thin and covered by talus from the Goat Seep Limestone above.

As shown by outcrops in the southern Guadalupe Mountains (King, P. B., 1948, p. 38), the sandstone tongue is equivalent to the lowest part of the typical Cherry Canyon Formation of the Delaware Mountains, and represents an extension of its sandy beds from the Delaware basin across the marginal areas; in the marginal areas, the place of higher parts of the Cherry Canyon Formation is taken by the Goat Seep Limestone. Typical Cherry Canyon Formation is apparently exposed at the foot of the Delaware Mountains in the northeastern part of the report area (pl. 1), but these exposures were not visted during the present investigation. In the northern part of the report area the sandstone tongue of the Cherry Canyon Formation is overlain conformably by the Goat Seep Limestone. In places, layers of the Goat Seep seemingly intertongue with the sandstone.

GOAT SEEP LIMESTONE

The Goat Seep Limestone is named for Goat Seep on the west side of the Guadalupe Mountains (King, P. B., 1942, p. 588), where it is a succession of massive limestone banks and reefs that are equivalent to the middle and upper parts of the Cherry Canyon Formation of the basin area. Northward on the west side of the Guadalupe Mountains, the Goat Seep loses its massive character and passes into back-reef or platform deposits, which are thick-bedded dolomitic limestone with many thin-bedded or sandy partings. These back-reef deposits extend into the central Guadalupe Mountains of New Mexico, where they have been termed the "Grayburg-Queen sequence" (Boyd, 1958, p. 15–16), after formations whose type areas are in the northern Guadalupe Mountains.

The equivalent of the Goat Seep Limestone in the northern part of the Sierra Diablo region resembles the back-reef beds of the Guadalupe Mountains, and formation names of the northern Guadalupe Mountains might be applied to it, as was done by Stehli (1954, p. 275). However, it is somewhat more convenient to retain the term Goat Seep for it in the same manner as has been done for back-reef beds in the southern Guadalupe Mountains (King, P. B., 1948, p. 40).

LITHOLOGIC FEATURES

In the report area the Goat Seep Limestone is preserved only north of the Babb flexure, where it forms the resistant caps of South Mesa and Middle Mesa (pl. 1 and upper view pl. 12). Other outliers occur farther north, on North Mesa and the hills west of Dos Alamos. On South Mesa the Goat Seep is about 200 feet thick (geologic section 43b, unit 24), but its top is not preserved, either here or elsewhere in the region.

On South Mesa the Goat Seep is mainly light-gray or pink dolomitic limestone in beds a few feet thick containing irregular knotted small to large chert masses and poorly preserved fossils. Most of the fossils are silicified, and many form voids lined by crystalline calcite.

Thicker layers of gray-brown dolomitic limestone and medium-grained dolomitic sandstone are interbedded whose surfaces weather dark gray and pitted. Some of the more sandy layers are crossbedded. Bedding in the Goat Seep is very irregular, in places chaotic, in others inclined in a consistent direction, the beds extending with primary dip to the base of the formation where they seemingly intergrade with the upper part of the sandstone tongue of the Cherry Canyon Formation.

On North Mesa, beds like those on South Mesa are overlain by a unit of thicker bedded dolomitic limestone containing many fusulinids, which forms prominent dark jagged ledges.

FOSSILS AND AGE

The Goat Seep Limestone of the Sierra Diablo region contains a rather abundant fauna (table 9), mainly of brachiopods, but adequate collections are difficult to obtain because of poor preservation of the fossils.

TABLE 9.—*Fossils identified from Goat Seep Limestone, northern Sierra Diablo*

[Identifications by P. E. Cloud, Jr., Helen Duncan, R. M. Finks, L. G. Henbest, and E. L. Yochelson. Explanation of symbols: X, species or genus present; C, common; A, abundant; R, rare]

Distribution of fossils in stratigraphic section, locality, and collection number indicated	43-South Mesa 8548-F2688	North Mesa 8549	Dos Alamos 2697
Foraminifera:			
Parafusulina maleyi referta Dunbar and Skinner	--------	--------	X
Fusulinids indet	X	--------	--------
Porifera:			
Actinocoelia meandrina Finks	X	--------	--------
Actinocoelia? sp	X	--------	--------
Stioderma coscinum Finks	X	--------	--------
Coelenterata:			
Horn coral indet	X	--------	--------
Bryozoa:			
"*Acanthocladia*" sp	C	--------	--------
Polyporoid indet	--------	X	--------
Brachiopoda:			
Chonetes (*Chonetinella*) sp	X	--------	--------
Composita sp	A	X	--------
Dictyoclostus (*Chaoiella*) cf, *D. guadalupensis* (Girty)	X	X	--------
Dielasma sp	X	--------	--------
Enteletes spp	R	--------	--------
Hustedia cf. *H. mormoni* (Marcou)	C	--------	--------
Leptodus cf. *L. americanus* Girty	C	--------	--------
Linoproductus? sp	--------	X	--------
Marginifera aff. *M. lasallensis*? (Norwood and Pratten)	--------	X	--------
"*Marginifera*" aff. "*M.*" *occidentalis* Schwellwein of R. E. King and "*M.*" *walcottianus* (Girty)	C	--------	--------
"*Marginifera*" sp	X	--------	--------
Marginifera? sp	--------	R	--------
Neospirifer sp	C	--------	--------
Phricicothyrinid indet	X	--------	--------
"*Pustula*" sp	--------	X	--------
Rhynchopora? sp	R	--------	--------
Stenocisma sp	C	R	--------
Wellerella cf. *W. elegans* (Girty)	R	--------	--------
Wellerella sp	--------	X	--------
Lamellibranchiata:			
"*Aviculopecten*" sp	X	--------	--------
Gastropoda:			
Platyceras sp	X	--------	--------

Available collections include 15 genera of brachiopods, of which *Composita*, *Stenocisma*, *Neospirifer*, *Leptodus*, and "*Marginifera*" are most significant. They also contain a few sponges, corals, bryozoans, and mollusks. Fusulinids are abundant in many layers and are probably mainly large forms of *Parafusulina*, although specific indentification can be made of only a few specimens.

Physical matching of sections and tracing of beds in the Guadalupe Mountains indicate that the Goat Seep Limestone is equivalent to part of the Cherry Canyon Formation of middle Guadalupe age. This fact is confirmed by what is known of its fauna. The large parafusulinids are characteristic of beds of early and middle Guadalupe age, and according to R. E. King (1931, p. 15), most of the brachiopods are like those of the Word Formation of the Glass Mountains, which is of early and middle Guadalupe age.

STRATIGRAPHIC RELATIONS

In the Sierra Diablo region the Goat Seep Limestone is the highest Permian formation preserved, and it is unknown whether higher strata of the system were ever laid down there. Any such strata have long since been removed by erosion, because the Permian of the region is overlain unconformably by rocks of the Cretaceous System. The Goat Seep Limestone itself is not in contact with Cretaceous rocks, but its upper surface on South, Middle, and North Mesa is accordant with a surface elsewhere in the region on which Cretaceous rocks were deposited and later removed. This accordant surface extends westward from South Mesa, across the Goat Seep Limestone onto the Victorio Peak Limestone, which is overlain by Cretaceous rocks at Sierra Prieta.

CRETACEOUS

Rocks of the Cretaceous System in the Sierra Diablo region are mainly preserved in the western part of the report area. They border the Sierra Diablo on the west, down the dip from the Paleozoic and Precambrian rocks, although they are preserved in a few small outliers farther east (pl. 1). They also form the whole of the bedrock in the southwest corner of the report area southwest of Eagle Flat, along the southeastward extension of Devil Ridge and in the foothills of the Eagle Mountains. The Cretaceous rocks of the Sierra Diablo are the fringe of a much more extensive body to the west, southwest, and south, in the Finlay, Quitman, Eagle, Van Horn, and other mountain ranges.

The Cretaceous formations of northern Trans-Pecos Texas were first defined and described by Richardson

(1904, p. 46–50), but modern conceptions of their stratigraphy are based largely on work done here and elsewhere in the State by Adkins (1933, p. 272–400). Cretaceous rocks west and southwest of the Sierra Diablo region have been reported on for the U.S. Geological Survey by Albritton and Smith (1964) and by Gillerman (1953, p. 15–33); those to the south are currently under study by DeFord and associates (Brand and DeFord, 1958; DeFord and Brand, 1958; Twiss, 1959). The description given in this report of the Cretaceous rocks southwest of Eagle Flat is based on publications of Smith (1940), Gillerman (1953), and Albritton and Smith (1965).

Cretaceous rocks of the Sierra Diablo region belong mainly to the Comanche, or Lower Cretaceous Series. Rocks of the Gulf, or Upper Cretaceous Series, are preserved only southwest of Eagle Flat, although they may once have extended over the region farther north. The formations recognized in the region are listed in the table below.

Cretaceous formations of the Sierra Diablo region

	Southwest of Eagle Flat	Western Sierra Diablo	Sierra Prieta
Gulf Series	Eagle Ford Formation	[1]	[1]
Comanche Series	Washita Group	[1]	Washita Group
	Kiamichi Formation [2]	Kiamichi Formation	Cox Sandstone
	Finlay Limestone	Finlay Limestone	
	Cox Sandstone	Cox Sandstone	
	Bluff Mesa Formation	Campagrande Limestone	Campagrande Limestone
	Yucca Formation	[3]	[3]

[1] Not preserved.
[2] Not exposed.
[3] Absent.

Lower Cretaceous rocks of the Sierra Diablo region resemble those of the classic area of the Comanche Series in central and north-central Texas, and like them, record an overlap of Cretaceous deposits on an eroded surface of the Paleozoic rocks—the Wichita paleoplain of Hill (1901, p. 363). Thus, the Yucca Formation resembles the Travis Peak of central Texas; the Bluff Mesa Formation and Campagrande Limestone, the Glen Rose; the Cox Sandstone, the Paluxy; and the Finlay Limestone, the Edwards. The Washita Group shows the same northward change from dominant limestone in the south into shale, marl, and sandstone to the north. In the Sierra Diablo region, however, the surface of overlap is more steeply canted; variations which occur along the outcrop in distances of several hundred miles in central and north-central Texas are compressed here to within a few scores of miles (pl. 13).

Not far southwest of the Sierra Diablo region, geosynclinal conditions prevailed during Cretaceous time, and a great thickness of Early Cretaceous sediments was deposited, in places following on the latest Jurassic. The Yucca and Bluff Mesa Formations of the southwestern part of the report area were deposited along the margins of this geosyncline. Cretaceous rocks farther north, along the west edge of the Sierra Diablo, were deposited on a shelf area that bordered the geosyncline toward the northeast.

Overlap relations in the shelf area along the west edge of the Sierra Diablo are not completely preserved, because of fragmentation of the Cretaceous rocks by erosion. It is clear, however, that the Yucca Formation is missing by overlap, and that the Bluff Mesa has passed into a thinned equivalent, the Campagrande Limestone. The overlying Cox Sandstone, a thick extensive sheet of quartzose sands, must replace the Finlay Limestone and Kiamichi Formation northward, for at Sierra Prieta, sandstone like the Cox is overlain directly by basal strata of the Washita Group, of Duck Creek age. A further extension of the same overlap north of the report area is indicated in the Cornudas Mountains, near the Texas-New Mexico boundary, where Adkins (1932, p. 354) observed Duck Creek fossils in sandstone less than 30 feet above the base of the Cretaceous sequence.

PRE-CRETACEOUS SURFACE

Cretaceous rocks of the Sierra Diablo region were deposited on a surface that evenly bevels the rocks beneath. For the most part the Cretaceous lies on Permian rocks, although in an area in the Sierra Diablo foothills northeast of Eagle Flat it lies directly on the Precambrian Hazel and Allamoore Formations. This area was the locus of greatest uplift during pre-Permian deformation, where the pre-Permian Paleozoic formations had been removed by erosion, and where the Permian itself was deposited in a smaller thickness than elsewhere. Rather oddly, the Cretaceous rocks have nowhere been observed in contact with any of the Paleozoic formations which elsewhere intervene between the Precambrian and Permian.

South of the Victorio flexure the Cretaceous lies on the Hueco Limestone, and in places on Precambrian rocks (section *K–K′*, pl. 16); north of the flexure it lies on the higher Victorio Peak Limestone (section *A–A′*, pl. 16). North of the Babb flexure the Cretaceous was probably deposited on younger Permian formations of the Guadalupe Series, but it is not now preserved above them. In contrast with the earlier unconformable surfaces in the Sierra Diablo region (as at the base of the Van Horn Sandstone and at the base of the Hueco Limestone), the surface at the base of the Cretaceous is remarkably even. Except in the area where it lies on Precambrian rocks in the Sierra Diablo foothills, no hills or hollows occur. The surface of the pre-Cretaceous rocks was reduced to a peneplain, formed in part by prolonged subaerial erosion during early Mesozoic time, and afterwards perfected by marine erosion of the advancing Cretaceous seas.

Over wide areas in the Sierra Diablo, Cretaceous rocks are no longer preserved, but its topographic summits are an accordant surface which is probably the peneplain upon which the Cretaceous was once deposited and later removed by erosion. Some remnants of Cretaceous rocks are perched on this surface, as on the west rim of Victorio Canyon and at Black Knobs, and it seemingly extends beneath the larger bodies of Cretaceous farther west. The summits of the downfaulted Baylor Mountains to the east are probably parts of the same surface, for a few remnants of Cretaceous sandstone are preserved there in downfaulted blocks.

The pre-Cretaceous peneplain in the Sierra Diablo is preserved on accordant divides, some at altitudes greater than 6,000 feet. These divides were not produced by stripping of the bedding planes of the underlying Permian rocks as they truncate the bedding—at a low angle in most places, but more steeply on the Victorio and Babb flexures. The peneplain is preserved most extensively on the Victorio Peak Limestone in the northeastern part of the Sierra Diablo, between Victorio and Apache Canyons, where many of the valleys are separated by nearly level summits as much as half a square mile in area. On these summits, the underlying limestone is thinly covered by red-brown residual clay, through which limestone pinnacles project, and in which large quantities of residual chert are embedded, different from the sparser chert that occurs in the limestone is the adjacent valleys. The residual clay and chert were surely formed at a time earlier than that during which the adjacent valleys were cut, and they may have been produced by weathering before the Cretaceous deposits were laid over the region.

Albritton and Smith (1950, p. 1440) have described features on the basal Cretaceous surface in the Finlay Mountains which they believe are "part of an ancient soil profile, probably reworked and similar in origin to lime-enriched zones of the southwestern United States, and developed by weathering of calcareous parent material in a semiarid or arid climate." They suggest (Albritton and Smith, 1965) that the features observed on the summit areas in the Sierra Diablo are not compatible with those in the Finlay Mountains, and probably were formed by weathering under more humid conditions. Clearly, knowledge regarding pre-Cretaceous conditions of weathering remains elusive, and further evidence must be awaited.

YUCCA FORMATION

The Yucca Formation, or oldest Cretaceous unit in the Sierra Diablo region, occurs only southwest of Eagle Flat (pl. 1), where its exposures are segments of two belts of outcrop that are extensive beyond the report area. The Yucca in Love Hogback and the Red Hills lies above the Devil Ridge thrust and is exposed thence northwestward along Devil Ridge (Smith, 1940, p. 604). The Yucca farther east, north of Eagle Spring, lies beneath the Devil Ridge thrust and is at the end of a belt of outcrop which extends southward along the foothills of the Eagle Mountains (Gillerman, 1953, p. 15).

The Yucca Formation consists of interbedded limestone, conglomeratic sandstone, and shale, all of red, brown, or gray colors. The sequence above the Devil Ridge thrust is more than 1,600 feet thick, but the base is not exposed (geologic section A, pl. 13). The full sequence below the Devil Ridge thrust near Eagle Spring is 330 feet thick (geologic section B, pl. 13), but farther south the formation wedges out entirely in places by overlap on the Hueco Limestone.

The Yucca Formation contains few fossils, but it is clearly of early Comanche age, and is perhaps approximately equivalent to the Travis Peak Formation of central Texas. Southwest of the report area it may include strata of earliest Cretaceous age, or older than the base of the Comanche Series in its type area.

BLUFF MESA FORMATION

The Bluff Mesa Formation, which overlies the Yucca, is also differentiated only southwest of Eagle Flat (pl. 1); but strata equivalent to its upper part extends farther north, where they are termed the Campagrande Limestone. Like the Yucca, the Bluff Mesa is exposed above the Devil Ridge thrust in the southwest corner of the report area and below the Devil Ridge thrust near Eagle Spring farther east.

The Bluff Mesa consists of massive limestone beds, with some marl partings and minor units of sandstone and shale. Above the Devil Ridge thrust near the report area it is about 1,000 feet thick (geologic section A, pl. 13), but it thickens northwestward to as much as 1,600 feet at the type locality on Bluff Mesa south of

Sierra Blanca. Below the Devil Ridge thrust near Eagle Spring, the Bluff Mesa is no more than 250 feet thick, and the limestone is interbedded with much shale, sandstone, and conglomerate (geologic section C, pl. 13).

The Bluff Mesa is rather abundantly fossiliferous throughout, and contains a fauna like that of the Glen Rose Formation in central Texas. *Exogyra quitmanensis* Cragin is common in the lower part, and *Orbitolina texana* (Roemer) occurs from base to top.

CAMPAGRANDE LIMESTONE

The Campagrande Limestone is the basal Cretaceous unit in the Sierra Diablo and farther west in the Diablo Plateau, although it is equivalent to strata well above the base of the Cretaceous in the area southwest of Eagle Flat, that is, to the upper part of the Bluff Mesa Formation.

The Campagrande Limestone is named for the feature shown on modern maps as Campo Grande Arroyo (Richardson, 1904, p. 47), in the Finlay Mountains about 25 miles west of the report area. At its type locality it is 630 feet thick, but it varies from 375 to 800 feet elsewhere in the Finlay Mountains (Albritton and Smith, 1965.) In the foothills south of the Sierra Diablo it is as much as 200 feet thick in places (geologic sections 45, 46, p. 174–175) but is generally less. Farther north it is mostly less than 50 feet thick, although it attains 80 feet on the east side of Sierra Prieta (geologic section 53, pl.13 and p. 170–171).

SIERRA DIABLO FOOTHILLS

The Campagrande Limestone forms a nearly continuous band of outcrop south of the south-facing escarpment of the Sierra Diablo, where it is overlain toward the west by Cox Sandstone (pl. 1). It is also preserved in smaller outliers in the Bean and Streeruwitz Hills farther south. Toward the north and west the Campagrande lies on the Hueco Limestone, but in most of the foothills it bevels the Hueco and lies directly on the Precambrian Hazel and Allamoore Formations.

Basal beds of the Campagrande are conglomerate with a limestone matrix, containing numerous pebbles of Hueco Limestone, minor pebbles of chert, and toward the base, fragments of Precambrian rocks. In places the conglomerate is as much as 80 feet thick; but it varies abruptly in thickness within short distances by overlap on irregularities of the pre-Cretaceous surface, and in places is missing entirely.

The overlying part of the formation, about 100 feet thick, has a more regular stratigraphy, and includes two beds of ledge-making limestone. The lower ledge maker, informally termed the "cap ledge," is a massive bed of light-gray limestone 25–50 feet thick. Parts are lumpy and perhaps contain algal balls, but no other fossils were observed. Analysis of a specimen from the Bean Hills indicates 93.66 percent $CaCO_3$, 1.18 percent $MgCO_3$, and 5.50 percent insoluble material (K. J. Murata, written commun., 1940). In most of the Bean and Streeruwitz Hills the "cap ledge" is the highest bed preserved. The upper ledge maker, informally termed the "Nodosaria bed," is a darker gray, more distinctly bedded, more fossiliferous limestone 15–25 feet thick. At a few places its weathered surfaces are studded with shells of the medium-sized foraminifer *Haplostiche* ("*Nodosaria*"), and in many places it contains oyster and echinoid fragments.

Between and above the two ledge-making beds are shale, marl, and nodular limestone, parts of which are bioclastic and contain oyster fragments and traces of rudistids.

WESTERN SIERRA DIABLO

In the plateau country west of the Sierra Diablo the basal Cretaceous is a set of calcareous strata, no more than 25 feet thick in most places, but thickening to 50 feet at Black Knobs and to 80 feet on the east side of Sierra Prieta. These strata are not easily recognized on first view: in some places they resemble the underlying Permian and in others, modern caliche and limestone gravel. Their nature as a basal Cretaceous deposit is made clear in favorable exposures.

These calcareous strata are classed with the Campagrande Limestone, because field relations suggest that they were once physically joined to the Campagrande farther south. However, they are not only thinner than the Campagrande in its more typical exposures, but they lack its regular stratigraphy, are nearly without fossils, and may be partly of younger age. They much resemble the Yearwood Formation of the Apache Mountains east of the report area, as described by Brand and DeFord (1958, p. 373–376), which is also a thin basal Cretaceous unit, mainly limestone, with a basal conglomerate.

Near Cox Mountain (geologic section 49, pl. 13) the Campagrande is limestone, partly nodular and marly, containing limestone and chert pebbles in its lower part; in places it has a strong ledge at the top. Most of the limestone is light gray or white, but it is commonly mottled yellow or red, so that it has a "burnt" appearance. On the east side of Sierra Prieta (geologic section 53, pl. 13), where the formation is somewhat thicker, limestone of the sort described forms ledges several feet thick, separated by white or buff marl and clay. Poorly preserved oysters and gastropods occur at various levels, and nodules or lumps in the marly layers may be of algal origin.

Relations of these basal Cretaceous strata in the western Sierra Diablo are puzzling. At Cox Mountain and farther south they are overlain by many hundreds of feet of Cox Sandstone, Finlay Limestone, and Kiamichi Formation; whereas at Sierra Prieta to the north they are overlain by less than 200 feet of sandstone, part or all of which is of Finlay and Kiamichi age. Either the calcareous strata are a transgressive deposit which becomes younger toward the north, or they are separated from the overlying sandstones by a disconformity, the magnitude of whose hiatus increases northward. A disconformity is reported between the calcareous Yearwood Formation and the overlying Cox Sandstone in the Apache Mountains (Brand and De Ford, 1958, p. 376–377).

FOSSILS AND AGE

The Campagrande Limestone in the Sierra Diablo foothills is fossiliferous, but no significant collections were obtained during the present investigation. In the type area in the Finlay Mountains it contains many foraminifers and various megafossils, including *Porocystis globularis* (Giebel), corals, pelecypods, various rudistids, and gastropods, such as *Turritella* (Albritton and Smith, 1965). This fauna, like that of the Bluff Mesa Formation, is of Glen Rose or late Trinity age.

COX SANDSTONE

The Cox Sandstone is named for Cox Mountain (Richardson, 1904, p. 47), west of the Sierra Diablo within the report area; but a better reference locality is perhaps in the Finlay Mountains beyond the report area, where it lies in sequence between the type Campagrande Limestone and type Finlay Limestone.

Toward the north the Cox is a nearly continuous body of sandstone, which is a little more than 400 feet thick on Cox Mountain and 540–675 feet thick in the Finlay Mountains. The Cox Sandstone thickens southward, attaining more than a thousand feet southwest of Eagle Flat; as it thickens, it becomes finer grained and acquires many interbedded layers of limestone and shale. The Cox is one of the most prominently exposed parts of the Cretaceous sequence, projecting in buttes, mesas, and hogbacks, on which its sandstone beds form massive ledges.

SOUTHWEST OF EAGLE FLAT

The Cox Sandstone is 1,066 feet thick in a measured section a little west of the edge of the report area (geologic section A, pl. 13), and is as thick or thicker in the belt of outcrop farther east near Eagle Spring (geologic section C, pl. 13). It consists of brown sandstone that is finer grained and more quartzitic than farther north, with fewer crossbeds and ripple marks, and with much interbedded shale, siltstone, and fossiliferous limestone (Smith, 1940, p. 612).

SIERRA DIABLO FOOTHILLS AND COX MOUNTAIN

The most extensive exposures of the Cox Sandstone are along the base of the south-facing escarpment of the Sierra Diablo in its western half (pl. 1). Small to large outliers occur farther east, near the Gifford-Hill rock crusher in the northwestern Carrizo Mountains, and to the north in the plateau country, in the area near Cox Mountain. The top of the formation is preserved only on Cox Mountain (geologic section 49, pl. 13), where it is overlain by Finlay Limestone; but the part of the formation which is preserved on Dome Peak (geologic section 47, pl. 13) and in the northwestern Carrizo Mountains (geologic section 48, p. 171) is as thick or thicker.

The most conspicuous parts of the formation are massive sandstone beds, forming units 15 to more than 100 feet thick. The sandstone beds weather brown and break out in great rectangular or cubical blocks that strew the slopes below. These blocks tend to overwhelm and obscure any interbedded less resistant units, which actually form a considerable part of the formation toward the south, although they are probably less important near Cox Mountain.

The massive sandstone beds, which are formed of medium- to coarse-grained quartz sand, have great variations in texture and structure from layer to layer. Many parts are crossbedded, in part on a large scale, and some bedding surfaces are ripple marked. Much of the sandstone contains dispersed well-rounded quartz and chert pebbles as much as an inch in diameter; in places these pebbles are concentrated in streaks or lenses, or in beds of conglomerate. The sandstone is characteristically dotted with small brown ferruginous spots or nodules, which are especially conspicuous on weathered surfaces and which may have originated from pyritic segregations in the original rock.

In the Sierra Diablo foothills less resistant interbedded units 10 to 25 feet thick occur throughout the formation, but they are thicker and more prominent in the lower few hundred feet. In the upper part most of the interbedded units are thinner bedded finer grained lighter brown sandstone; but lower down they include red and purple silty shale and marl and scattered beds of nodular gray limestone or dense brown to red limestone. Within the report area none of the limestone beds are fossiliferous, but near Sierra Blanca farther west they contain the thick-shelled gastropod *Actaeonella* and various oysters (geologic section P, pl. 13). On Cox Mountain the interbedded units are apparently thinner, but some beds of purplish shale were observed; 15 feet of nodular limestone has been reported 225 feet below the top (DeFord and Brand, 1958, p. 23, pl. 7).

OUTLYING AREAS

East of the exposures described, smaller outliers of the Cox are preserved in places atop the dominant terrain of Permian carbonate rocks (pl. 1). A small patch of sandstone no more than 10 feet thick overlies the tilted Bone Spring Limestone of the Victorio flexure on the west rim of Victorio Canyon (northwestern part of sec. 14, block 43) (section X–X', pl. 4) and is capped by a remnant of Tertiary vesicular basalt. Farther west in the same vincinity sandstone patches are scattered over the upland. Some of these patches may be layers in the Bone Spring Limestone, but some are certainly outliers of the Cretaceous. Cretaceous fossils have been collected in this area by the local ranchmen, but none were observed during the present investigation.

Similar outliers of the Cretaceous occur in the Baylor Mountains, in Red Tank Canyon a mile east of Red Tank (west-central part of sec. 8, Block 66), where steeply dipping sandstone overlies the Hueco Limestone and is downfaulted against it on the south.

In all these outlying areas sandstone lies directly on the Permian rocks, and the Campagrande Limestone that intervenes on the western slopes of the Sierra Diablo is missing.

SIERRA PRIETA

At Sierra Prieta, 18 miles north of Cox Mountain, the lower part of the Cretaceous includes a unit of massive sandstone which is mapped with the Cox (pl. 1), although its relations are somewhat different from those of the Cox farther south. The sandstone is underlain by Campagrande Limestone, but it is overlain directly by the Washita Group. The Finlay Limestone and Kiamichi Formation which should intervene are not represented as such. Physical connection of the sandstone on Sierra Prieta with the typical Cox is not demonstrated, as a wide alluvial-covered area intervenes; nevertheless, the two sandstones are probably parts of the same transgressive body.

In the eastern part of Sierra Prieta the sandstone is 135 feet thick (geologic section 53, pl. 13), but in the western part it is as much as 190 feet (geologic section 54, pl. 13). The upper part includes 50 or 60 feet of massive brown medium- to coarse-grained sandstone, in part crossbedded and pebbly like the Cox. Above it is a smaller thickness of lighter brown finer grained thinner bedded sandstone; below it is a greater thickness of friable buff sandstone, marly sandstone, and gray, buff, or purple shaly sandstone.

Many of the sandstone beds contain fragments of silicified wood, and some of their bedding surface show fucoidal markings. In the western part of Sierra Prieta invertebrate shells occur in the upper half of the sandstone, and are especialy abundant in massive beds 120 feet below the top where *Exogyra texana* Roemer, *Alectryonia carinata* (Lamarck), and various pelecypods and gastropods of Fredericksburg type are reported (Adkins, 1932, p. 354).

Presumably part or all of the sandstone on Sierra Prieta is equivalent to the Finlay Limestone and Kiamichi Formation elsewhere in the Diablo Plateau, although it might include equivalents of the typical Cox Sandstone in its lower part. Disappearance of the Finlay toward Sierra Prieta seems abrupt on first view, as mesas capped by its limestone beds occur within 6 miles to the southwest, and at only slightly greater distances to the south and west. However, these limestone beds are no more than a few feet thick, and most of the Finlay on the mesas is marl and sandy marl, with several conspicuous sandstone beds. The Kiamichi(?) Formation which overlies the Finlay in an outlier 9 miles southwest of Sierra Prieta (Block 35, west of report area) is all sandstone.

FOSSILS AND AGE

No fossils were observed in the Cox Sandstone in the report area, except for those in beds probably younger than the typical Cox on Sierra Prieta. To the west, near Sierra Blanca and in the Finlay Mountains, gastropods and pelecypods of marine origin occur in limestone and marl that is interbedded with the massive sandstone of the upper half, whereas the silty shale units of the lower half contain charophytes, ostracodes, and silicified wood, probably of littoral origin (Albritton and Smith, 1965). The thick-shelled gastropod *Actaeonella* is the most abundant marine invertebrate fossil.

The poorly fossiliferous Cox Sandstone intervenes between fossiliferous beds of Trinity age (Bluff Mesa and Campagrande) and of Fredericksburg age (Finlay), indicating that it lies near the boundary between these two groups. Evidence is insufficient to prove whether the Cox is of Trinity age, of Fredericksburg age, or includes beds of both ages.

FINLAY LIMESTONE

The Finlay Limestone is named for the Finlay Mountains (Richardson, 1904, p. 47–48), about 25 miles west of the report area, where it overlies the Cox Sandstone with the top not preserved; elsewhere, as near Sierra Blanca and on Cox Mountain, it is followed by the Kiamichi Formation. The Finlay characteristically includes ledge-making beds of rudistid-bearing limestone, but these beds vary greatly in number and thickness; they form most of the unit southwest of Eagle Flat, but are interbedded northward with increasing thicknesses of nodular limestone, marl, and sandstone. Like the underlying Cretaceous formations, the Finlay thins northeastward. It is more than 350 feet thick southwest of Eagle Flat and as much as 200 feet thick in the Finlay Mountains; the full thickness north of Sierra Blanca, however, is 150 feet and on Cox Mountain, 60 feet.

The Finlay Limestone is only scantily preserved in the report area (pl. 1), and its outcrops are mainly extensions of larger ones farther west—those southwest of Eagle Flat of the outcrops in Devil Ridge, and those west of the Sierra Diablo of the outcrops in the Diablo Plateau (Albritton and Smith, 1965). A small isolated outlier surmounts the Cox Sandstone on Cox Mountain.

LOCAL FEATURES

Southwest of Eagle Flat, the Finlay above the Devil Ridge thrust is a nearly continuous sequence of limestone beds a few feet to more than 5 feet thick with only a few marly partings; fossils are abundant but poorly preserved. About 350 feet of Finlay overlies the Cox on Devil Ridge just west of the report area, but the top is missing (geologic section A, pl. 13). The Finlay is more extensively exposed on the pediment northeast of the Devil Ridge thrust; however, outcrops are low and obscure, and little is known of the sequence.

On Cox Mountain (geologic section 49, pl. 13) where the full thickness of the Finlay is 60 feet, it includes two ledge-making beds of gray limestone, one at the top and another near the middle, with slope-making nodular limestone, sandy limestone, and marl between and below. The ledge-making beds contain rudistids, the slope-making beds contain oysters and gastropods.

Northwest of Cox Mountain the Finlay Limestone forms Roberts Mesa (Block 39) and Norton Mesa (Block 34), each several square miles in area, which are outliers of more extensive tablelands farther west (pl. 1). Only about 80 feet of the formation is exposed (geologic sections 51, 52, p. 173–174), the base being concealed by alluvium and the top being a stripped surface of the limestone caprock. This caprock is probably near the top of the formation, for it is overlain by sandstone of the Kiamichi(?) Formation west of the report area (Block 35).

Near Roberts and Norton Mesas the only strong limestone bed is the caprock at the top, which is no more than 6 feet thick. Below is marl and calcareous sandstone, with several beds of brown massive sandstone, the most conspicuous of which is 8 or 10 feet thick and has been separately mapped (pl. 1). The sandstone is medium grained, crossbedded, and ripple marked, the ripples commonly trending northwestward. Tracing of the sandstone beds from mesa to mesa along the west edge of the report area indicates that they wedge out southward. The limestone caprock contains poorly preserved rudistids; the marl beneath, abundant pelecypods and gastropods; and the sandstone beds, fragments of silicified wood.

FOSSILS AND AGE

In the Finlay Mountains the Finlay Limestone contains a varied invertebrate fauna, including the foraminifer *Dictyoconus* ("*Orbitolina*") *walnutensis* Carsey; *Exogyra*, *Gryphaea*, rudistids, and other pelecypods; the ammonite *Engonoceras;* gastropods; and echinoids (Albritton, and Smith 1965). Collections from the report area, largely from the marl beds, are more restricted, consisting of pelecypods, gastropods, and a few echinoids; rudistids are common in the ledge-making beds but are poorly preserved. The fauna of the Finlay Limestone is of Fredericksburg age, and the formation is equivalent to part or all of the Edwards Limestone farther east in Texas.

Table 10 indicates the fossils of the Finlay Limestone which have been identified from collections made west of the Sierra Diablo, in or near the report area. All but the first lot were identified by R. W. Imlay (written commun., 1940, 1950).

TABLE 10.—*Fossils identified from Finlay Limestone, western part of Sierra Diablo region, Texas*

[Identifications by R. W. Imlay]

	Locality and fossil collection number				
	Cox Mountain (De Ford and Brand, 1958)	Southwest of Roberts Ranch (USGS 17844, 17843)	Roberts Mesa (USGS 17844, 17843)	Norton Mesa (USGS 17281, 17900)	Northeastern part of Triple Hill quad. (Albritton and Smith, 1965)
Lamellibranchiata:					
Ostrea crenulimargo Roemer			×		
Exogyra texana Roemer		×	×	×	×
Trigonia sp					×
Pecten (Neithea) occidentalis Conrad				×	
Lima sp				×	
Modidus concentrice-castellatus (Roemer)					×
Homomya? cf. *H.*? *alta* Roemer				×	
sp			×		
Toucasia sp	×				
Sphaera cf. *S. roblesi* (Böse)					×
Cardita sp				×	
Protocardia filosa Conrad	×				
multistriata Shumard					×
texana (Conrad)		×	×	×	×
sp					×
Tapes? sp					×
Brachydontes sp					×
Gastropoda:					
Neritina? *elapsensis* Stanton					×
sp		×			
Natica? cf. *N.*? *pedernalis* Roemer			×		
sp				×	
Ampullina? sp				×	
Tylostoma sp	×	×	×		×
Gyrodes? sp					×
Turritella seriatim-granulata Roemer					×
Nerinea cf. *N. incisa* Gabb				×	
Cerithium? cf. *C.*? *pecosense* Stanton					×
Anchura? sp		×		×	
Aporrhais? sp					×
Monodonta? sp					×
Echinoidea:					
Enallaster cf. *E. bravoense* Böse		×			
cf. *E. texanus* (Roemer)				×	

KIAMICHI FORMATION

The Kiamichi Formation is named for the Kiamichi River in southeastern Oklahoma, from whence it extends southward into north-central Texas as far as the Brazos River. Adkins (1932, p. 351–355) has demonstrated the wide extent of the same unit in Trans-Pecos Texas.

Within the report area the Kiamichi Formation is preserved only on Cox Mountain (geologic section 49, pl. 13), where 65 feet of fossiliferous marly limestone, marl, and thin-bedded sandstone overlie the Finlay limestone and are followed unconformably by Tertiary basalt. Similar strata with the same fauna, 100 feet thick, occur farther west near Flat Mesa north of Sierra Blanca (geologic section D, pl. 13), and are capped by sandstone with a Duck Creek fauna (Adkins, 1932, p. 352).

The Kiamichi evidently passes northward into sandstone, because at Sierra Prieta the Washita Group is underlain directly by sandstone whose upper part contains a Fredericksburg fauna (see under "Cox Sandstone"). In the area between Cox Mountain and Sierra Prieta, a little west of the report area (Block 35), 34 feet of fossiliferous sandstone, probably the Kiamichi Formation, is preserved in an outlier on the Finlay Limestone (Albritton and Smith, 1965).

The Kiamichi Formation is not exposed southwest of Eagle Flat within the report area, its position being occupied by an alluvial-covered swale (section 19, Block 69, Twp. 8; pl. 1). However, it probably exists in this area, as Gillerman (1953, p. 25) observed the formation, with its characteristic fossils, farther southeast in the same outcrop belt in the foothills of the Eagle Mountains (geologic section C, pl. 13).

On Cox Mountain the Kiamichi Formation contains a varied fauna of pelecypods, gastropods, and cephalopods, and minor corals and echinoids. The most characteristic fossils are various species of the cephalopod *Oxytropidoceras* and the oyster *Gryphaea navia* Hall, the first indicating broadly a late Fredericksburg age, and the second more specifically a Kiamichi age.

Table 11 lists fossils that have been identified from the collections made in the Kiamichi Formation on Cox Mountain. The first four lots were identified by R. W. Imlay (written commun., 1940).

TABLE 11.—*Fossils identified from Kiamichi Formation, Cox Mountain, Tex.*

[Identifications by R. W. Imlay, except in last two columns]

	Fossil collection number				Adkins 1932, p. 353	DeFord and Brand, 1958
	USGS 17838	USGS 17837	USGS 17836	USGS 17280		
Coelenterata:						
Parasmilia sp., and other horn corals					×	
Colonial corals					×	
Lamellibranchiata:						
Gryphaea navia Hall	×			×	×	×
cf. *G. corrugata* Gabb	×				×	
Exogyra texana Roemer	×	×				
sp. juv				×		
Trigonia emoryi Conrad	×			×	×	
sp.						×
Pecten (Neithea) subalpinus Bose	×				×	
(Neithea) irregularis Bose					×	
sp.		×		×		
Monopleura sp.						×
Protocardia filosa Conrad						×
texana (Conrad)				×		
Gastropoda:						
Natica? sp.	×	×				
Lunatia? sp.			×			
Tylostoma sp.		×			×	×
Turritella sp.					×	
Nerinea? sp.	×				×	
Cephalopoda:						
Oxytropidoceras acuticarinatum (Shumard)	×					
bravoense Bose	×					
cf. *O. supani* (Lasswitz)		×				
sp.				×		×
Adkinsites sp.						×
Echinoidea:						
Enallaster texanus (Roemer)		×				

WASHITA GROUP

Within the report area the Washita Group, or highest unit of the Comanche Series, is preserved only southwest of Eagle Flat and on Sierra Prieta (pl. 1), although outcrops are more extensive in the surrounding region. Within the region all three facies of the group that were distinguished by Adkins (1932, p. 361) occur—the marginal sandy facies; the normal neritic facies of limestone, marl, and shale; and the reef limestone facies—but they are compressed within a shorter distance than in central and north-central Texas. On Sierra Prieta the group consists largely of the marginal facies; southwest of Eagle Flat, the neritic facies; and farther to the south, the reef facies.

Various formations of the Washita Group have been differentiated in adjoining areas to the south and east (Gillerman, 1953, p. 25–31; Brand and DeFord, 1958,[5] p. 379–386; Twiss, 1959). In the report area varied ages of different parts of the group are indicated by the fossil collections, but it has not been feasible to subdivide the group on any other than a zonal basis.

SOUTHWEST OF EAGLE FLAT

The Washita Group occurs below the Devil Ridge thrust southwest of Eagle Flat, where it crops out in low parallel ridges and forms a band of outcrop several miles wide (pl. 1). About a thousand feet of strata lies beneath the Eagle Ford Formation, but although the Finlay Limestone underlies them on the northeast, the intervening Kiamichi Formation and the basal beds of the Washita Group are concealed.

[5] Brand and DeFord (1958, p. 378) have proposed a "Sixshooter Group" to encompass the Finlay Limestone of Fredericksburg age and the overlying formations of Washita age, but justification for supplanting the long-established Washita Group in this region is not apparent.

Here the Washita Group is chiefly thin-bedded limestone, in part marly and sandy (geologic section B, pl. 13). The lower 680 feet is limestone and marly limestone; the middle 150 feet, sandstone, calcareous sandstone, and shale; and the upper 200 feet, limestone and sandy limestone (Albritton and Smith, 1965). Fossils are abundant in marly beds of the lower unit 480 to 580 feet below the top of the group and include such diagnostic species as *Alectryonia quadriplicata* (Shumard), *Turrilites brazoensis* Roemer, and *Mortoniceras wintoni* (Adkins) (Smith, 1940, p. 616–617), which occur in north-central Texas at levels between the Weno and Mainstreet Formations. The three units southwest of Eagle Flat may correspond approximately to the Georgetown Limestone, Grayson Formation, and Buda Limestone as differentiated by Gillerman (1953, p. 25–31) in the foothills of the Eagle Mountains a few miles to the southeast (geologic section C, pl. 13), but this correlation has not been verified.

SIERRA PRIETA

On Sierra Prieta the Washita Group overlies the sandstone mapped as Cox, and is variably truncated above by the thick sill of igneous rock which caps the mountain (pl. 1; section *A–A′*, pl. 16). As the beds are poorly resistant to erosion, they are extensively masked by landslides and float from the igneous rock and are exposed mainly in ravines (upper view, pl. 12). However, fairly complete sections can be measured in several places. At the east end of Sierra Prieta (geologic section 53, pl. 13) 350 feet of Washita beds is preserved below the sill, and at the west end (geologic section 54, pl. 13), 175 feet.

Most of the group is marl, nodular limestone, sandy shale, and thin-bedded sandstone. No very distinctive lithologic subdivisions are apparent, although a considerable range in age is indicated by the fossils, which are abundant throughout. At all localities the basal 40 or 50 feet of beds is of Duck Creek age; these beds contain abundant *Eopachydiscus*, *Mortoniceras*, *Pervinqueria*, and other ammonites, some of which must have been of exceptional size, for preserved fragments are several feet across. Higher in the section, layers of oyster shell coquina are interbedded at various levels, composed mainly of *Gryphaea washitaensis* Hill. The age of the strata above the Duck Creek horizon can be determined only approximately. Imlay (written commun., 1940) suggests correlation of successive collections in the thick sequence at the east end of the mountain with the "Denton or Weno," and the "Fort Worth or Denton," and states that the highest collection is "not younger than Mainstreet." Adkins (1932, p. 354) tentatively correlated the highest beds in the thinner sequence at the west end of the mountain with the Weno.

TABLE 12.—*Fossils identified from beds of Duck Creek age in Washita Group of Sierra Prieta, Tex.*

[Identifications by R. W. Imlay, except in last column]

	Fossil collection number				
	17904	17905	17915	17901–18091	Adkins, 1932
Lamellibranchiata:					
Pinna sp	×				
Inoceramus cf. *I. comancheanus* Cragin	×				
Ostrea sp	×				
Alectryonia aff. *A. carinata* Lamarck	×			×	
quadriplicata (Shumard)				×	
Gryphaea washitaensis Hill				×	×
Trigonia sp	×			×	
Pecten (*Neithea*) *subalpinus* Böse	×			×	×
(*Neithea*) sp		×			
Spondylus sp				×	
Lima leonensis Conrad	×				
sp	×			×	
Pholadomya cf. *P. shattucki* Böse	×			×	
Homomya cf. *H. ligeriensis* (d'Orbigny)	×			×	
Astarte? sp				×	
Tapes? cf. *T.*? *chihuahuensis* Böse	×				
Cercomya sp	×				
Gastropoda:					
Pleurotomaria sp				×	
Anchura sp	×				
Cephalopoda:					
Cymatoceras texanum (Shumard)	×			×	
C.? sp				×	
Hamites sp		×			
Idiohamites cf. *L. fremonti* (Marcou)	×				
cf. *I. comancheanus* (Adkins and Winton)	×				
sp					×
Eopachydiscus brazoense (Shumard)	×		×	×	×
Eopachydiscus? cf. *E.*? *laevicaniculatum* (Roemer)			×		
sp. juv	×				
Mortoniceras cf. *M. leonensis* (Conrad)	×			×	×
Pervinqueria cf. *P. kiliani* (Lasswitz)		×	×	×	
nodosa (Böse)					×
trinodosa (Böse)			×		×
sp	×	×		×	
Echinoidea:					
Dumblea? sp	×				
Phymosa cf. *P. maxicanum* Böse	×			×	
Holectypus sp				×	
Pseudopyrina parryi (Hall)	×			×	
Enallaster texanus (Roemer)	×			×	
Plio taxaster whitei (Clark)	×			×	
Brachiopoda:					
Kingena? cf. *K.*? *leonensis* (Conrad)	×			×	
Kingena cf. *K. wacoensis* (Roemer)				×	
Kingena? sp		×		×	

FOSSILS

Tables 12 and 13 indicate fossils which have been identified from collections made in the Washita Group on Sierra Prieta. Table 12 shows the fossils from the Duck Creek horizon; table 13 shows those from higher strata that are known to include faunas of several horizons, probably ranging from Fort Worth to Mainstreet. All the identifications are by R. W. Imlay (written commun., 1940), except those by W. S. Adkins in the last column.

EAGLE FORD FORMATION

The Eagle Ford Formation, the only unit of the Gulf Series in the report area, is preserved southwest of Eagle Flat, where it forms a belt of outcrop about a mile wide between the Washita Group and the Devil Ridge thrust, which truncates its top (pl. 1). About

TABLE 13.—*Fossils identified from beds younger than Duck Creek age in Washita Group of Sierra Prieta, Tex.*
[Identifications by R. W. Imlay, except in last column]

	Fossil collection number									Adkins 1932
	17907	17908	17909	17910	17911	17912	17913	17914	17902	
Lamellibranchiata:										
Pinna sp.			×							
Alectryonia aff. *A. carinata* Lamarck			×							
quadriplicata (Shumard)								×		
cf. *A. subovata* (Shumard)								×		
Gryphaea corrugata Say	×	×								
washitaensis Hill		×	×	×	×		×	×	×	×
Trigonia Cf. *T. emoryi* Conrad	×									
Pecten sp.										×
(*Neithea*) *subalpinus* Böse			×	×						
texanus (Roemer)					×					
sp.								×		
Lima wacoensis (Roemer)			×	×						
sp.	×		×							
Pholadomya cf. *P. sanctisabae* (Roemer)			×					×		
Cardita sp.								×		
Isocardia cf. *I. medialis* (Conrad)			×							
Cyprimeria cf. *C. crassa* Meek			×							
cf. *C. texana* (Roemer)			×							
sp.			×							
Tapes? cf. *T.*? *vibrayeana* d'Orbigny			×							
Cercomya sp.			×							
Gastropoda:										
Natica sp.		×								
Amauropsis? sp.			×							
Tylostoma harrisi Whitney		×	×							
Tylostoma? sp.				×						
Turritella sp.		×		×						
Anchura? sp.				×						
Cephalopoda:										
Cymatoceras texanum (Shumard)			×							
Probysteroceras (*Goodhallites*) *whitei* Böse										×
Probysteroceras? sp.			×							
Mortoniceras (*Durnovarities*) *wintoni* (Adkins)			×							
Pervenqueria cf. *P. trinodosa* Böse									×	×
Engonoceras sp.			×							
Nautilus? sp.								×		
Echinoidea:										
Tetragramma cf. *T. taffi* (Cragin)				×						
Diplopodia sp.										×
Dumblea symmetrica Cragin			×							×
Salenia sp.										×
Phymosa cf. *P. texanum* (Roemer)			×							
sp.										×
Holectypus limitus Böse			×							
Pyrina sp.										×
Pseudopyrina clarki (Böse)				×						
cf. *P. inaudita* (Böse)			×							
Holaster simplex Shumard			×							
Enallaster bravoinsis (Böse)								×		×
cf. *E. texanus* (Roemer)			×	×						
sp.									×	
Macraster sp.									×	×
Hemiaster sp.								×		
Brachiopoda:										
Kingena? sp.						×		×	×	

1,400 feet of strata is preserved, which is black fissile bituminous shale that passes upward into buff sandstone, in part quartzitic, interbedded with some shale and chalky limestone. Fossils are not abundant, but various foraminifers, *Inoceramus*, *Ostrea*, and other pelecypods, and a few genera of gastropods have been reported (Smith, 1940, p. 618).

IGNEOUS ROCKS

In the Sierra Diablo region igneous rocks occupy much smaller areas than the sedimentary rocks, but they are varied and widely distributed (pl. 1). Some lie in the Precambrian sedimentary and metamorphic rocks and are themselves of Precambrian age; these rocks have been described above (p. 22–23, 24). Others, which intrude or lie on rocks as young as of Permian and Cretaceous ages, are probably of Tertiary age. They are outliers of much more extensive Tertiary intrusive and extrusive igneous rocks to the west and south (Albritton and Smith, 1965, Gillerman, 1953, p. 34–49; Twiss, 1959; Hay-Roe, 1957).

The largest bodies of intrusive rocks are near Marble and Mine Canyons in the northeastern Sierra Diablo and at Sierra Prieta northwest of the Sierra Diablo; smaller bodies occur farther south (pl. 1). The only extrusive rock is basalt, which is preserved in a few small outliers in the western Sierra Diablo. Compositions and relations of the various intrusive and extrusive rocks differ so much that they were probably formed during widely separated parts of Tertiary time, and at least one body, that at Mine Canyon, may include igneous rocks of several different ages.

MARBLE CANYON-MINE CANYON INTRUSIVE COMPLEX

The most varied assemblage of intrusive rocks is in the northeastern part of the Sierra Diablo west of the Figure Two Ranch, on the lower slope of the escarpment near Marble Canyon and Mine Canyon (pl. 14). Here, the Permian rocks are invaded by two stocks, each about half a mile in diameter, and by various outlying dikes and sills. One of the stocks, at the head of Marble Canyon, is composed of coarse plutonic rocks of granitic texture, and has been eroded into a basin. The other stock, south of the portal of Mine Canyon, is composed largely of finer grained porphyries and breccias, and projects in Cave Peak, a conical summit prominently in view from Texas Highway 54 (lower view, pl. 10).

At their present levels of erosion both stocks invade mainly the dolomitic strata of the Hueco Limestone; in places however, their contacts extend as low as the basal clastic Powwow Member of the Hueco, and in others as high as the siliceous black limestone beds of the Bone Spring Limestone. Neither stock has notably deformed the country rock beyond a few feet from its contact. Nevertheless, the country rock has been metamorphosed for distances as much as 400 feet from the igneous rocks—the main body of the Hueco Limestone to varieties of marble, and the rocks below and above it to various complex lime and magnesian silicate hornfelses.

The intrusive complex near Marble and Mine Canyons was studied by the writer at various times during the present investigation. It was also studied for the U.S. Geological Survey, in the field or laboratory, by W. T. Holser (in Warner and others, 1959, p. 140–143, pl. 5), Earl Ingerson (written commun., 1937), S. J. Lasky (oral commun., 1938; written commun., 1940), and Charles Milton (written commun., 1940). Chemical analyses of some of the rocks were made by K. J. Murata (written commun., 1937, 1940). The present account is compiled from these various observations.

MARBLE CANYON STOCK

The Marble Canyon stock is oval in plan, about three-quarters of a mile long and a quarter of a mile wide, and is elongated north-south (pl. 14). Where the contact of the stock with the country rock is exposed, it is nearly vertical. The core of the stock, comprising most of its volume, is a quartz-bearing syenite of coarse granitic texture. The syenite is bordered by a discontinuous band of darker gabbroic rock; both are traversed by many dikes of aplite and pegmatite, some of which extend short distances into the country rock on the west.

The syenite has been eroded into a basin, partly covered by arkosic sand and soil, from which project rounded knobs and boulders. It is cut by several sets of joints, spaced tens of feet apart, of which the most prominent in the southern part trend east-west. Specimens of the syenite which were examined in thin section by Ingerson and Milton are dominantly potassium feldspar and sodic plagioclase (oligoclase), the proportions varying from specimen to specimen. Quartz is minor, comprising less than 6 percent of the rock, and mainly forms graphic intergrowths with the potassium feldspar. Mafic minerals include brown biotite, brownish-green hornblende, and gray-violet diopsidic pyroxene. Some specimens contain minor amounts of calcite, in crystals as much as 0.5 mm in diameter, which extinguish uniformly. Ingerson suggests that the calcite is not an alteration product, but was dissolved in the magma and crystallized during the orthomagmatic stage.

Between syenite and country rock is a band of darker gabbroic igneous rock of granitic texture like the syenite, although somewhat finer grained. Specimens that have been studied in thin section by Ingerson and Milton are dominantly intermediate plagioclase (andesine); potassium feldspar is subordinate. Mafic minerals include brown biotite, diopsidic pyroxene, and olivine and minor quantities of magnetite, ilmenite, and sphene.

The dark gabbroic rock is somewhat more resistant to erosion than the syenite, and in places projects as a low wall between it and the country rock. The outcrop of the gabbroic rock in the northern and southern parts of the stock is as much as 400 feet wide; elsewhere, it is narrower, and at several places on the east and west sides is missing altogether. Throughout its extent it maintains its entity as a distinct rock unit, and no gradational phases between it and the syenite were observed. The contact between them is nowhere exposed, but in a few float boulders a syenitic rock was observed to intrude gabbroic rock. Apparently the gabbroic rock is an early phase of the intrusion of the stock and is not merely a border phase of the syenite produced by assimilation of the adjacent country rock.

On the east side of the stock, for 8 to 10 inches from the country rock, the dark gabbroic rock is finer grained than the remainder, indicating a chilled contact. Within 15 feet of the contact at the same locality it contains several aplite and pegmatite dikes, as well as inclusions of a dark hornfels of different composition from the adjacent country rock, which was probably brought up from a lower level. On the north side of the stock the dark gabbroic rock (or the syenite where this is missing) is separated from the country rock by a zone 10 or 20 feet wide, which is a confused mass of stringers of coarse igneous rock, aplite and pegmatite, and hornfels.

Both the syenite and the dark gabbroic rock are traversed by widely spaced dikes a few inches to as much as 8 inches across, mainly of fine-grained aplite but including some coarse pegmatite. Specimens from the dikes, according to Ingerson and Milton, consist mostly of potassium feldspar and a little quartz, plagioclase feldspar being nearly or wholly lacking. However, one of the dikes in the dark gabbroic rock on the east side of the stock contains abundant nepheline, its only occurrence in the complex; it is associated with potassium feldspar, partly replaced by "chessboard" albite.

MINE CANYON STOCK

The Mine Canyon stock is three-quarters of a mile northeast of the Marble Canyon stock and superficially resembles it, as it lies in Permian carbonate rocks and has a diameter of about three-quarters of a mile (pl. 14). Nevertheless, its internal character is almost wholly different, as it includes few rocks of granitic texture, and is formed mainly of units of fine-grained porphyry and breccia. Observed contacts with the country rock are nearly vertical, like those in the Marble Canyon stock, but the light rhyolite breccia of the stock projects in several bosses on the slope of Marble Canyon to the south, suggesting a low dip of the contact away from the main stock. However, the light rhyolite breccia is a late component of the stock and probably invaded the country rock more irregularly than the earlier components.

The components of the Mine Canyon stock are discrete units of light rhyolite porphyry, dark rhyolite porphyry, porphyritic granite, and light rhyolite breccia, which are ringed concentrically around a center on the slope north of Cave Peak. Not all the units are progressively younger from the periphery inward, as one might assume. The dominant rock of the stock, or light rhyolite breccia, occurs mainly toward the periphery, yet it is the youngest major igneous unit in the complex.

Light rhyolite porphyry forms irregular masses as much as 400 feet wide against the country rock on the south and east sides of the stock; it is also preserved as inclusions in the light rhyolite breccia farther west. Much of the porphyry is poorly exposed and is covered extensively by float from the adjacent light rhyolite breccia. Most of it is aphanitic, greenish gray where fresh, and weathers light gray or buff. In places it contains phenocrysts of feldspar and quartz as much as 3 mm in diameter, but elsewhere these are smaller or lacking altogether. According to Milton, the groundmass is an aggregate of randomly oriented feldspar laths, strewn with brown biotite and opaque minerals.

Dark rhyolite porphyry crops out in a band about 500 feet wide on the north slope of Cave Peak, encircling the core of porphyritic granite. The porphyry is dense, dark gray to black, and breaks along joints into straight-sided blocks. It contains abundant phenocrysts of feldspar, and a few of quartz, about 2 mm in diameter. Microscopic examination by Milton indicates that the feldspar is slightly albitized orthoclase, and that the groundmass is formed of interlocking feldspar and quartz, many small euhedral plates and patches of biotite, and minor sphene. The porphyry grades irregularly into a breccia of the same material whose fragments are as much as 1 inch across. In a band about 10 feet wide next to the central core of porphyritic granite, the porphyry has been silicified and traversed by quartz veinlets, producing a rock that resembles an aplite.

The core of the Mine Canyon stock is prophyritic granite which forms a cylindrical mass about 500 feet in diameter, exposed on the north slope of Cave Peak. The porphyritic granite is medium grained and is composed of quartz and orthoclase phenocrysts in a finer grained groundmass. Microscopic examination by Milton indicates that the orthoclase phenocrysts are somewhat albitized, and that the groundmass is an interlocking aggregate of quartz and feldspar, with a few epidotized skeletons of biotite.

Light rhyolite breccia forms the greatest surface area, and probably the greatest volume, of any of the intrusive units in the Mine Canyon stock. Cave Peak is formed of it, and its weathered blocks are the principal constituents of the outwash from the stock. The breccia occupies a wide band around the periphery of the stock; nevertheless it intrudes and crosscuts all the igneous units previously described and it must have the structure of a ring dike. On the east side of the stock the breccia lies within concentric bands of light rhyolite porphyry and metamorphosed country rock. On the west side it crosses these bands and invades little-altered country rock; here, light rhyolite porphyry and metamorphosed country rock remain only as inclusions in the breccia. The light rhyolite breccia was evidently intruded after the climax of the contact metamorphism.

The light rhyolite breccia is an aphanitic light-gray or white igenous rock which contains closely to widely spaced angular fragments an inch to several feet across. Many of the fragments are like the matrix, others are rhyolite porphyry with conspicous flow structure, and a few are metamorphosed limestone and other country rocks. Inclusions of other rocks of the stock 10 feet or more across occur in places, especially on the west side and near the summit of Cave Peak. Microscopic examination by Ingerson of speciments from an outlying boss of the breccia on the north slope of Marble Canyon indicates that the matrix is mainly quartz and potassium feldspar, partly forming small phenocrysts, but chiefly a groundmass which also includes much secondary calcite.

The light rhyolite breccia has been somewhat mineralized throughout, as indicated by extensive iron oxide staining of weathered surfaces. Most of the introduced minerals form threads or narrow veinlets which trend westward, northwestward, or northward. Mineralization is most extensive on the east side near the contact with the dark rhyolite porphyry and on the west side near the contact with light rhyolite porphyry inclusions. The dominant mineral is pyrite, but there is also chalcopyrite, fluorite, and huebnerite (iron-manganese tungstate). According to Holser, some of the veinlets contain minor amounts of beryllium (less than 0.1 percent BeO).

Rocks of the Mine Canyon stock are cut by widely spaced vertical dikes, some as much as 4 feet wide. A specimen from one of the dikes on the east side of the stock is described by Milton as a dull light-gray fine-grained rock, composed of interlocking particles of alkali feldspar with sparing phenocrysts of the same feldspar and a few embayed phenocrysts of quartz, and apparently without mafic minerals.

OUTLYING IGNEOUS ROCKS

East and north of the Marble Canyon and Mine Canyon stocks are numerous smaller bodies of intrusive rocks, mainly dikes and sills (pl. 14). Except for minor aplite dikes, none seem to be related to the Marble Canyon stock. Most of them probably originated during later phases of the intrusion of the Mine Canyon stock.

On the north slope of Marble Canyon, a boss of light rhyolite breccia, which is an offshoot of the main breccia intrusion, projects into the Hueco Limestone. Not far away the marl and thin limestone beds of the Hueco are traversed by sills less than a foot thick of light-gray aphanitic igneous rock, whose affinity to the main breccia mass is suggested by their content of breccia fragments. South of Marble Canyon aphanitic igneous rock forms a dike that follows a northwest-trending fault.

Outlying intrusions are extensive from Mine Canyon northward for 4 miles, nearly to Apache Canyon (pl. 1). Most of them are sills which follow the relatively weak strata of the Powwow Member of the Hueco Limestone, but two plugs invade the fossiliferous shale of Pennsylvanian age just north of Mine Canyon. In the segment between Mine Canyon and Apache Canyon the strata have been displaced by block faulting and the sills have been similarly displaced, indicating that the igneous rocks were intruded before the faulting.

Most of the igneous rocks of the outlying masses are light-gray aphanitic much-jointed felsite. The felsite has been greatly kaolinized and iron stained by weathering, so that no fresh specimens could be collected that would be suitable for petrographic study.

METAMORPHIC ROCKS

Intrusion of both the Marble Canyon and Mine Canyon stocks produced much contact metamorphism in the adjacent host rocks, mainly the Hueco Limestone. Most of the contact metamorphism is related to the emplacement of the coarse-grained intrusive rocks and is less related to the finer grained porphyries and breccias. Effects of the metamorphism vary not only with distance from the stocks, but also with the compositions of the rocks in the stratigraphic sequence. Most of the country rock that has been metamorphosed is dolomite and limestone of the main body of the Hueco Limestone; in some places, however, the clastic rocks of the Powwow Member are involved, in others the siliceous black limestone of the Bone Spring Limestone.

Close to the stocks the metamorphic rocks are varieties of hornfels.

A dark heavy hornfels forms large inclusions in the dark gabbroic rock on the east side of the Marble Canyon stock. Its sedimentary origin is shown by varying mineral compositions of its bedding laminae. According to microscopic determinations by Milton and Ingerson, it is composed of tiny grains of diopside and a little calcite, quartz, and sphene, which are poikilitically enclosed in a groundmass of andesine feldspar. This hornfels differs so much from the adjacent country rock that it has either been carried up from a lower stratigraphic level, or has absorbed much material from the igneous rock in which it lies.

Nearby on the east side of the Marble Canyon stock, the country rock close to the intrusive has been altered to a white or light-gray hornfels that is difficult to distinguish from the more extensive marble adjacent to it. Microscopic examination by Milton indicates that this hornfels is a mosaic of equidimensional quartz grains crowded with tiny diopside crystals and with veinlets and irregular areas of zeolite.

A more complex hornfels has been formed from the marl and marly limestone of the Powwow Member of the Hueco Limestone within a few feet of the intrusive contact of the Mine Canyon stock on its east side. Chemical composition of this rock is as follows:

Chemical analyses, in percent, of hornfels from Powwow Member of Hueco Limestone on east border of Mine Canyon stock

[Analyst, K. J. Murata, 1940]

	797 A (white phase)	*797 B (gray phase)*
Insoluble	5.56	6.28
SiO_2	25.38	24.56
CaO	55.00	54.04
MgO	3.93	3.06
R_2O_3	1.62	2.80
CO_2	5.95	7.00
H_2O+	2.03	2.09
H_2O-	.29	.09
Total	99.76	99.92
SiO_2 in insoluble	3.60	1.00
F	.21	.05
SO_3	.14	None

An intensive study of this hornfels was made by Milton. Most of it is very fine grained, consisting for the most part of sharply defined areas that vary from white to shades of green or gray, each variation indicating a different mineral composition. Much of the hornfels is spurrite ($CaCO_3 \cdot 2Ca_2SiO_4$) and merwinite ($Ca_3Mg(SiO_4)_2$), but some assemblages contain variable amounts of calcite ($CaCO_3$), periclase (MgO), vesuvianite ($Ca_6[Al(OH,F)]Al_2(SiO_4)_5$), wollastonite ($CaSiO_3$), and grossularite ($3CaO \cdot Al_2O_3 \cdot 3SiO_2$). The spurrite and merwinite are replaced by radiophyllite ($CaSiO_3 \cdot H_2O$), and there are minute veinlets of thaumasite ($CaSiO_3 \cdot CaCO_3 \cdot CaSO_4 \cdot 15H_2O$). Some specimens include breccia fragments of diopside and quartz, probably altered from chert. The principal assemblages belong to the sanidine facies of metamorphism, which according to Turner (in Fyfe, Turner, and Verhoogen, 1958, p. 213–215), is conditioned by very high temperature (600°–1000° C) and very low pressure (pH_2O generally less than a few hundred bars). Alteration of the assemblages to the hydrous minerals radiophyllite and thaumasite represents a retrogression from the intense initial metamorphism.

Another variant of the hornfels occurs on the south side of the Marble Canyon stock, where black limestone extends into the zone of metamorphism. Original bedding, which is still preserved, is indicated by alternating thin white and gray layers. Chemical composition of this rock is as follows:

Chemical analyses, in percent, of hornfels from Bone Spring Limestone on south side of Marble Canyon stock

[Analyst, K. J. Murata, 1940

	787 A	*787 B*
SiO_2	44.20	36.90
CaO	45.00	48.01
MgO	6.29	12.25
R_2O_3	1.90	2.48
CO_2	2.06	.43
H_2O+	.77	.26
H_2O-	.34	.08
Total	100.56	100.41

This hornfels is largely akermanite ($Ca_2MgSi_2O_7$) and merwinite ($Ca_3Mg(SiO_4)_2$), proportions of which vary from one specimen to another, and minor calcite. Part of the merwinite forms large crystals which poikilitically enclose the smaller grains of akermanite. One specimen contains thick light-gray veins of wollastonite.

Beyond the hornfels zone around the Marble Canyon and Mine Canyon stocks a much larger volume of the country rock has been altered to white marble. The white marble forms a band around the Marble Canyon stock 200–400 feet wide. The marble band is somewhat narrower around the Mine Canyon stock, and is truncated in the western part of its periphery by the younger intrusive mass of light rhyolite breccia.

The following analyses indicate the nature of the marble surrounding the Marble Canyon stock. The first group of analyses is of marble from various places around the periphery. The second group illustrates variations in the composition of altered and unaltered rocks at about the same stratigraphic level, eastward along Marble Canyon from the stock.

Chemical analyses, in percent, of white marble around the periphery of the Marble Canyon stock

[Analyst, K.J. Murata, 1937, 1940]

	788	772	783	784	785	786
Inorganic insoluble	0.42	0.60	0.50	0.18	0.29	0.73
Soluble R_2O_3	(1)	.60	(1)	(1)	(1)	(1)
$CaCO_3$	61.14	64.89	64.73	85.25	61.80	63.98
$MgCO_3$	12.79	None	2.67	14.02	6.02	5.49
$Mg(OH)_2$	25.57	33.21	31.88	None	31.92	29.82
Total	99.92	99.30	99.78	99.45	100.03	100.02

[1] Not determined.

788. White marble, southeast side of stock, high on slope and 50 ft below top of Hueco Limestone.
772. White marble, east side of stock not far from contact, lower part of Hueco Limestone.
783. White marble, north side of stock, 2–10 ft from contact, upper part of Hueco Limestone.
784. White marble, northwest side of stock, 15–30 ft from contact, Hueco Limestone or basal Bone Spring Limestone.
785. White marble, west side of stock, not far from contact, upper part of Hueco Limestone or basal Bone Spring Limestone.
786. White marble, west side of stock south of preceding locality, not far from contact, upper part of Hueco Limestone or basal Bone Spring Limestone.

Chemical analyses, in percent, of marble and unaltered limestone on east side of Marble Canyon stock along Marble Canyon

[Analyst, K. J. Murata, 1937]

	772	773	774 A	774 B
Inorganic insoluble	0.60	1.28	1.26	0.27
Organic insoluble	None	.26	.06	.10
Soluble R_2O_3	.60	.27	.12	.25
$CaCO_3$	64.89	68.56	86.88	55.49
$MgCO_3$	None	30.07	11.69	44.01
$Mg(OH)_2$	33.21	None	None	None
Total	99.30	100.44	100.01	100.12
CaO	36.35	38.42	46.68	31.09
MgO	22.95	14.38	5.59	21.05

772. White marble, east side of stock not far from contact, lower part of Hueco Limestone.
773. Black "baked" limestone at gateway in Marble Canyon, east of intrusive.
774 A. Unaltered Hueco Limestone from about same horizon as specimen 773, north slope of Marble Canyon several hundred yards east of gateway; from lower beds of calcitic limestone.
774 B. Same locality as preceding: from upper beds of dolomitic limestone.

The marble is uniformly white and fine grained. Chemical analyses of five of the specimens tabulated above show a content of 61–66 percent calcite ($CaCO_3$) and 21–33 percent brucite ($Mg(OH)_2$). Much of the marble probably has a similar composition, as it was derived from original dolomitic limestone beds of the Hueco and Bone Spring. However, one specimen contains no brucite and much more calcite, and was probably derived from a calcitic limestone bed. According to Ingerson, the brucite was derived from serpentine, which formed from hydrothermal alteration of olivine, the olivine having developed by action of siliceous vapors on the original magnesian limestone. Much of the brucite still retains the serpentine structure, and many of the brucite patches enclose remnants of olivine in the serpentine mesh.

Just beyond the band of white marble is a somewhat narrower band of finely crystalline black limestone with a "baked" or calcined appearance, which is less altered than the marble although thoroughly recrystallized. This is prominently exposed on the slopes of Marble Canyon east of the Marble Canyon stock, but is less conspicuous elsewhere. Its black color is caused by an enrichment of organic matter, now carbonized, as shown by the 0.26 percent of organic insoluble in the analyzed specimen (773), as compared with none in the marble and 0.06–0.10 percent in the unaltered limestone. The organic matter was probably expelled from the original limestone of the marble zone during metamorphism. The black limestone contains traces of original bedding, chert concretions, and fossils. The boundary between it and the marble is abrupt, but it fades gradually into unaltered limestone and extends farther away from the stocks in some strata than in others.

INTERPRETATION

The Marble Canyon and Mine Canyon stocks were emplaced before the block faulting of the Sierra Diablo. Outlying sills are faulted, and the proximity of the stocks themselves to the fault scarp at the edge of the range is incompatible with their relatively deep-seated origin. During intrusion of the stocks they were probably at least covered by the Permian carbonate rocks of the Sierra Diablo which now extend 1,500 feet or more above the present outcrops of the stocks. During part of the intrusive epoch the Permian rocks themselves were probably covered by several thousand feet of sandy and shaly Cretaceous strata.

The Marble Canyon and Mine Canyon stocks must have been formed initially during a single intrusive epoch, but they have had different subsequent histories. The zones of contact metamorphism around these stocks were formed during the initial epoch, at a time of maximum burial. The postulated maximum depth of cover is compatible with the spurrite and other minerals of the metamorphic suite, which indicate recrystallization under conditions of high temperature and low pressure. The stocks were emplaced without deforming the country rock more than a few feet from their contacts. Their mode of intrusion has not been determined. Evidence for assimilation of the country rock is inconclusive, but not much assimilation is likely to have occurred in such shallow intrusives. The dark gabbroic rock around the Mable Canyon stock is not a contaminated border facies of the central syenite but a somewhat earlier intrusive. There is no indication of stoping, as the stocks contain few or no inclusions of country rock; but possibly blocks of country rock were pushed upward ahead of the intrusives.

During the initial intrusive epoch the magma of the Marble Canyon stock solidified as a coarse-grained granitic rock, and the stock has had no subsequent igneous history. By contrast, the Mine Canyon stock became a conduit that was utilized by later ascending magmas, producing a complex of later porphyries and breccias. At least the latest of these, the light rhyolite breccia, was emplaced under conditions of much lower temperature and pressure than the initial intrusions, as it crosscuts the earlier metamorphic aureole and in places is in contact with little-altered limestone.

The brecciated nature of both the light rhyolite breccia and the earlier dark rhyolite breccia suggests that the Mine Canyon stock was open to the surface during their emplacement, and formed a volcanic conduit. Perhaps by this time the surface had been stripped of its cover of poorly resistant Cretaceous strata, down to the top of the resistant Permian carbonate rocks whose top is little more than 1,500 feet above the present exposures of the stock. Two epochs of later intrusion and possible volcanism are indicated. The first marked the time of emplacement of the dark rhyolite porphyry and breccia and ended with solidification of the core of porphyritic granite. During the second, the light rhyolite breccia invaded the periphery of the earlier core as a ring dike and irregularly invaded the country rock. Perhaps at about the same time the surrounding country rocks were intruded by felsite dikes and sills, some as much as 2 or 3 miles north of the Mine Canyon stock.

SIERRA PRIETA INTRUSIVE

In the Diablo Plateau northwest of the Sierra Diablo is the Sierra Prieta, a crescentic mass of intrusive rock about 4 miles long, which projects 500–1,000 feet above its surroundings (pl. 1). The igneous rock of Sierra Prieta forms a thick sill of complex structure, which dips beneath Hueco Limestone of Permian age on the south side and overlies shale, marl, and sandstone of the Washita Group of Cretaceous age on the north and east sides (section *A–A′*, pl. 16). In places the intrusive rock crops out in cliffs and ragged ledges; but in many others it has broken down into blocks and boulders, some of which are nearly in place, others of which have moved varying distances from their original positions. On the north and east sides of the mountain are extensive masses of disordered, land-slipped blocks of igneous rock, now in process of dissection, produced by undercutting of the weak strata of the Washita Group beneath the sill. Some of these land-slipped masses are as much as a mile from the present outcrops of igneous rock on the mountain and were probably derived from greater extensions of the sill during an earlier time.

IGNEOUS ROCKS

The igneous rock of the Sierra Prieta is an alkalic porphyry, whose main body is conspicuously spotted by phenocrysts of dark-green mafic minerals that lie in a gray finely crystalline felsic groundmass. In the central part of the intrusive the spots are half an inch across, but they are smaller toward the margins. The rock splits into plates and flags whose surfaces have a lustrous schistose appearance. A specimen examined under the microscope by C. S. Ross (written commun., 1938) consists of—

a coarsely felted groundmass of sodic plagioclase, with a few phenocrysts of nepheline. Ferromagnesian minerals are aegerite-augite and an amphibole resembling riebeckite. The latter commonly forms a reaction rim around the nepheline grains, or even occurs within them. Analcite and another zeolite are associated with the nepheline.

At the margins of the intrusive the coarse spotted igneous rock gives place to a uniformly fine-textured rock 25 feet or more thick, which in places forms massive ledges. According to D. E. Lee (written commun., 1959)—

An estimated 80 percent of the rock is made up of a finely felted groundmass of feldspar blades. An X-ray diffraction pattern of crushed material indicates that this groundmass is mostly sodic plagioclase but includes perhaps as much as 25 percent orthoclase. The rock also contains smaller amounts of analcite and a mineral that may be chabazite. Tiny grains of unidentified pyroxene are scattered throughout the rock.

METAMORPHIC ROCKS

The Hueco Limestone that overlies the igneous rock on the south side has been metamorphosed to marble for 3–25 feet from the contact, beyond which it is blackened and "baked" for as much as 50 feet farther. In places marble also extends beyond the main body as dikelike masses, probably adjacent to joints or fractures. Inliers of altered limestone are exposed in valleys south of the intrusive contact, indicating a low dip of the igneous rock beneath the limestone. The following analyses indicate that the marble consists of variable amounts of calcite and brucite, so that the Hueco Limestone has been altered in much the same manner as it has been near the Marble Canyon and Mine Canyon stocks.

Analyses of marble and altered limestone from Hueco Limestone on south side of Sierra Prieta intrusive

[Analyst, K. J. Murata, 1940]

	809	810	811
Insoluble	1. 16	1. 66	0. 19
R_2O_3	1. 16	. 16	n. det.
$CaCO_3$	67. 23	96. 30	64. 03
$MgCO_3$	None	2. 82	None
$Mg(OH)_2$	29. 72	None	35. 15
Total	99. 27	100. 94	99. 37

809. Marble from just above igneous contact, three-quarters of a mile northwest of Black Mountain Tank (center of sec. 17, block N).
810. Black "baked" limestone, 30 ft above contact, same locality as preceding.
811. Marble, forming a dikelike mass in limestone, half a mile east of preceding locality.

The Cretaceous rocks which underlie the intrusive are little altered, except for slight induration of the shale of the Washita Group close to the contact. The Cox Sandstone, where it is in contact with the intrusive on the west side of the southeastern prong of the mountain, contains cavities coated by concentric growths of a blue mineral which C. S. Ross has determined to be fluorite.

STRUCTURE

The igneous rock of the Sierra Prieta forms a thick south-dipping sill that is broadly accordant with the strata adjacent to it (section *A–A′*, pl. 16). However, the sill overlies the Washita Group of Cretaceous age on its north side and underlies the Hueco Limestone of Permian age on its south side. The intrusive must, therefore, have zigzagged through the strata during its ascent, partly following the bedding, partly breaking across it.

These inferred general relations are illustrated by outcrops in the eastern prong of the mountain. In much of the prong the intrusive is a sill that overlies strata near the top of the Washita Group. Farther west, however, the base of the intrusive descends abruptly across the edges of the Washita Group and all the underlying formations down to the Hueco Limestone (lower view, pl. 12). The abruptly descending contact is bordered by a ledge 25 feet or more thick of the fine-grained phase of the intrusive, which is broken by joints normal to the contact.

A tabular inclusion of Hueco Limestone 300 feet long and 75 feet thick was observed near the center of the intrusive (center of sec. 25, block N); this inclusion may be a part of a septum connected with the main body of the Hueco farther south. Other inclusions of Hueco may exist in the intrusive, but if so, they are covered by the extensive surface debris of the igneous rock.

The igneous rock is broken by many vertical joints, spaced 10 or 15 feet apart, and by flat or gently dipping joints a few feet apart. These joints outline the weathered blocks which strew the surface. Many of the vertical joints trend west or west-northwest, and some faults of the same trend drop the igneous rocks and the Cretaceous strata northward. Possibly these faults are not fundamental displacements, and instead, resulted from superficial settling of joint-bounded blocks of the massive sill over the weaker underlying strata of the Washita Group.

REGIONAL RELATIONS

The Sierra Prieta intrusive is part of an extensive group of alkalic intrusive of Tertiary age in Trans-Pecos Texas (Warner and others, 1959, p. 131). It is the southeasternmost of a chain of sills, laccoliths, and stocks which extend 40 miles northwestward across the Diablo Plateau beyond the report area and include those of Antelope Hill, Sierra Tinaja Pinta, Cerro Diablo, and the Cornudas Mountains (King, P. B., 1949). Beyond this chain are similar intrusives of alkalic igneous rocks in the Hueco Mountains (King, P. B., King, R. E., and Knight, J. B., 1945, sheet 1), and a small plug in the southern part of the report area (see below).

INTRUSIVE ROCKS OF SOUTHERN PART OF REPORT AREA

Small bodies of intrusive rocks of probable Tertiary age occur at widely separated places in the southern part of the report area (pl. 1).

On the east side of the Carrizo Mountains (sec. 5, Block 6, Twp. 9) are several small dikes and sills of diabase, the largest of which follows the unconformable contact between the Carrizo Mountain Formation and Van Horn Sandstone (Flawn, in King, P. B., and Flawn, P. T., 1953, p. 67).

At the southwest end of the Streeruwitz Hills 2½ miles west-northwest of Eagle Flat section house (center of east line of sec. 3, Block 69, Twp. 8) a small plug of massive unsheared spotted igneous rock lies in metarhyolite of Precambrian age (King, P. B., in King, R. E., and Flawn, P. T., 1953, p. 100). Although the rock was not examined microscopically, it much resembles the alkalic intrusive rocks of Sierra Prieta and elsewhere in the Diablo Plateau.

Southwest of Eagle Flat, small sills of rhyolite porphyry intrude the Washita Group and Eagle Ford Formation (sec. 20, Block 67½; sec. 3, Block 69, Twp. 9; Smith, 1940, p. 619–620). They are probably related to the more extensive igneous masses of the Eagle Mountains adjacent to the south.

BASALTIC VOLCANIC ROCKS

Small bodies of basalt of surface or near-surface origin occur at widely separated places in the western part of the report area (pl. 1).

Remnants of a flow of vesicular basalt form the summit of Cox Mountain (secs. 19 and 20, Block 45½), and a remnant of another flow is preserved on the west rim of Victorio Canyon (sec. 14, Block 43). The flows at both places lie on an eroded surface of the Cretaceous rocks—at Cox Mountain on the Kiamichi Formation with a few feet of intervening limestone gravel and at Victorio Canyon on a small thickness of Cox Sandstone. Regarding the rock at Cox Mountain, D. E. Lee reports (written commun., 1960)—

> The rock is a porphyritic olivine basalt. The phenocrysts are olivine and calcic plagioclase as much as 2 mm across. Most crystals in the groundmass are less than 0.2 mm in size, and some are as small as 0.03 mm. The dominant molecule in the olivine phenocrysts must be forsterite. Most of these phenocrysts are in process of alteration to a bowlingitelike mineral. In part this alteration is complete; elsewhere the altered material forms a rim around the olivine. The groundmass, in estimated order of abundance, consists of calcic plagioclase, magnetite-ilmenite, clinopyroxene, olivine, and carbonate. Some of the carbonate is concentrated in ill-defined patches including other minerals. Apatite is also present.

In the Sierra Diablo foothills farther south are several basalt plugs, one northeast of England Tank in the Cox Sandstone (northwestern part of sec. 24, Block 51), two others northwest of the Keen Ranch in the Campagrande Limestone (sec. 6, Block 56). The latter were examined by Flawn (in King, P. B., and Flawn, P. T., 1953, p. 100), who reports that the plugs consist of black aphanitic basalt that contains small phenocrysts of black glassy augite and spinel. Associated with the plugs are basalt sills less than 5 feet thick which contain numerous phenocrysts of olivine, spinel, and augite as much as 1–2 cm in diameter and a few augite phenocrysts with the surprising dimensions of 4–5 cm. However, some of this basaltic rock is vesicular, indicating that it was intruded near the surface.

UNCONSOLIDATED DEPOSITS OF QUATERNARY AGE

Unconsolidated deposits of Quaternary age cover about a third of the report area; they are separated into a number of units on the geologic map (pl. 1) based more on differences in character, surface form, and origin than on chronological sequence. The unconsolidated deposits were mapped partly by cursory field study and partly from air photographs.

The environment and origin of the unconsolidated deposits has already been discussed in this report (see section on "Geography"), and the similar unconsolidated deposits in the nearby southern Guadalupe Mountains were treated at length in an earlier publication (King, P. B., 1948, p. 127–160). Here, the unconsolidated deposits in the Sierra Diablo region are described briefly as map units.

The unconsolidated deposits that lie at the surface in the Sierra Diablo region are all of Quaternary age. Some of these, on the alluvial fans at the edges of the mountains and on the valley bottoms and pediment surfaces within the mountains, are of Recent age and are in process of formation today. Others, which have been dissected by modern drainage or buried beneath the surface deposits, are of earlier and probable Pleistocene age. In the intermontane areas of the Salt Basin and Eagle Flat, where the unconsolidated deposits are known from well drilling to be hundreds or thousands of feet thick, the older and deeper deposits may be of late Tertiary age. However, no unconsolidated deposits of late Tertiary age are exposed in the region, and no means are at present available to distinguish possible buried unconsolidated deposits at this age from those of Quaternary age.

LANDSLIDE DEPOSITS

Among the oldest unconsolidated deposits in the region are landslides on the slopes of the intrusive igneous body of Sierra Prieta, in the northwestern part of the map area. They are disordered bouldery masses of igneous rock derived from the intrusive, and occur on its west, north, and southeast sides. Those on the north side are especially extensive, and conceal the bedrock over an area of several square miles. All the landslides occur where the intrusive lies as a sill on shale and other weak beds of the Washita Group of Cretaceous age; they were formed by undermining of the massive igneous rock by erosion of the weak beds. Talus and small landslides of igneous rock are forming today on outcrops of the Washita Group by such undermining, but the main landslides are much older, are much dissected, and in part are preserved as detached erosion remnants. Moreover, some of the landslide masses north of Sierra Prieta are as much as a mile from present outcrops of the igneous sill on the mountain, and probably formed when it was more extensive than now. All the main landslides appear to be of the same general age, and they may have formed at a time when the erosional and climatic regime differed considerably from that of today.

DEPOSITS OF FLOOR OF SALT BASIN

The Salt Basin, the large intermontane area along the east side of the Sierra Diablo region, is deeply filled by unconsolidated deposits washed in from the higher lands around it. A well in the basin north of the Sierra Diablo region is reported to have been drilled in the deposits to a depth of 1,620 feet without reaching their base (Baker, 1927, p. 40). The West & Armour, I Davis Investment et al. oil test, between the Baylor Mountains and Apache Mountains, drilled 1,150 feet in the deposits before reaching Permian bedrock. Most of the wells drilled near Van Horn and in the Wildhorse Valley irrigation district to the east are less than 600 feet deep and fail to reach the base of the deposits (Richardson, 1914, p. 9; Follett, 1954, p. 6–9), but two wells about 950 feet deep that were drilled 8 miles east-northeast of Van Horn (sec. 19, Block 63) are reported to have entered limestone bedrock (Leonard A. Wood, written commun., 1959). The age of the deeper unconsolicated deposits of the Salt Basin is undetermined, but those at the surface are of Pleistocene and Recent age.

The surface of the lowest part of the Salt Basin, north of the Baylor Mountains, is a nearly level floor more than 5 miles wide, formed of clay, silt, and sand which are shown as a unit on the map (pl. 1). The clay, silt, and sand were probably deposited on the bottom of a lake or succession of lakes during Pleistocene time (King, P. B., 1948, p. 137, 156–157). Their nearly level surface may be a relatively old feature, inherited from the lake bottom and modified only by minor shifting of material by the wind. No material derived from the adjacent mountains seems to be in process of deposition on the floor today.

The floor of the Salt Basin is diversified by alkali flats, hills of gypsiferous clay, and areas of drifted quartz sand which are differentiated on the map (pl. 1), all of which have been partly or wholly shaped by the wind.

One set of alkali flats (locally called "salt lakes") is east of the northern part of the Sierra Diablo, another is just north of the end of the range. Grayton Lake, an alkali flat of similar character, forms the lowest part of the closed depression of Eagle Flat in the southwestern part of the map area. The alkali flats may be the final remnants of more extensive lakes of an earlier period, yet today they contain water only at long intervals; they are maintained principally by the wind, which sweeps material from their surfaces down to groundwater level, an effective limit to downward erosion.

The hills of gypsiferous clay have no clearly discernible pattern over extensive areas toward the north; but on the east side of the floor opposite the northern part of the Sierra Diablo, they form a remarkable set of closely spaced parallel ridges, trending north-northwestward, which curve westward just north of the Baylor Mountains. These ridges, and others like them farther north, probably mark the shores of one of the latest shallow lakes of Pleistocene time (King, P. B., 1948, p. 156–157, pl. 23), along which the clays were raised into low dunes. Later modifications of the clay hills by the wind is indicated by superposition on the gross features of a more delicate grain trending eastward or east-southeastward. Between the alkali flats and hills of gypsiferous clay, the floor of the basin is a level meadowland, underlain by brown clay.

The areas of drifted quartz sand occur only in the northeastern part of the map area, at the lower ends of alluvial fans extending out from the Delaware Mountains east of the Salt Basin. The sand was probably derived ultimately from erosion of sandstones of the Delaware Mountain Group which form a conspicuous part of these mountains; the absence of sand adjacent to the Sierra Diablo and other mountains west of the Salt Basin is due to these mountains being composed largely of carbonate rocks. Within the report area the drifted sands form a relatively featureless expanse without dune forms, although conspicuous dunes of the same material occur farther north (King. P. B., 1948, p. 138).

FANGLOMERATE

Along the edges of the Salt Basin are deposits of fanglomerate which are built into alluvial fans that slope toward the basin from the adjacent mountains. The fans have coalesced into an alluvial slope less than 1 mile to more than 5 miles wide that is nearly continuous along the edges of the Sierra Diablo and other mountains west of the Salt Basin. East of Beach Mountain and the Baylor Mountains the alluvial slopes extend from the mountains on either side of the Salt Basin to its axis, where Wildhorse Creek drains northward. Farther north the alluvial slopes on the two sides do not meet, because they are separated by the basin floor, discussed above.

The fanglomerate, which has been in process of formation since the mountains assumed their present form, probably has a wide range in age. The older fanglomerate, now buried, is probably of Pleistocene or even earlier age; but part of the fanglomerate at the surface is in process of accumulation today, the moderately dissected remainder being only a little older. The fanglomerate at the surface must be younger than the bulk of the deposits on the floor of the Salt Basin, as the alluvial fans are being prograded toward the floor.

The fanglomerate varies in composition, depending on the bedrock of the source areas in the mountains from which it was derived, and in texture, depending on the sizes and gradients of the streams which supplied it. The fanglomerate of large fans of low gradient, composed of relatively fine material, is differentiated on the map (pl. 1) from that of fanglomerate of lesser fans with steeper gradients built by smaller streams, composed of coarser materials. Large fans have been built by Hackberry and Sulphur Creeks near Van Horn and by Red Wash farther north. Lesser fans with the steepest gradients and the coarsest fanglomerate are along the segment of the Sierra Diablo north of the Baylor Mountains, where relatively recent faulting has created a regime of active erosion and deposition.

OLDER ALLUVIAL DEPOSITS

Within the mountains small thicknesses of alluvial deposits have been spread over the bottoms of valleys or over more extensive rock-cut plains and pediments. Most of these deposits are near the levels of modern drainage and are of relatively young age, but earlier periods of alluviation are indicated by gravel-capped remnants as much as a hundred feet above modern drainage.

These remnants are most extensive in the foothills south and southeast of the southeastern angle of the Sierra Diablo, where they overlie former pediments that were cut on red sandstone of the Hazel and Van Horn Formations. For the most part the pediments and gravel deposits were formed by tributaries of Sulphur and Hackberry Creeks which drain eastward into the Salt Basin; but the western ones, north of the Millican Hills, were formed by streams draining into the east end of Eagle Flat. Toward the west the older gravel deposits merge with the younger alluvial cover of Eagle Flat, so that the two sets of deposits cannot be differentiated. Dissection of the older gravel deposits southeast of the Sierra Diablo may be related to renewed downfaulting of the Salt Basin, which revived erosion in the mountain areas.

Within the Sierra Diablo the bottoms of many canyons and valleys have been filled by alluvial deposits, which were later dissected to depths of 50 or 100 feet and partly removed. In many of the valleys that drain westward from the mountains, dissection has no more than trenched the alluvium; but in most of those which drain eastward into the Salt Basin, the older alluvial deposits have been reduced to terrace remnants. Most of these older deposits are not recorded on the map (pl. 1), being either omitted or not differentiated from the younger alluvial deposits, but they are sufficiently extensive and prominent to be shown separately in Apache Canyon. Causes of the canyon filling and subsequent dissection indicated by these deposits are undetermined. They may be related to a time of tectonic stability, followed by one of renewed downfaulting in the Salt Basin, or they may be related to climatic fluctuations during Pleistocene time.

YOUNGER ALLUVIAL DEPOSITS

Most of the unconsolidated deposits within the Sierra Diablo and west of it, as well as in Eagle Flat, are mapped as an undifferentiated unit of younger alluvial deposits (pl. 1). Deposits included in the unit are undoubtedly complex, but data obtained from field investigation and study of air photographs are insufficient to provide a meaningful separation. Most of the alluvial deposits at the surface that are included in the unit must be relatively young, as they lie at or near the levels of modern drainage and are partly in process of formation today; some that are moderately dissected are slightly older. The younger alluvial deposits in some areas probably overlie deposits of Pleistocene age, and in Eagle Flat perhaps still older deposits.

The younger alluvial deposits accumulated in three drainage areas, one on the east side of the Sierra Diablo and adjacent ranges leading directly into the Salt Basin, another on the west slope of the Sierra Diablo in the northwestern part of the map area leading northwestward by circuitous route into the Salt Basin, and a third in the southwestern part of the map area leading into Eagle Flat.

The younger alluvial deposits in the drainage area on the east side of the Sierra Diablo are mostly of small extent and fill the bottoms of valleys that indent the escarpments. Their composition and texture is like that of the fanglomerate in the fans down the slope, beyond the edges of the mountains, but they are differentiated because they are relatively thin and were deposited on eroded bedrock. The most extensive alluvial deposits in this drainage area lie between the Baylor Mountains on the east and the higher escarpments of the Sierra Diablo on the west, where the bedrock is mainly sandstone rather than carbonate rocks. Here, tributaries of Sulphur Creek and Red Wash have cut extensive pediments which were subsequently covered by a small thickness of sand and gravel.

On the west slope of the Sierra Diablo, narrow strips of alluvium extend up the valleys—in places nearly to the mountain crest—and expand down the slope west of the mountains into broad alluvial plains separated by widely dispersed rock hills and mesas. The bedrock in parts of this western area has been folded and faulted, but so long ago as not to have shaped the present topography. The plains are thus erosional rather than tectonic depressions, and their alluvial cover, although extensive, is probably rather thin. The alluvial deposits toward the south have nearly featureless gently sloping surfaces, but north of the Victorio flexure they are dissected to depths as great as 50 feet. Along some of the larger drainage courses are alluvial flats lower than the tops of the dissected deposits, so that there have been several cycles of cutting and filling.

In the drainage area of Eagle Flat modern erosional depositional processes are less active than in the Salt Basin, partly because of the circuitous drainage connection between them, and partly because of the greater tectonic stability of Eagle Flat in the recent past. The central part of Eagle Flat is doubtless a tectonic depression like the Salt Basin; but because of its present stability, its unconsolidated deposits are not capable of an obvious subdivision like that in the main basin. They are therefore mapped as undifferentiated younger alluvial deposits (pl. 1). Along the northern and southwestern margins of the flat, the alluvial deposits cover broad rock-cut plains or pediments that extend between and through low hills of deformed Precambrian and Cretaceous rocks. Within the flat itself the alluvial slopes extend from either side of the axis. Alluviation has cut off the western part of the flat from the remainder to form a closed depression surrounding the alkali flat of Grayton Lake. The sandy surface materials in many parts of the flat have been raised by the wind into low dunes, shown by a stippled pattern on the topographic base (pls. 1, 9).

Like the Salt Basin, the tectonic depression of Eagle Flat, within its encircling pediments, must be thickly filled by unconsolidated deposits of Pleistocene or even earlier age. At Hot Wells these deposits have been penetrated to a depth of 1,000 feet without reaching their base (Baker, 1927, p. 40), but little other data are available as to their thickness, nature, or extent.

TECTONICS

The Sierra Diablo region lies within the Basin and Range province. Present topographic features have largely been shaped by block faulting that originated during Cenozoic time, which produced mountains and plateaus in places, and intermontane lowlands in others that are now for the most part filled by erosional debris.

Nevertheless, the Sierra Diablo region had a considerable prior tectonic history, so that the geologic structure varies, not only from one place to another, but between rock systems of different ages. Successive times of disturbance are indicated by the several angular unconformities that interrupt the rock sequence—between the formations of Precambrian age and the Van Horn Sandstone of Precambrian(?) age, between the Van Horn Sandstone and the Bliss Sandstone of Ordovician age, between the rocks of Pennsylvanian age and the Hueco Limestone of Permian age, and between formations of Permian age and those of Cretaceous age. At least two of these unconformities—that beneath the Van Horn Sandstone and that beneath the Hueco Limestone—record times of major orogeny.

By Permian time the Sierra Diablo region had evolved into a positive area, the Diablo platform, which subsided less than the Delaware basin to the northeast, and perhaps other basins to the southwest. Once cre-

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ated, this positive area persisted into later times, so that Cretaceous deposits overlapped it from the southwest and were later strongly deformed on the southwest side; whereas the rocks of the Sierra Diablo region itself remained little disturbed until later in Cenozoic time. The block-faulted structure produced during later Cenozoic time was thus not newly born, but had its antecedents in the complex events of earlier times.

The tectonic history of the Sierra Diablo region is summarized in table 14.

TABLE 14.—*Tectonic history of Sierra Diablo region, Texas*

Age	Record in the rock sequence	Kind of structure
Late Tertiary to Pleistocene.	Bolson deposits.	Block faulting along north-trending and west-northwest-trending faults; uplift of mountain areas and depression of Salt Basin and Eagle Flat.
Early Tertiary	Unconformity between Cretaceous sedimentary rocks and Tertiary volcanic rocks south of the report area.	Folding and thrusting of Cretaceous rocks southwest of Eagle Flat.
Early Mesozoic	Angular unconformity between Cretaceous and Permian rocks.	Mild regional deformation and local flexing.
Permian	Fâcies variations in Permian rocks	Greater subsidence of Delaware basin than Diablo platform; local flexing.
Late Pennsylvanian	Angular unconformity between Hueco Limestone and older rocks.	Deformation of pre-Permian rocks into broad anticlines and synclines; local displacement along west-northwest-trending faults and flexures.
Between Ordovician and Precambrian(?)	Unconformity between Bliss Sandstone and Van Horn Sandstone.	Tilting and local faulting.
Between Precambrian(?) and Precambrian	Angular unconformity between Van Horn Sandstone and older rocks.	Faulting of west-northwest trend with strike-slip displacement.
		Intense folding and faulting of Allamoore and Hazel Formations; emplacement of Streeruwitz thrust sheet.
Later Precambrian	Probable unconformity between Hazel and Allamoore Formations; coarse conglomerate in Hazel Formation.	Probable deformation.
Earlier Precambrian		Deformation of Carrizo Mountain Formation, progressive and retrogressive metamorphism, injection of rhyolite and greenstone into sedimentary rocks.

Structural features of the Sierra Diablo region are illustrated in horizontal dimensions by the tectonic map (pl. 15), which shows the same items of structure as on the geologic map (pl. 1), except for omission of those in the Precambrian Hazel, Allamoore, and Carrizo Mountain Formations that formed before Van Horn time. In addition, the tectonic map shows known or inferred structure contours on the top of Precambrian and Precambrian(?) rocks and data on the nature and trends of joints. Structural features are also illustrated in vertical dimension by 10 structure sections extending generally eastward across the northern and eastern parts of the region (pl. 16) and by 10 structure sections extending generally northward across the southern part of the region (pl. 16).

STRUCTURE OF PRECAMBRIAN AND PRECAMBRIAN(?) ROCKS

STREERUWITZ THRUST FAULT

The major structural feature of the Precambrian rocks of the Sierra Diablo foothills and the Carrizo Mountains is the Streeruwitz thrust fault (King, P. B., in King P. B., and Flawn, P. T., 1953, p. 102–103), which forms a boundary between the much-metamorphosed Carrizo Mountain Formation and its associated intrusive rocks on the south and the disturbed but little-metamorphosed Allamoore and Hazel Formations on the north (pl. 1). The fault is exposed discontinuously along the south edge of the Sierra Diablo foothills from the Streeruwitz Hills eastward to a locality 2 miles northeast of Allamoore (sec. 16, Block 67, Twp. 8), and it reappears in a small area near the Texas and Pacific Railway in the northern Carrizo Mountains (sec. 17, Block 66, Twp. 8), thus having a known strike length of about 15 miles. Besides, several small patches of metarhyolite lie amidst the Allamoore Formation in the Millican Hills more than 1½ miles north of the trace of the Streeruwitz fault (sec. 5, Block 67, Twp. 8), and are probably klippen of its thrust sheet (section *O–O′*, pl. 16).

At all places the overriding rocks along the Streeruwitz fault are metarhyolite, which is cataclastically altered, with strongly developed lineation and streaks of mylonite. Lineation trends generally southward, normal to the trace of the thrust, and is probably parallel to the *a* fabric axis. In the Carrizo Mountains this metarhyolite intrudes the base of the Carrizo Mountain Formation, a metasedimentary sequence some 19,000 feet thick (section *T–T′*, pl. 16). The Carrizo Mountain Formation probably forms most of the overriding block of the thrust, although it is nowhere known to be in contact with it. The steeply dipping homoclinal beds of the formation strike northeastward (pl. 1), whereas the Streeruwitz fault strikes west-northward. Presumably the northeast-striking homocline is truncated by the fault.

The Streeruwitz fault overrides the Allamoore Formation, which is extensively silicified and marmorized near it, and for a greater distance away from it is intensely deformed by folds with a west-northwest strike parallel to the fault trace. The Hazel Formation is nowhere in contact with the fault but is preserved a short distance to the north where it is as much deformed as the Allamoore (sections *K–K′*, *O–O′*, *P–P′*, and others, pl. 16). Emplacement of the Streeruwitz thrust sheet must have occurred after Hazel time.

Actual contacts between the overriding metarhyolite and the overriden Allamoore Formation are exposed in many ravines or hillsides in the Sierra Diablo foothills, but there is no sharply marked cleancut surface. Near the contact the metarhyolite is lineated and mylonitized, the Allamoore is schistose and marmorized, and both units are strongly silicified; but in many places the contact is masked by schistose amphibolite or by quartz veins. Aberrant dips of foliation and trends of lineation in the metarhyolite near the contact attest further movement after the creation of the cataclastic structure.

The Streeruwitz fault is clearly older than the Hueco Limestone of Permian age, as the Hueco lies unconformably on the fault trace in the Streeruwitz Hills (section *K–K′*, pl. 16). The fault must also be older than the Van Horn Sandstone of Precambrian (?) age, as the Van Horn lies unconformably on Hazel, Allamoore, and Carrizo Mountain Formations that were deformed during the thrusting, and as it contains fragments of metarhyolite that was lineated and mylonitized during these movements.

STRUCTURE OF ALLAMOORE AND HAZEL FORMATIONS

The Allamoore and Hazel Formations for 3 miles north of the trace of the Streeruwitz fault are intensely folded and faulted as a result of forces directed from the south; presumably the disturbance in this belt is related to emplacement of the Streeruwitz thrust sheet. Rocks of the disturbed belt have been altered by dynamic and hydrothermal processes; but little of the original sedimentary structure has been lost, and there is no trace of the cataclastic metamorphism that is prominent in the metarhyolite south of the thrust. Further north the disturbance decreases, and the Hazel Formation along the eastern and southern escarpments of the Sierra Diablo dips at low angles.

The coarse thick conglomerate of the lower part of the Hazel Formation attests that the Allamoore Formation was deformed just before and during the early part of Hazel time. Part of the complex structure now visible in the Allamoore Formation must have been produced by this deformation; but this cannot be unraveled from the dominant structure, shared by both the Allamoore and Hazel, which is of post-Hazel and pre-Van Horn age.

The exposed contact between the Allamoore and Hazel Formations is of complex origin. In places the original unconformable upper surface of the Allamoore may be preserved, but in most places there has been movement between the two formations of undetermined magnitude, caused mainly by differences in competency of their rocks. In some places the Allamoore Formation even overlies parts of the Hazel Formation well above its base, and the two are separated by a low-angle thrust fault of large displacement. These conditions vary from place to place along the contact in a manner that cannot easily be differentiated. Rather than introduce possibly unjustified interpretations on the geologic map (pl. 1) and structure sections (pl. 16), the contact between the Allamoore and Hazel is therefore indicated as a "surface of movement."

Just north of the Streeruwitz thrust fault in the Sierra Diablo foothills is a belt of Allamoore Formation a mile or more wide (pl. 1). In this belt the Allamoore is strongly folded and faulted in a manner that has not been completely worked out. In the Millican and Bean Hills some downfolds preserve bodies of conglomerate of the Hazel Formation, and in the Millican Hills other downfolds preserve bodies of metarhyolite which are klippen of the Streeruwitz thrust sheet. Toward the east, between Buck Spring and Carrizo Spring, the structures plunge eastward and the Allamoore and Hazel Formations are folded together into several steeply dipping anticlines.

The southern belt of Allamoore Formation is bordered on the north by the Hazel Formation. In both the Millican Hills and Streeruwitz Hills the adjacent Hazel is a massive coarse conglomerate as much as 2,000 feet thick, which is probably a basal deposit. In the Streeruwitz Hills successive units of limestone, phyllite, and volcanics are cut off against the conglomerate (pl. 1), due either to an angular unconformity or to thrusting. In other places, notably in the Bean Hills, Allamoore Formation lies against red sandstone of the Hazel without conglomerate, and the contact is more clearly a thrust fault.

Thrusting of Allamoore over Hazel at the north edge of the southern belt is most convincingly displayed west of the Garren Ranch in the Millican Hills (sec. 4, Block 67, Twp. 8) where a "subsidiary nappe," or recumbent fold of Allamoore Formation, overrides the Hazel Formation across a breadth of about a mile (section *O–O′*, pl. 16). The carapace of the nappe is limestone which is traceable, with a few interruptions, from its lower to its upper limb. The core of the nappe is volcanic rock and phyllite. The nappe is enclosed by conglomerate of the Hazel Formation, which is discordant below and accordant above. The discordant conglomerate beds beneath the nappe contain numerous tourmalinized slickensided surfaces.

North of the southern belt of Allamoore Formation is a belt of Hazel Formation, whose south edge in the Millican and Streeruwitz Hills includes the thick bodies of coarse conglomerate already mentioned. In most places the Hazel dips homoclinally northward, with gradually flattening dips, but greater complexity than would otherwise be inferred is indicated by reappearance of bodies of Allamoore Formation north of the belt.

Most of these northern bodies of Allamoore Formation have a synclinal structure and overlie the Hazel Formation adjacent to them. This feature is well displayed in an area of high relief near Tumbledown Mountain (sec. 27, Block 66, Twp. 7; section *R–R*, pl. 16; upper view, pl. 10), where about 2,000 feet of Allamoore is synclinally downfolded in the Hazel and is repeated by a thrust in its lower part. A much larger body of Allamoore Formation with similar structure is preserved in the Bean Hills (section *L–L′*, pl. 16). In the Millican Hills a northern body of Allamoore Formation likewise has a synclinal structure (section *P–P′*, pl. 16), but is still tenuously connected with the southern belt by a narrow band of limestone, indicating that this body is the inverted forward edge of a recumbent fold. In an exceptional area near the Garren Ranch (northwestern part of sec. 3, Block 67, Twp. 8) Allamoore of the northern body dips 20° W. in normal order beneath conglomerate of the Hazel Formation, but tracing of the contact indicates that these strata have been rotated nearly 360° from their original position.

Some of the northern bodies of the Allamoore Formation lie far to the north, over gently dipping red sandstone that is probably high in the Hazel sequence. Several of them occur at the foot of the south-facing escarpment of the Sierra Diablo 3 to 6 miles west of the Old Circle Ranch (sections *L–L′* and *M–M′*, pl. 16), but the body of greatest interest is near the Sancho Panza, St. Elmo, and Blackshaft mines (sec. 16, Block 67, Twp. 7; pl. 1) where a thin layer of Allamoore is tectonically intercalated in the Hazel. Toward the southeast this layer dips steeply or is overturned, but to the northwest it dips at low angles eastward or northeastward. The layer is not more than 10 feet thick and is highly sheared and sporadically mineralized. As shown in mine workings, the under surface is marked by grooves or steps parallel to the strike, and includes horses of the underlying sandstone. The upper surface is a strong firm sandstone, which may itself have been sheared over the Allamoore beneath.

North of the main northern outliers of the Allamoore Formation, the Hazel Formation stands steeply in places, as along Hackberry Creek, where vertical beds of red sandstone and interbedded conglomerate are well exposed. Farther north the structure flattens abruptly, forming the "north edge of the steep-dip zone" of the geologic map (pl. 1). Near the Hazel mine (sec. 14, Block 66, T. 7) the red sandstone layers are nearly horizontal, but from there northward toward Victorio Peak they dip at angles of 30° or less toward the south (section *P–P′*, pl. 16). Similar low dips of the red sandstone are visible at various places farther west, even where the sandstone is overlain by displaced masses of Allamoore Formation (section *M–M′*, pl. 16).

FAULTS WITH STRIKE-SLIP DISPLACEMENT

The Sierra Diablo foothills are crossed by west-northwestward-trending faults, most of the longer of which displace Van Horn and Paleozoic formations, but some of the shorter of which occur only in the Allamoore and Hazel Formations. The obvious larger displacements on these faults are of Cenozoic age, although some have moved earlier, between Cretaceous and Van Horn time. Displacement during these Cenozoic and earlier times was dominantly dip slip.

However, some of these faults may have had still earlier strike-slip displacements. Such earlier strike-slip displacements are indicated most convincingly along the Grapevine fault, where there is a left-lateral offset of the "north edge of the steep-dip zone" in the Hazel Formation by about half a mile (pl. 1). Elsewhere in the area of outcrop of Hazel and Allamoore Formations are shorter faults of the same trend which do not extend into younger rocks, and which displace nearly vertical Allamore and Hazel Formations in the same sense. Perhaps these were displaced during the same epoch of strike-slip movement.

The left-lateral strike-slip displacements along the faults of west-northwestward trend do not seem to be related to dip-slip displacements on these and similar faults seen in the Van Horn and younger formations. A period of strike-slip faulting is thus suggested, at some time after deformation of the Allamore and Hazel Formations and before deposition of the Van Horn Sandstone. Strike-slip displacement of the west-northwestward-trending faults may have established a "grain" in the region which was utilized during later times of deformation by differently directed forces.

FRACTURE ZONES IN HAZEL FORMATION

In the gently dipping red sandstone of the Hazel Formation just south and east of the southeast corner of the Sierra Diablo are the Hazel and Pecos fracture zones. The Hazel fracture zone is a set of en echelon fractures 3½ miles in length, trending nearly eastward from the Mohawk mine. The Pecos fracture zone extends 2 miles north-northeastward, past the Pecos mine and Eureka prospect.

The fractures are vertical mineralized fissures on which the ore bodies of the Hazel mine and other mines and prospects are located. Within the zones, the fractures lie parallel or en echelon, or diverge at acute angles. Outcrops of the fractures are commonly indicated by bleaching of the red sandstone immediately adjacent. In vertical section the fractures are zones a few feet to 40 feet wide of bleached, brecciated, and sliced country rock, interlaced with a gangue of barite, calcite, and quartz, which contains sulfides of copper, silver, and other metals.

The relative ages of these fracture zones and the high-angle faults and joints of adjacent areas are uncertain. The fracture zones extend across the dominant west-northwestward-trending faults and joints, apparently without offsetting them or being offset by them, yet the west-northwestward-trending faults seem to have been displaced intermittently from late Precambrian to late Tertiary time. Moreover, emplacement of the metallic-mineral deposits may have occurred much later than the time of formation of the fractures themselves, in zones of weakness already created. It has been suggested (King, P. T., and Flawn, P. T., 1953, p. 151) that the metallic mineral deposits were emplaced in Tertiary time, but the fractures themselves might have been created at any time following the deposition and deformation of the Hazel Formation.

STRUCTURE OF VAN HORN SANDSTONE

The Van Horn Sandstone of Precambrian(?) age does not share the structure of the Carrizo Mountain, Allamoore, and Hazel Formations, but lies on their deeply eroded surfaces and truncates their folds and faults. The Van Horn itself was tilted and faulted before Early Ordovician (Bliss) time, as shown where the contact is exposed in Beach Mountain and the Baylor Mountains. Discordance between the Van Horn and Bliss is generally only a few degrees, but it is as much as 20° on the north face of Beach Mountain. Faulting before Bliss time is shown on Tumbledown Mountain where the Van Horn was dislocated by the Dallas and Grapevine faults. The Dallas fault and the Van Horn and Allamoore Formations that were displaced by it are truncated by the Bliss Sandstone and no later movement occurred along the fault. The Grapevine fault was downthrown to the south both before and after Bliss time, so that the Van Horn is preserved only on its south side, whereas the displaced Bliss occurs on both sides. Along the Carrizo Spring fault to the south, tilted Van Horn is truncated by Bliss, suggesting that it likewise was displaced before Bliss time.

Throughout most of its extent the Van Horn is overlain unconformably by the Hueco Limestone of Permian age. The Hueco truncates the several widely dispersed basinlike areas in which the Van Horn is now preserved. These basinlike areas conform broadly to the structure of the succeeding pre-Permian formations, suggesting that they were formed at least partly during the late Paleozoic pre-Hueco deformation.

The Van Horn Sandstone is tilted and broadly warped, so that it dips commonly at angles of 5° or 10°, although in places it lies nearly horizontal, and in parts of the Red Valley it dips as steeply as 45°. In the Red Valley there appear to be several broad folds or eastward-plunging noses. To the north near Carrizo Spring, dips are northeastward or eastward; near Threemile Mountain they are generally southeastward; south of Threemile Mountain they are again northward.

STRUCTURE OF THE PRECAMBRIAN SURFACE

The known or inferred configuration of the upper surface of the Precambrian and Precambrian(?) rocks in the Sierra Diablo region is illustrated by structure contours on plate 15. The regional configuration of the surface in northern Trans-Pecos Texas was presented earlier (King, P. B., and Flawn, P. T., 1953, pl. 19B; Flawn, 1956, pl. 1; DeFord and Brand, 1958, p. 38).

The surface chosen for contouring is the top of the Carrizo Mountain, Allamoore, Hazel, and Van Horn Formations. For the most part this is not the surface of a "basement," as most of the rocks which form the surface are sedimentary and toward the north are little altered or deformed; moreover, one unit, the Van Horn Sandstone, is unconformable on the remainder. The Van Horn Sandstone must be included with the formations contoured because its erratic thickness is unpredictable away from areas of outcrop. Information on the configuration of the surface is reliable in the southern half of the Sierra Diablo region, where the top of the Precambrian and Precambrian(?) rocks is exposed in many places. The configuration farther north can only be inferred, and the contours there are extrapolated from higher formations. Such extrapolation is fairly accurate where pre-Permian formations are exposed, as these have nearly constant thicknesses throughout the region. It is much less accurate where only Permian or younger formations are exposed, because of their variable thicknesses and the one or more angular unconformities beneath them.

Contours on the upper surface of the Precambrian and Precambrian(?) rocks of the report area (pl. 15) show that it stands high throughout the southern half of the Sierra Diablo, as well as in the foothills to the south and the Carrizo Mountains beyond. The surface culminates at an altitude of somewhat more than 6,000 feet near the southeastern angle of the Sierra Diablo and lies at more than 5,000 feet over extensive areas nearby. In the northern half of the Sierra Diablo and in the Baylor Mountains, the surface is generally much lower, in the former area standing at altitudes between 1,000 and 2,000 feet, and perhaps descending to sea level near the north end of the range. The border between the high-standing and low-standing parts of the surface in the southern and northern parts of the Sierra Diablo is seemingly near the Victorio flexure in the exposed rocks, where the surface may have been abruptly flexed or faulted.

Configuration of the surface of the Precambrian and Precambrian(?) rocks is a product of all the deformations to which it was subsequently subjected. Many of its complexities in the map area are an obvious result of the block faulting of later Cenozoic time, yet most of its gross features were produced by the pre-Hueco deformation of later Paleozoic time, during which the rocks of earlier Paleozoic, Precambrian(?), and Precambrian age were uplifted and deeply eroded before the Permian was deposited over them (fig. 2).

Features of the Precambrian surface within the map area are part of a larger pattern of positive and negative areas in northern Trans-Pecos Texas which were also produced by successive deformations during Paleozoic and later times. Precambrian rocks are exposed not only in the southern part of the Sierra Diablo, but in several mountain areas adjacent to it on the south (fig. 8), where their upper surface rises to an altitude of more than 5,000 feet. This high-standing area has been called the "Van Horn dome" by Baker (1927, p. 41; 1934a, p. 182), who interpreted it as "the highest uplift in Texas." Certainly it is the highest-standing regional feature in the State, although Precambrian rocks project higher in the much narrower more localized uplift of the Franklin Mountains farther west (Adams, 1944). Northeast of the high-standing area the Precambrian surface probably descends below sea level beneath a thick body of Paleozoic rocks in the Delaware basin; southwest of the high-standing area it probably descends to as great a depth beneath a thick body of geosynclinal Mesozoic rocks.

The area of high-standing Precambrian rocks is domical only in the broadest sense, as it now consists of a number of distinct but closely adjacent mountain uplifts, separated by downfaulted areas; it may have been a more continuous feature before block faulting of later Cenozoic time. It probably originated mainly during the pre-Hueco deformation of later Paleozoic time. The pre-Permian Paleozoic sequence of the region is like that elsewhere in northern Trans-Pecos Texas and southern New Mexico, and provides no indication of any nearby positive area. Moreover, the high-standing area does not appear to be related to any special part of the Precambrian complex, as it crosscuts diverse Precambrian rocks and structures. The positive area, once created, manifested itself in various guises during later times—during Permian and Mesozoic times when it received smaller thicknesses of sediments than surrounding areas, during Late Cretaceous and early Tertiary time when it was less deformed than the area to the southwest, and in late Tertiary and Quaternary time when it was raised by block faulting. During these times its role was perhaps relatively passive or even accidental. For example, uplift was probably greater during the late Cenozoic block faulting in the Guadalupe Mountains than in the area of high-standing Precambrian rocks, yet the uplift there was insufficient to raise the Precambrian rocks as high because of the much thicker overburden of Paleozoic strata.

STRUCTURE OF PRE-PERMIAN PALEOZOIC ROCKS

Much of the complexity of the map pattern of the pre-Permian Paleozoic rocks in the Sierra Diablo region results from the unconformity at the base of the Hueco Limestone, which causes the Hueco, at one place or another, to lie on all the older rocks of the sequence (pl. 1). This unconformity resulted from folding, faulting, and deep erosion of the underlying rocks—events that were of Late Pennsylvanian age, as rocks of Early Pennsylvanian age lie unconformably beneath the Hueco in the northern Sierra Diablo.

The pre-Hueco deformation is strikingly illustrated by the distribution of the Ordovician rocks in the southeastern foothills of the Sierra Diablo (pl. 1). On Beach Mountain they overlie the Van Horn Sandstone and comprise the Bliss Sandstone, El Paso Limestone, and Montoya Dolomite, a mass nearly 2,000 feet thick. Three miles to the northwest, at the southeast corner of the Sierra Diablo, the Hueco Limestone lies on red sandstone of the Hazel Formation; all the Ordovician rocks and the Van Horn Sandstone are missing. A paleogeologic map of the surface on which the Hueco was deposited (fig. 2) indicates that Beach Mountain lay near the southwest end of a broad syncline that plunged northeastward, whereas the southeast corner of the Sierra Diablo lay on the crest of the next broad anticline to the northwest.

Another syncline is indicated farther north, in the northeastern part of the Sierra Diablo where Barnett Shale of Mississippian age and limestone and shale of Pennsylvanian age are preserved beneath the Hueco Limestone. In most of this syncline the angular divergence between the Hueco and older rocks is only a few degrees; but on the south flank, at an inlier in Victorio Canyon (sec. 13, Block 43), the Montoya Dolomite dips 75° N., whereas the overlying Hueco dips only gently in the same direction. On the north flank the Fusselman Dolomite and beds of Devonian age diverge at only slight angles from the Hueco, except at a locality 1½ miles northwest of the Figure Two Ranch (sec. 12, Block 66, Twp. 5) where the Fusselman is nearly vertical, and is either faulted or sheared against the Montoya and Devonian beds on either side.

Abrupt truncation of pre-Hueco formations near some of the west-northwestward-trending faults of the region suggests that these faults were dislocated during the pre-Hueco deformation. This is most strikingly shown along the Hillside fault (section *Q–Q′*, pl. 16). On the northern or downthrown side of the fault, the Powwow Member of the Hueco Limestone lies on the Van Horn Sandstone, but contains coarse angular fragments of Precambrian metarhyolite; these fragments were obviously derived from south of the fault and decrease in abundance away from it. Presumably the metarhyolite projected as a scarp along the Hillside fault during deposition of the Powwow Member. Where the Sulphur Creek fault crosses the Sierra Diablo escarpment 1 mile north of the Hazel mine, the Hueco Limestone of the northern or upthrown side overlies 750 feet of Van Horn Sandstone, whereas on the southern or downthrown side it lies on red sandstone of the Hazel Formation (section *Q–Q′*, pl. 16). The Van Horn is folded into a syncline whose correspondence with the fault may be partly coincidental, as the syncline seemingly diverges from the fault farther east. On the South Diablo fault west of the Old Circle Ranch, the Hueco Limestone again lies on the Van Horn Sandstone on the upthrown side, whereas some miles to the south it lies on Hazel and Allamoore Formations. The pre-Hueco structure thus indicated had much the same position as the later South Diablo fault, although it may have been no more than a broad flexure.

Other faults or abrupt flexures were probably displaced at this time, some of which are indicated hypothetically on the paleogeologic map (fig. 2) and the structure sections (pl. 16). A fault along the Victorio flexure is likely, because on the escarpment south of Victorio Peak, Hueco Limestone is known to lie on Precambrian Hazel Formation at least part of the distance across the flexure (section *Y–Y′*, pl. 4), whereas 2 miles to the west in Victorio Canyon the Hueco on the flexure lies on steeply tilted Upper Ordovician Montoya Dolomite (section *X–X′*, pl. 4). This tilting may be related to a fault of pre-Hueco age, downthrown to the north (section *N–N′*, pl. 16). A fault or flexure nearly coinciding with the present Cox Mountain fault is also possible (sections *K–K′*, *L–L′*, and *M–M′*, pl. 16). North of the fault, Hueco Limestone lies on Lower Ordovician El Paso Limestone, whereas in the nearest exposures to the south it lies on Precambrian(?) Van Horn Sandstone or Precambrian Hazel Formation.

All these faults or abrupt flexures, known or inferred, are downthrown northward, toward the dominantly negative area that resulted from the pre-Hueco deformation, whereas in Cenozoic time the displacement on most of the faults was southward.

STRUCTURES OF PERMIAN AND EARLY MESOZOIC AGE

Cretaceous formations of the Sierra Diablo region lie unconformably on the older rocks in the same manner as the Hueco Limestone at the base of the Permian. Where the Cretaceous is no longer preserved, an extension of its basal unconformity is indicated by wide areas of even-crested summits from which an original Cretaceous cover has been removed by erosion. The preserved base of the Cretaceous and its exhumed surface show that truncation of rocks beneath is less than at the base of the Permian. In most of the Sierra Diablo region the Cretaceous was deposited on Permian rocks—on Guadalupe Series in the north, on Leonard Series in the middle, and on Wolfcamp Series in the south. The only exception is in the western part of the Sierra Diablo foothills where the Cretaceous lies on Precambrian rocks (pl. 1). Curiously, the Cretaceous at no place lies directly on earlier Paleozoic formations which intervene elsewhere in the region between the Permian and the Precambrian.

In most places the angular discordance between the Cretaceous and older rocks is slight, but it is greater on several monoclinal flexures that extend west-northwestward across the region, on which Permian strata are downbent north-northeastward (pls. 1, 15; fig. 8).

The northernmost, or Babb flexure, is at the north end of the Sierra Diablo and is named for the old Babb Ranch, west of which it is prominently exposed (upper view, pl. 12). It has been traced thence west-northwest into the Diablo Plateau for more than 10 miles, past the north side of Sierra Prieta. It may also extend east-southeastward for nearly the same distance to the mouth of Apache Canyon, but here its course is obscured by the North Diablo fault zone of Cenozoic age. The Victorio flexure is about 12 miles farther south and is named for Victorio Peak, south of which it is exposed on the Sierra Diablo escarpment (upper view, pl. 10). It has been traced thence west-northwest into the Sierra Diablo and east-southeast into the Baylor Mountains for a distance of 21 miles.

Both the Babb and Victorio flexures are a mile or two wide. On the flexures Permian rocks dip mostly 10° northward, but they dip less in places and more than 15° in others. Structure on the flexures is obscured by irregular bedding of many units involved, but some evenly bedded units cross them, such as the Hueco Limestone on the Victorio flexure and the Victorio Peak Limestone on the Babb flexure (sections *B–B′*, *N–N′*, and *P–P′*, pl. 16; sections *X–X′* and *Y–Y′*, pl. 4). Displacement on the flexures, as determined by differences in height of the evenly bedded units at the upper and lower ends, is 1,700 feet on the Victorio flexure and 1,000 feet on the Babb flexure.

A third flexure that was truncated by the unconformity at the base of the Cretaceous is indicated farther south, along the South Diablo fault, where the possibility of pre-Hueco flexing has already been noted. At a place 3½ miles west of the Old Circle Ranch (sec. 2, Block 56) about 900 feet of Van Horn Sandstone and Hueco Limestone form an escarpment north of the fault, whereas Campagrande Limestone lies directly on red sandstone of the Hazel Formation to the south (section *M–M′*, pl. 16). This must have been caused by northward downflexing in pre-Cretaceous time, in the same direction as on the Babb and Victorio flexures, but opposite from the downthrow on the later South Diablo fault. The flexure evidently diverged westward from the fault, as in this direction the Van Horn and Hueco extend a short distance south of it (section *L–L′*, pl. 16).

The flexures and other features just described developed at some time after deposition of the Permian rocks now preserved in the Sierra Diablo region and before deposition of the Cretaceous rocks. Tilted Permian rocks on the Babb and Victorio flexures are truncated by the pre-Cretaceous surface, and on the Victorio flexure west of the rim of Victorio Canyon a small remnant of Cretaceous sandstone overlies the tilted Permian rocks (section *N–N′*, pl. 16; section *X–X′*, pl. 4).

Nevertheless, the flexures are an accentuation of features existing in the region during Permian time, which were themselves inherited from the pre-Hueco deformation. Pre-Hueco deformation caused the southern part of the Sierra Diablo region to become a positive area and the part to the north a negative area (fig. 2). During Permian time the positive area, or Diablo platform, received relatively shallow-water deposits, mainly carbonates; whereas the negative area, or Delaware basin, received relatively deep-water deposits, including black limestone and siliceous shale during Leonard time (figs. 6, 7) and fine-grained sandstone during Guadalupe time. During Leonard time limestone reefs and banks formed along the boundary between the platform and basin (sections *U–U′*, *X–X′*, and *Y–Y′*, pl. 4). The Hueco Limestone extends with little change across these flexures, as well as the flexure near the South Diablo fault zone. Initial flexing must have occurred immediately after Hueco time, as there is a prominent unconformity at the top of the formation on the Babb and Victorio flexures. Inequalities of relief produced by this unconformity probably influenced location of reefs and banks during Leonard time, although flexing may have continued during deposition of the Leonard Series itself.

STRUCTURES OF LATE CRETACEOUS OR EARLY TERTIARY AGE

Southwest of Eagle Flat, in the southwest corner of the map area, Cretaceous rocks are strongly deformed, as first observed by Baker (1927, p. 5). These rocks and structures are a small segment of the northeastern front of the Chihuahua tectonic belt (DeFord and Brand, 1958, p. 72), which was deformed after the Cretaceous rocks were deposited, and mainly before volcanic rocks of probable Tertiary age were spread over them. The front of the Chihuahua tectonic belt extends northwestward beyond the report area through Devil Ridge, the Quitman Mountains, and Malone Mountain (Albritton and Smith, 1965) (figs. 3, 8), and southeastward through the Eagle Mountains and Indio Mountains (Gillerman, 1953, p. 39–40; DeFord and Brand, 1958, p. 72–85). The area of deformed rocks in the United States is only a small part of the Chihuahua tectonic belt, most of which lies in Mexico.

Two major faults break the rocks southwest of Eagle Flat—the Devil Ridge thrust and the Red Hills thrust, about 2 miles farther southwest (Smith, 1940, p. 630–631) (pls. 1, 15.) These faults are exposed in few places; but the Devil Ridge thrust at one place dips 54° SW., and the Red Hills thrust at another dips 22°

SW. Smith estimates that the minimum displacement of the Devil Ridge thrust is about 4½ miles and that of the Red Hills thrust about 3 miles.

The Devil Ridge thrust carries Yucca and Bluff Mesa Formations over Washita Group and Eagle Ford Formation. The Washita and Eagle Ford are thrown into complex minor folds for a mile or two northeast of the fault trace, beyond which the underlying Cretaceaus rocks are less deformed. The Yucca, Bluff Mesa, Cox, and Finlay Formations above the Devil Ridge thrust dip homoclinally southwestward, mainly at angles of 15°–30°, but in places an overturned syncline is preserved next to the Red Hills thrust.

In the Sierra Diablo region northeast of the Chíhuahua tectonic belt neither the Cretaceous nor the underlying Paleozoic rocks contain structures like those southwest of Eagle Flat, and this region probably remained little disturbed until later in Tertiary time.

STRUCTURES OF LATE TERTIARY AND QUATERNARY AGE

GENERAL FEATURES

The Sierra Diablo is one of a group of ranges in northern Trans-Pecos Texas in which the surface features have been shaped largely by tectonic movements during late Tertiary and Quaternary time—as elsewhere in the Basin and Range province of which the region is a part. On the east is the upheaved block of the Guadalupe, Delaware, and Apache Mountains; next to the west is the depressed block of the Salt Basin; beyond is the upheaved block of the Sierra Diablo (fig. 8).

Faults are the dominant structural features of the boundaries between the mountains, or areas of upheaval, and the Salt Basin, or area of depression. Most of the steep escarpments that face the basin have been outlined by such faults, which have dropped the strata thousands of feet toward the basin. It places between the mountains and basin are foothills of downdropped strata, such as the Patterson Hills west of the Guadalupe Mountains, and Beach Mountain and the Baylor Mountains east of the Sierra Diablo.

The general trend of the faults along the edges of the basin is northerly, although there are offsets along faults that trend in other directions. Faults of the northerly system on the east side of the Sierra Diablo trend irregularly in various directions east and west of north (fig. 8). Many faults of the northerly system moved several times during late Tertiary and Quaternary time. The last movements were of late Pleistocene age and produced low scarps that still persist in the older alluvial deposits and the adjacent bedrock. In the Guadalupe Mountains the dominant joint set is parallel to the dominant north-northwestward-trending faults of the area.

In the southern part of the region another fault system trending west-northwestward crosses the northerly system. Its faults are most abundant in the Sierra Diablo, but some occur in the Apache Mountains and southern Delaware Mountains east of the Salt Basin (fig. 8). Like the northward-trending faults, they moved in late Tertiary time; but they are generally in the interiors of the ranges rather than along their borders, and they do not share the latest movements of the northerly faults. Some of them have had a considerable pre-Cenozoic history, as discussed above. In the Sierra Diablo the dominant joint set is parallel to the west-northwesterly faults, rather than to the northerly faults that border the range (pl. 15). The west-northwesterly faults seemingly follow lines of weakness in the crust more ancient than those followed by the northerly faults.

FAULTS BORDERING THE MOUNTAINS

The Sierra Diablo and adjacent mountains and foothills are probably bordered continuously by faults along the edge of the Salt Basin, although these are generally concealed by Quaternary deposits and are exposed at only a few places. The longest segments, on the East Diablo and East Baylor faults, are parts of the northerly fault system; but these segments are separated by others on the North Diablo and North Baylor faults belonging to the west-northwesterly fault system, whose positions nearly coincide with the Babb and Victorio flexures. Small segments of the faulted margins of the Delaware and Wylie Mountains along the east side of the Salt Basin also extend into the report area.

NORTH DIABLO FAULT ZONE

The North Diablo fault zone extends east-southeastward for 8 miles from near the old Babb Ranch to the salient of the Sierra Diablo near Apache Peak. The zone consists of subparallel interlacing faults that enclose narrow wedges, mainly of Victorio Peak Limestone, dropped 1,000–1,500 feet below equivalent strata on the main escarpment to the south (upper view, pl. 12), which are intermediate in structural height between the bedrock of the escarpment and that beneath the Salt Basin. The principal faults are downthrown toward the Salt Basin; but complications are produced by minor faults downthrown toward the escarpment and by steep tilting or folding of the rocks in some of the fault blocks, so that black limestone of the Bone Spring Formation emerges in places (section *C–C′*, pl. 16).

The surface of the large fault at the foot of the Sierra Diablo escarpment is exposed 1½ miles west of the

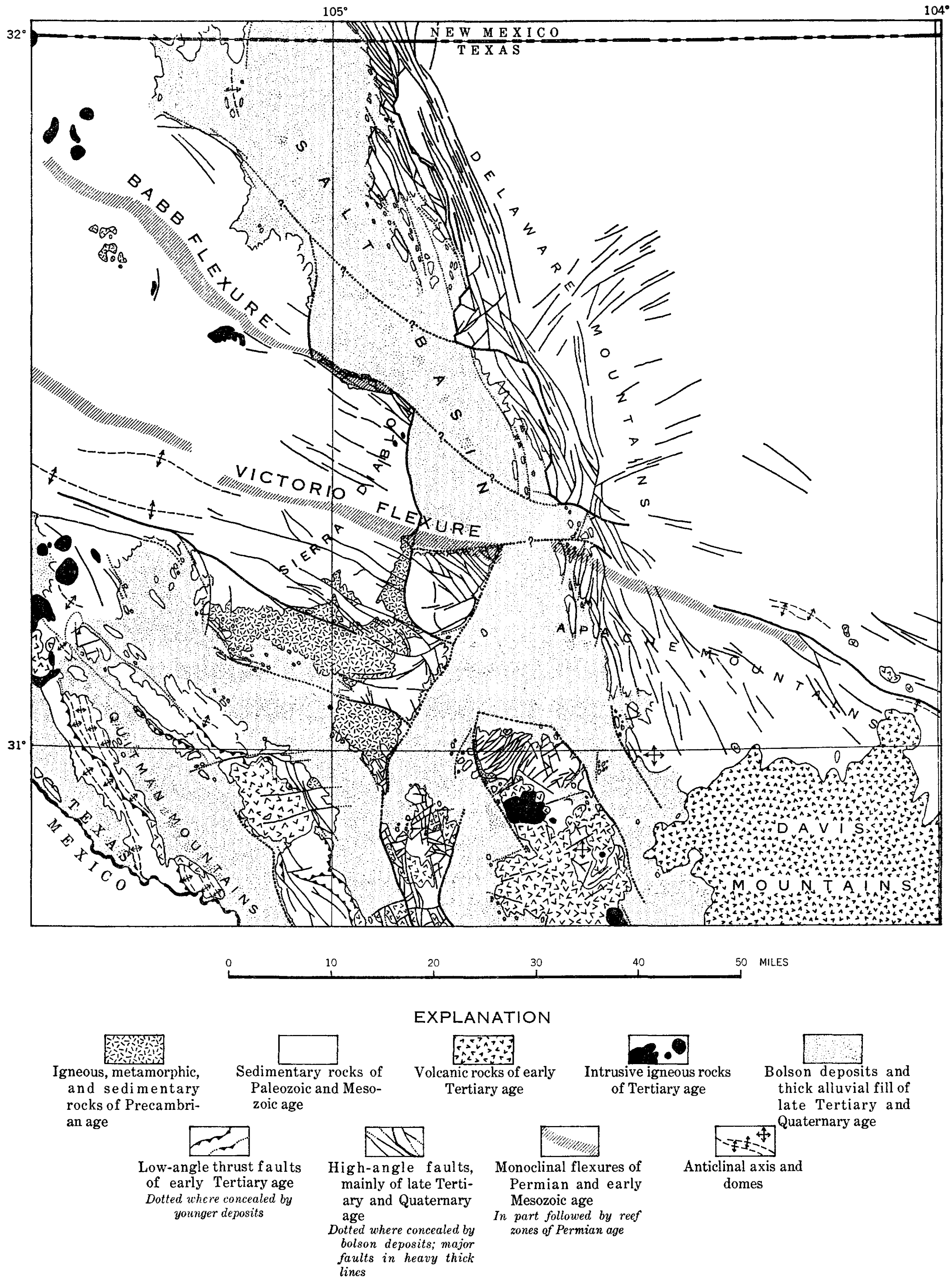

Figure 8.—Map of Sierra Diablo region and adjacent areas showing faults and related structural features. Faults and flexures of west-northwesterly trend extend across the width of the map, and are crossed by other faults of diverse trend.

portal of Apache Canyon, and dips 70°–80° toward the downthrow, with flat-lying black limestone of the Bone Spring on the upthrown side and gently tilted Victorio Peak Limestone on the downthrown side.

At the west and east ends of the North Diablo fault zone, the displacement at the border of the mountains continues along northward-trending faults—to the west along a fault which extends northward at the bases of South, Middle, and North Mesas and to the east along the East Diablo fault which extends southward. The western prolongation of the North Diablo fault zone itself coincides with the Babb flexure, which is broken in places by small faults of the same trend (section *B–B′*, pl. -6). The fault zone was probably formed by renewed movement along one segment of the flexure in late Tertiary and Quaternary time. The steep tilting and folding of the Permian rocks in parts of the fault zone may antedate the faulting and be related to the earlier flexing.

EAST DIABLO FAULT

The East Diablo fault borders the Sierra Diablo on the east for 25 miles. It has a bight and cusp pattern, with three cusps or salients—near the Hazel Mine, Victorio Peak, and Apache Peak—separated by two curved bights, each about 10 miles across.

East of the southern bight the Sierra Diablo is separated from the Salt Basin by the intermediate block of the Baylor Mountains, whose summits stand a thousand feet or more below those of the Sierra Diablo. Opposite the Baylor Mountains the East Diablo fault is bordered by pediments and bedrock hills, rather than by thick alluvial deposits.

In the central and northern salients and the intervening northern bight, the East Diablo fault borders on the Salt Basin, and its displacement is greater than in the southern bight. In most places bedrock on the downthrown side is concealed by a series of coalesced alluvial fans, many of which are still in process of growth. At a few places between Victorio Canyon and Marble Canyon, however, small patches of steeply dragged bedrock emerge on the downthrown side of the fault (section *G–G′*, pl. 16). Some contain Victorio Peak Limestone, whose base is 1,200 feet lower than at the nearest point on the escarpment to the west. Total displacement in the zone of the East Diablo fault is probably much greater, the remainder being accounted for by drag of the downthrown beds and displacement on probable faults to the east, which are concealed by the Quaternary deposits.

The East Diablo fault follows the base of the east-facing escarpment of the Sierra Diablo, 2,000 feet or more high (pl. 10). In the northern bight the crest of the escarpment has receded a mile or so from the fault, but the bench of Hueco Limestone at the base ends on an even line along the fault and is little dented by the heads of alluvial fans. In the southern bight the Hueco Limestone, which forms the rim of the escarpment, has receded a mile or two from the fault; the slopes below it, which are formed of poorly resistant red standstone of the Hazel Formation, have been carved into a concave surface, with pediments at the base.

Landforms of the Sierra Diablo escarpment suggest that the East Diablo fault along its base moved rather late in geologic time—the even base line of the outer bench, the actively growing alluvial fans in front, and the small length of most of the canyons behind. Late movements are further indicated by low fault scarps a short distance east of the main fault (pls. 1, 15). One crosses the alluvial fans northeast of Apache Peak, somewhat north of the end of the East Diablo fault. It extends for 3 miles with a trend slightly west of north and is about 15 feet high. Another scarp of about the same height occurs in the southern bight east of the Pecos mine, in alluvium overlying Ordovician rocks of the Baylor Mountains block.

The surface of the East Diablo fault, or of rocks closely adjacent to this surface, is exposed between Marble and Victorio Canyons in the northern bight, adjacent to the outcrops of downfaulted bedrock. The Hueco Limestone of the upthrown block extends horizontally to the fault and is not internally disturbed except for north-trending vertical joints, some veined by calcite, which are nearly parallel to the main fault. By contrast, the downthrown strata are steeply dragged, greatly jointed, shattered, and silicified. Best exposures of the fault surface are three-quarters of a mile north of the portal of Victorio Canyon (opposite elevation point 4550, sec. 3, Block 66, Twp. 6), where it is followed by a breccia zone 25–50 feet wide, of angular fragments of black limestone derived from the downthrown block. The fault surface is nearly vertical, or dips eastward at a steep angle.

Rocks near the East Diablo fault are exposed in the southern bight 1½ miles northwest of Red Tank (sec. 21, Block 54½), where the fault is adjoined on the downthrown side by low hills of El Paso Limestone. Close to the fault the limestone is much brecciated and is traversed by north-trending vertical joints and wide calcite veins that are probably nearly parallel to the main fault.

NORTH BAYLOR FAULT

The Baylor Mountains project northeastward into the Salt Basin as an acute-angled salient, on the north side of which are much eroded hills that extend westward with a nearly straight front for 9 miles to the East Baylor fault. These hills are probably bordered on the north, beneath the adjacent alluvium, by the North Baylor fault, which separates the Baylor Mountains block from the deeply depressed part of the Salt Basin beyond.

The North Baylor fault produces an easterly offset of the mountain front similar to that on the North Diablo fault zone, and like it, nearly coincides with a major structure in the Permian rocks, the Victorio flexure. The flexure is prominently exposed on the Sierra Diablo escarpment just west of the terminus of the North Baylor fault; its easterly extension is indicated in the Permian rocks of the northeastern Baylor Mountains, where there are depositional features and northward-tilted beds similar to those on the flexure farther west. The inferred trace of the North Baylor fault would lie within the prolongation of the flexure, although it seemingly trends eastward and the flexure east-southeastward.

EAST BAYLOR FAULT

The East Baylor fault, like the East Diablo fault, forms a boundary between bedrock of the mountains and unconsolidated deposits of the Salt Basin. It follows the east side of the Baylor Mountains, Beach Mountain, Threemile Mountain, and the Carrizo Mountains for a distance of about 20 miles, probably terminating a few miles south of the edge of the map area near the line of the Southern Pacific railroad. Unlike the East Diablo fault, its course is nearly straight in a north-northeasterly direction (pls. 1, 15), although minor irregularities are suggested by recesses in the base line of the adjoining mountains.

The East Baylor fault is nowhere exposed, but its presence is indicated by the steep faces of the adjoining mountains; the Baylor Mountains rise nearly as high above the Salt Basin, and with nearly as even a base line, as the Sierra Diablo along the East Diablo fault. Moreover, some miles out in the basin southeast of the Baylor Mountains (sec. 25, Block 65, Twp. 7) is an isolated flat-topped hill, composed of Hueco Limestone that stands at least 1,200 feet lower than in the mountains (pls. 1, 15; section *I–I′*, pl. 16). Although the rock spurs along the fault terminate on an even line, they are variously indented by the heads of alluvial fans, and there are large reentrants where Sulphur Creek and Hackberry Creek enter the Salt Basin. Nevertheless, some late faulting may have occurred in places. In the northeastern Baylor Mountains narrow pediments at the base of the scarp are slightly higher than adjacent alluvial deposits on the east; farther south the wide pediment cut on Van Horn Sandstone near Hackberry Creek terminates in a scarp about 25 feet high along the edge of the Salt Basin.

Some of the bedrock exposed at the foot of the Baylor Mountains, mostly El Paso Limestone, is probably close to the East Baylor fault. Northeast of the high point of the mountains (BM 5568) the limestone is stained red and yellow, is sliced by closely spaced joints, dips steeply and erratically, and in places is much brecciated. South of Red Tank Canyon the El Paso near the mountain base dips steeply northwestward, perhaps mainly as a result of pre-Hueco deformation. It is cut by closely spaced northeastward-trending joints, some nearly vertical, others dipping 50°–60° SE., and is offset by minor faults downthrown toward the Salt Basin, probably related to the main fault at the edge of the mountains.

FAULTS ON EAST SIDE OF SALT BASIN

Short segments of faults which border the mountains along the east side of the Salt Basin extend into the map area in places, one along the Delaware Mountains in the northeast corner, another along the Wylie Mountains in the southeast corner (pls. 1, 15).

The part of the Delaware Mountains in the northeast corner of the map area is a prominent salient that projects westward into the Salt Basin at about midlength in the range (fig. 8). Bedrock ends toward the basin along a remarkably even baseline, strikingly shown on air photographs, different parts of which trend northward, northeastward, and west-northwestward. Behind the base line the mountains rise 1,500 feet, and are formed nearly to their tops by poorly resistant thin-bedded black limestone of the Bone Spring Formation. The salient was probably upfaulted relatively late in geologic time.

In a canyon about a mile south of the north end of the salient (sec. 9, Block 65, Twp. 4), where the faulted contact between the black limestone of the mountains and the fanglomerate of the basin is well exposed, the fault surface is nearly vertical and is followed by a zone of calcite 5 feet wide, containing angular fragments of black limestone. Stratification in the adjacent bedrock is nearly horizontal and shows little indication of internal disturbance.

South of the salient, downfaulted bedrock forms low hills at the foot of the high scarp and is tilted toward the Salt Basin, although it may be faulted beneath the alluvium farther out.

The Wylie Mountains, part of which form the southeast corner of the map area (pls. 1, 15), are bordered on the west by the West Wylie fault, which has been discussed by Baker (1927, p. 42; 1928, p. 370–371), Hay-Roe (1957), and others. East of the fault is an escarpment about 1,200 feet high, at whose base the Precambrian Carrizo Mountain Formation emerges from beneath the Hueco Limestone. West of the fault, toward a southern arm of the Salt Basin drained by Wildhorse Creek, are hills of downfaulted west-tilted Hueco Limestone, partly separated by alluvium. Hay-Roe (1957) estimates that displacement of the Hueco Limestone on the West Wylie fault is about 480 feet.

The north side of the Wylie Mountains, facing the main part of the Salt Basin, forms a moderately straight front, much frayed by erosion and indented by alluvial valleys. It may be bordered beneath the adjacent alluvium by a fault of nearly east-west trend, as suggested on figure 8. However, the throw of this presumed fault cannot be great, as limestone was penetrated above a depth of 950 feet in two wells drilled about 4 miles north of the mountains and 8 miles east-northeast of Van Horn (sec. 19, Block 63) (Leonard A. Wood, written commun., 1959).

FAULTS AND RELATED STRUCTURES WITHIN THE MOUNTAINS

Many parts of the interiors of the mountains are faulted. Faulting is greatest in the mountain salients, especially in the northeast corners of the Sierra Diablo and Baylor Mountains, where the rocks are split into narrow parallel fault blocks. Elsewhere near the mountain borders in the Baylor Mountains and Beach Mountain, the rocks are broken into rectangular blocks, bounded by faults trending in various directions. The southern part of the Sierra Diablo is broken into blocks several miles wide along parallel faults which die out westward, but the northern part is less broken.

The faults in the interiors of the mountains had less direct influence on shaping the topography than the faults along the borders. Many of the interior faults are followed by scarps on their upthrown sides, but these scarps are resequent fault-line scarps formed of resistant limestones and caused by removal of weak beds from the downthrown sides by differential erosion. Moreover, along a few faults where rocks on the upthrown sides are weaker, obsequent fault-line scarps have formed on resistant rocks on the downthrown sides. Probably the faults in the interiors of the mountains participated in the main epoch of faulting in late Tertiary time, but they were largely inactive later, when there was further displacement on the faults along the mountain borders.

Most of the faults in the interior of the Sierra Diablo trend west-northwestward. Indications of earlier movements on the west-northwesterly faults, discussed above, and the prominence of joints of the same trend suggest that these faults formed by reactivation of a long-persistent grain. Minor west-northwesterly faults in the northern part of the Sierra Diablo are downthrown northward, and major west-northwesterly faults in the southern part are downthrown southward, perhaps on opposite flanks of the area of maximum upheaval during the main period of block faulting. By contrast, all the earlier faults and flexures along the same trend were downthrown northward, away from a positive area on the south.

Toward the east in the Baylor Mountains and Beach Mountain, the west-northwesterly faults give place to faults trending northeastward and northwestward, which variously offset or intersect each other. These trends are also reflected in the joint pattern (pl. 15). Evidently this expresses a fundamental change in the fracture pattern from that in the Sierra Diablo, as many of the west-northwesterly faults of that area curve eastward into northeasterly or northwesterly faults.

NORTHERN PART OF SIERRA DIABLO

The northern half of the Sierra Diablo, north of the Victorio flexure, is formed of a thick mass of Permian carbonate rocks, with the Victorio Peak Limestone at the top. Even-crested ridge summits on this limestone are remnants of an exhumed surface on which Cretaceous rocks were once deposited, from which can be reconstructed a half dome that was produced by warping after Cretaceous time. The summits rise from an altitude of 5,000 feet on the west and southwest to 6,638 feet at the apex near the North Diablo triangulation station in the northeastern part of the mountains. The remainder of the dome beyond, if it ever existed, is now broken off along the North Diablo and East Diablo faults. Permian rocks of the half dome are warped in the same manner as the summits, and the warping probably influenced the configuration of the top of the Precambrian. (See structure contours, pl. 15). Cretaceous rocks form widely spaced outcrops down the slope of the half dome on the west, and may underlie the alluvium-covered trough which separates it from the Victorio flexure on the southwest.

Most of the half dome is little broken, but it is crossed by widely spaced faults of small displacement (section *F–F′*, pl. 16), trending west-northwestward and downthrown to the north, and by prominent joints trending west-northwestward and north-northeastward (pl. 15). Some of the faults are prominently exposed on the walls of Apache Canyon (pl. 11), where they stand nearly vertical; but elsewhere they are expressed by faint scarps or alined topographic sags and are less easy to trace on the ground than on air photographs. The longest fault zone extends 12 miles east-southeastward across the mountains to the north rim of Victorio Canyon, where it fades out before reaching the edge of the mountains in an area of pervasive jointing (pls. 1, 15). Weathering along the joints causes a remarkable fluting in the cliffs of Victorio Peak Limestone north of Victorio Canyon.

A small tract in the salient of the Sierra Diablo east of Apache Peak has a much more complex structure than the rest of the northern part of the Sierra Diablo. Here, Permian and earlier Paleozoic rocks are broken by as many as six faults in a breadth of a mile or less, most of which trend northwestward but with a few at right angles. They are downthrown alternately northeastward and southwestward to create narrow intervening horsts and grabens (section *E–E′*, pl. 16). The faulted tract is bordered on the northeast and east by the North Diablo and East Diablo faults, at the edge of the Salt Basin, and is separated from the main part of the Sierra Diablo on the southwest by a large northwestward-trending fault along which the rocks are downthrown as much as 500 feet northeastward.

Location of the tract in a salient between the North Diablo and East Diablo faults suggests that it was broken during displacement of these faults, perhaps rather late in geologic time. The only direct indication of late displacements in the tract is the offsetting of felsite sills which lie at the same stratigraphic position in adjacent fault blocks. The sills are probably of Tertiary age and were injected late in the history of the adjacent Marble Canyon-Mine Canyon intrusive complex. (See section, "Igneous rocks," p. 92.)

SOUTHERN PART OF SIERRA DIABLO

In the southern half of the Sierra Diablo, south of the Victorio flexure, Hueco Limestone at the base of the Permian sequence forms the country rock over extensive areas and Precambrian and Precambrian(?) rocks, mainly sandstones of the Hazel and Van Horn Formations, lie near the surface. Structurally the southern half of the Sierra Diablo differs much from the northern, being a succession of north-tilted blocks several miles broad trending west-northwest and downthrown to the south (pls. 1, 15, 16).

On the Victorio flexure between the two halves of the Sierra Diablo, Permian rocks are tilted northward. The flexed Permian rocks may overlie a larger fault or flexure beneath (fig. 2; section *N–N′*, pl. 16), which separates an area of high-standing Precambrian rocks on the south from one of low-standing Precambrian rocks on the north. (See structure contours, pl. 15.) Unlike the other structures of the southern half of the Sierra Diablo, the flexure is largely a pre-Cretaceous feature. (See p. 105–106.) Although it trends in the same direction as the faults farther south, it is not faulted. Toward the east its tilted Permian rocks are truncated by the exhumed pre-Cretaceous surface, on which a few outliers of Cretaceous rocks are preserved. Toward the west, however, broad flexures and folds in the Cretaceous rocks follow the same trend (pls. 1, 15) and continue beyond the map area (fig. 8).

The faults of the southern part of the Sierra Diablo involve mainly the Hueco Limestone, which forms maturely dissected scarps on their upthrown sides, the height of some of which nearly equals the fault displacement. Along a few of the faults Cretaceous rocks are preserved on the downthrown sides. These may have covered much of the Sierra Diablo region at the time of the faulting, but were afterwards largely removed by erosion to produce resequent fault-line scarps in the limestone. Dissection of the scarps is enhanced where formations beneath the Hueco emerge—especially the poorly resistant red sandstone of the Hazel Formation. Where the red sandstone is exposed, the scarps are irregularly frayed and in places have retreated a mile or more from the faults.

The faults are named, from north to south, the Bat Cave fault, Cox Mountain fault, Sulphur Creek fault, Sheep Peak fault, Circle Ranch fault zone, and South Diablo fault. Each fault originates near the eastern border of the mountain block and dies out westward in plateau country beyond the mountains (pls. 1, 15). The Cox Mountain and South Diablo faults extend 20 miles across the map area and the latter continues at least 10 miles farther west, but the other faults are shorter. The Cox Mountain, Sheep Peak, and South Diablo faults are displaced more than a thousand feet in places, but most of the others were displaced a few hundred feet or less (pl. 16).

Long segments of the faults have nearly straight or gently curved traces, but the Sheep Peak and Sulphur Creek faults branch eastward. The Circle Ranch fault zone is not a continuous line of displacement, but consists of many minor faults, lying partly parallel, partly en echelon or branched, which separate two blocks that are less disturbed. The South Diablo fault, although a zone of continuous major displacement, consists of many segments of slightly different trend from which minor faults branch eastward on each side.

Toward the east the faults pass from the Hueco Limestone into the homogeneous red sandstone of the Hazel Formation, where their courses are difficult to trace on the ground. The Bat Cave and Cox Mountain faults may abut the East Diablo fault at the edge of the mountain block at nearly right angles, but the junctions are covered by alluvium. The Sulphur Creek fault is readily traceable on air photographs through the red sandstone to an acute-angled junction with the south end of the East Diablo fault between Beach Mountain and the

Baylor Mountains. The Sheep Peak, Circle Ranch, and South Diablo faults appear from air photographs to die out in the red sandstone within short distances east of the scarps of Hueco Limestone, but other faults of similar trend, lying en echelon, continue into Beach Mountain (pls. 1, 15).

Westward, all the faults except the South Diablo fault lose displacement and die out within the map area, but the disturbance on some is extended a short distance farther by flexures or folds. An abrupt flexure continues 2 miles beyond the end of the Sheep Peak fault, and a broad anticline occurs at the end of the Cox Mountain fault.

The planes of all the faults dip steeply, where visible. A steep dip toward the downthrow was observed on the Sheep Peak fault south of Sheep Peak and on the South Diablo fault north of the Keen Ranch. Similar steep dips may be inferred where the Bat Cave, Cox Mountain, and Sulphur Creek faults cross the cliffs of Hueco Limestone on the east-facing escarpment of the Sierra Diablo. However, a fault on the extension of the Sheep Peak fault, where exposed in a Hueco Limestone cliff 1¼ miles west of the Hazel mine, dips 60° N. toward the upthrown block. In a few places, as on the Cox Mountain fault west of the Pecos mine and the Sheep Peak fault west of Sheep Peak, calcite veins occur in the Hueco Limestone at or near the fault planes. The veins contain limonite and hematite, perhaps weathered from original sulfide minerals. Where the faults involve Hueco Limestone and Cretaceous formations, these rocks are dragged steeply on the downthrown sides, whereas the rocks on the upthrown sides are little disturbed. In some places, as on faults of the Circle Ranch zone southeast of the Circle Ranch, displacement by drag is greater than on the fault itself.

BAYLOR MOUNTAINS

The Baylor Mountains form an irregular quadrilateral block 9 miles long and 7 miles wide, implanted in the southern bight of the East Diablo fault. Their summits are about a thousand feet lower than those of the Sierra Diablo on the west and about a thousand feet higher than the floor of the Salt Basin on the east and north. The mountains are bordered on all sides by faults—the East Diablo, North Baylor, and East Baylor faults—and are a block that stands at an intermediate level between the heights of the Sierra Diablo and the depths of the Salt Basin. They consist of a plate of Permian rocks, whose foundation of earlier Paleozoic rocks crops out around the edges (pl. 1). The Permian rocks are flat lying or gently tilted, except at the northeast corner of the mountains where they dip more steeply northward, probably along an eastward extension of the Victorio flexure.

The rocks of the interior of the Baylor Mountains are greatly faulted on the northeastern and southeastern sides, where many narrow blocks have been downdropped away from a less disturbed nucleus in the west-central part. As in the greatly faulted northeastern salient of the Sierra Diablo, these blocks seemingly broke away from the more stable mountain area during displacement of the major faults on the northern and eastern sides of the mountains.

The internal faults are of two systems, one in the northeastern part which trends northwest, the other in the southeastern part which trends northeast. Those in the northeastern part are a quarter of a mile to a mile apart, but branch or interlace. Most are downthrown toward the northeast, dropping the intervening blocks toward the salient of the mountains (section *S–S′*, pl. 16). The traces of the faults across steep hills indicate that they stand nearly vertical. One of the longer faults near the center of the mountains extends northwestward to the East Diablo fault, where it apparently matches a fault of west-northwest trend on the Sierra Diablo escarpment to the west. Exposures are insufficient to determine the exact relations of the two faults to each other, or to the East Diablo fault. The faults in the southeastern part are fewer. One pair, with a curvature convex toward the southeast, bounds a narrow outlying block of Montoya Dolomite, and another set extends discontinuously along Red Tank Canyon. On one of the faults in Red Tank Canyon a small remnant of Cretaceous sandstone is preserved on the downthrown side. The faults of the two trends intersect near Red Tank Canyon on the eastern side of the mountains, where many of the northwest-trending faults abut the northeast-trending faults.

BEACH MOUNTAIN AND VICINITY

Beach Mountain, which borders the Salt Basin south of the Baylor Mountains, is a smaller mass which projects as high as or higher than the latter (pl. 2). Unlike the Baylor Mountains it is formed largely of Ordovician carbonate rocks. It is an erosion remnant rather than a fault block and is not structurally separated from the main block of the Sierra Diablo on the west. Like the Baylor Mountains it is much broken internally by two systems of faults trending nearly at right angles (pls. 1, 15).

One system includes the Grapevine and Carrizo Spring faults (sections *R-R′* and *S-S′*, pl. 16). Faults of the system originate in the Precambrian rocks west of Beach Mountain, where they trend west-northwest or west, but in the mountain they curve into east-northeastward or northeastward courses. The traces of the faults across the steep western face of the mountain indicate that they stand nearly vertical. In Beach Mountain the faults involve Ordovician formations and Hueco Limestone and were probably displaced during late Tertiary time, but the Grapevine fault and perhaps the Carrizo Spring fault had a considerable prior history. (See p. 103.) On the Grapevine fault deformed Hazel Formation was offset with left-lateral strike-slip displacement, probably during late Precambrian time, and the Van Horn Sandstone was downthrown to the south before Bliss time.

The faults of the second system, like those of the first, seemingly originate toward the west in the west-northwesterly system of the Sierra Diablo, but in Beach Mountain they curve into northwestward or north-northwestward courses. This is shown most clearly by a branch of the Sulphur Creek fault which curves southward into the northern part of Beach Mountain, where a thick sequence of El Paso and Montoya Formations is preserved on its downthrown eastern side (lower view, pl. 2). Like faults of the first system, some of those of the second were displaced before late Tertiary time. The Van Horn Sandstone was downthrown to the east along the Dallas fault before Bliss time and the fault was not displaced again later (see p. 102–103), yet it is parallel to others of the same trend which displace Ordovician formations and the Hueco Limestone.

The two fault systems meet complexly in the east-central part of Beach Mountain (pls. 1, 15). Faults trending north-northwest terminate against the Grapevine fault, but the Carrizo Spring fault terminates eastward against a fault of north-northwest trend. The Hueco Limestone at the east end of the mountain (section *J-J′*, pl. 16) is preserved in a block that is bounded on the west and north by faults of the two intersecting systems.

HILLSIDE FAULT AND RELATED STRUCTURES

The Hillside fault forms a major line of discontinuity in the southern part of the map area, between the Carrizo Mountain Formation and associated igneous rocks on the south and the Van Horn Sandstone, Hueco Limestone, and Cretaceous formations on the north. It extends west-northwest along the northern side of the Carrizo Mountains for a known distance of 8 miles, terminating eastward against the East Baylor fault near Van Horn and disappearing westward beneath the alluvium of Eagle Flat near Allamoore (pls. 1, 15).

Through most of its course the Hillside fault is followed on its northern downthrown side by a prominent escarpment of Hueco Limestone and Cretaceous formations as much as 500 feet high. This is an obsequent fault-line scarp, formed by more rapid erosion of the Carrizo Mountain Formation and associated igneous rocks on the southern upthrown side. The valley which has been eroded south of the scarp is followed by the line of the Texas and Pacific Railway in its course through the Carrizo Mountains from the Salt Basin to Eagle Flat. A major displacement on the fault occurred after Cretaceous time, perhaps during the late Tertiary, but erosional features along it indicate that it has been inactive since.

An earlier movement on the Hillside fault is indicated by the Powwow Member at the base of the Hueco Limestone north of the fault, in which fragments of metarhyolite derived from south of the fault increase in size and abundance toward it. Presumably newly upfaulted metarhyolite projected as a scarp along the fault at the time of deposition of the Powwow Member (fig. 2). These relations show further that no significant strike-slip displacement could have occurred along the fault during or since Hueco time, for the fragments in the Powwow Member on the northern side match rocks in place on the immediately adjacent southern side.

The Hillside fault forms the southern boundary of the thick bodies of Van Horn Sandstone in the Sierra Diablo region (pl. 1), and to the south the Powwow Member of the Hueco Limestone generally lies on the Carrizo Mountain Formation and associated igneous rocks. The boundary is not absolute, however, as a few thin remnants of Van Horn are preserved south of the fault along the eastern side of the Carrizo Mountains.

Toward the western end of the Hillside fault near the Gifford-Hill rock crusher (sec. 28, Block 67, Twp. 8), Cretaceous formations are downthrown northward against metarhyolite, and the displacement probably much exceeds 1,000 feet (section *T–T′*, pl. 16). Equally great displacement must have occurred several miles farther east (sec. 16, Block 66, Twp. 9) where Hueco Limestone, lying on Van Horn Sandstone and topped by a Cretaceous outlier, forms a high scarp north of the fault (section *Q–Q′*, pl. 16). Flawn (in King, P. B., and Flawn, P. T., 1953, p. 115) reports that on the south side of the fault a mile east of the rock crusher, a small patch of Powwow Member of the Hueco Limestone lies on metarhyolite, indicating not only that part of the displacement occured before Hueco time, but that the post-Hueco displacement is less than at nearby localities; however, the patch of Powwow may lie in a wedge that was displaced less than the main fault block to the south.

The surface of the Hillside fault, or rocks close to it, is exposed at several places in the segment extending 2 miles east from the rock crusher. In the easternmost exposure, metarhyolite is separated from the Van Horn Sandstone by a nearly vertical zone of brecciated quartz along the fault plane, the Van Horn to the north being bleached and closely jointed. Farther west the metarhyolite close to the fault contains several steeply dipping zones of breccia, which crop out in wall-like ridges. One zone dips 70° S., but may follow the foliation planes of the metarhyolite, rather than the fault plane. In this vicinity fragments in the Powwow Member north of the fault have been shattered by later deformation.

North of the Hillside fault in the eastern half of its trace, the Hueco Limestone and adjacent Van Horn Sandstone are broken by four or five minor faults trending north-northwest, the western group of which extends nearly across the Red Valley to the Carrizo Spring fault. In an exposure of one of the western minor faults, its surface dips 80° E., toward the downthrow. The minor faults reflect a pervasive fracturing of the block north of the fault along the same trend, as shown by abundant joints in the Hueco Limestone and Van Horn Sandstone which also trend north-northwest (pl. 15).

The Hillside fault may be part of a zone of faulting which extends somewhat farther east and west. It is nearly in line with the north side of the Wylie Mountains across the Salt Basin to the east, which may be bordered beneath the alluvium by a minor fault, likewise downthrown to the north (fig. 8). About 10 miles west of the known terminus of the Hillside fault, along the southern edge of the Streeruwitz Hills, are ridges and knobs of Hueco Limestone, tilted southward, which may lie in a fault zone between the hills and the tectonic depression of Eagle Flat (sections *K–K′*, pl. 16). This fault zone may continue farther east and west, but relations are concealed beneath the alluvial plains along the north side of the flat. The inferred fault zone has about the same trend as the Hillside fault, but is downthrown southward, in the opposite direction.

The Hillside fault has been ascribed an inordinate role in the tectonics of the region by Moody and Hill (1956, p. 1223–1224), who interpret it as a major element in the "Texas lineament" (Ransome, 1915, p. 295; Baker, 1935a, p. 211–214; Albritton and Smith, 1957), extending westward through the gap between Sierra Blanca and the Quitman Mountains (fig. 1), and perhaps past the south end of the Franklin Mountains near El Paso. They believe that it "represents a large-scale left-lateral wrench fault" and that the structures in the Mesozoic rocks south of Sierra Blanca are "second-order drag folds relative to this wrench."

This interpretation is not supported by local geologic relations. The composition of the Powwow Member north of the Hillside fault indicates that no significant strike-slip movement could have occurred on the fault during or since Hueco time. There is no indication of an extension of the Hillside fault zone west of the Streeruwitz Hills or east of Wylie Mountains. Neither in the gap between Sierra Blanca and the Quitman Mountains on the west; nor between the Apache Mountains and Davis Mountains on the east does the structure permit the existence of a throughgoing strike-slip fault. The folds and faults in the Mesozoic rocks south of Sierra Blanca are part of the Chihuahua tectonic belt, a regional feature that extends far southwestward and southeastward from the Hillside fault. Left-lateral strike-slip displacements have been observed on minor faults in the Precambrian rocks north of the Hillside fault (see p. 102–103), but there is no indication that these faults were displaced in this manner after Precambrian time.

JOINTS

The writer made systematic observations on the joints in the Sierra Diablo region, similar to those made earlier in the southern Guadalupe Mountains (King, P. B., 1948, p. 114–117, pl. 20). Summaries of the joints in the Sierra Diablo region have been published previously (King, P. B., and Knight, J. B., 1944, structure map; King, P. B., and Flawn, P. T., 1953 pl. 10), but further details are given here (pl. 15).

All the rocks of the Sierra Diablo region are cut by many joints. Those in the greatly deformed Precambrian formations trend in diverse directions, dip at all angles from horizontal to vertical, and are so complex that it was not considered worth the effort to record or analyze them. Those in the younger gently dipping stratified rocks—the Van Horn Sandstone, the Paleozoic formations, and the Cretaceous formations—dip steeply and are arranged in systematic patterns that are susceptible of measurement and study. Steeply dipping joints also occur in the gently tilted parts of the Hazel Formation, along with other joints inclined at lower angles, and some of these are recorded on the map (pl. 15).

Most of the steeply dipping joints in all the stratified formations are straight and smooth, even where they cut through irregularly bedded rocks or alternations of hard and soft strata. At the surface some of the joints are open fissures, but these probably were enlarged by weathering, and most of them narrow and tighten at depth. Single joints commonly extend across the entire breadth of any exposure, and where several sets occur, most of them cross one another without deflection. Spacing of the joints depends on the nature of the rock; they are widely spaced in massive rocks, such as the Van Horn and Cox Sandstones, and are closely spaced in thin-bedded brittle rocks, such as the Ordovician and Permian limestones and dolomites.

Nearly all the joints dip steeply or stand nearly vertical. During the field investigation, conspicuous deviations of the joints from the vertical were recorded, but it was found that such deviations were so slight that they could be ignored. The most significant features of the joints appear to be their trends in horizontal plan, and the largest number of observations were made on these trends. On the map (pl. 15) the trends of joints are summarized by two methods:

1. Joints at individual stations are shown by lines of various lengths, radiating from the point of observation. Records made at the stations commonly consisted of measurements at two or more points in the immediate vicinity, at each of which all joints were recorded, and notations were made of the dip and prominence of each; observations at a station may include as many as 20 individual measurements. It is impossible to represent all these measurements on the map (pl. 15); joints at each station are accordingly summarized, the most abundant four or five joint sets being plotted, with lengths of lines indicating their relative prominence. Besides the joints which were measured on the ground, joints which are prominent in air photographs are also indicated.

2. Joints are further summarized statistically by rosettes, which are overprinted at various places on the map (pl. 15). For purposes of summary the observations are grouped according to tectonic units of different ages and according to locality. Separate statistical summaries were made for joints of the Van Horn Sandstone, the Ordovician to Pennsylvanian rocks, the Permian rocks, and the Cretaceous rocks, each rock group representing a tectonic unit separated from the others by a significant structural unconformity. Occurrence of joints in the different tectonic units was further segregated into structurally significant units of area, whose boundaries are shown in an inset map accompanying plate 15.

Each rosette shows the relative abundance and prominence of the joints of various trends that were measured in each stratigraphic and areal unit. A tally was made of the number of joints in each 5° of arc, and each tally was converted into a percentage of the total number recorded. As a check, a tally was also made of the prominence of the different joint sets observed. This tally was found to agree closely with the number of joints of each set which were observed, indicating that the most abundant joints also tend to be the most prominent joints. As originally worked out, wide variations were found between percentages at some of the adjacent points on the arcs, probably because of a personal equation in making the observations. The percentages were therefore evened by means of moving averages. Each figure used in plotting the rosettes is thus the average of the original percentage for the direction shown, and the percentage of the two directions lying 5° on each side of it. To indicate the amount of information available for each unit summarized, the number of stations and number of observations used are marked by the different rosettes.

Observations on the trends of the joints are of interest, for they amplify and fill in the fracture pattern of the rocks which is otherwise only partly suggested by the fault pattern.

In the fault block formed by the Sierra Diablo and its foothills to the north and south, the dominant joints trend west-northwest, parallel to the west-northwest-trending faults and flexures of the same area. These joints dominate, not only near the faults and flexures, but also where the rocks are otherwise little disturbed. The next most abundant joints, in places of nearly equal magnitude, trend nearly at right angles to the north-northeast. Ordinarily, these joints are not followed by any faults, suggesting some fundamental difference in their nature. The remaining joints trend in all directions between those of the dominant sets, but in many of the units summarized two maxima are indicated on the rosettes that are about midway between the trends of the two dominant sets. A striking feature in the Sierra Diablo block is the subordination of joints trending northward parallel to the faults of northerly trend which border the range. As shown on the map (pl. 15), some north-trending joints are recorded close to the East Diablo fault, but their number is insufficient to influence significantly the form of the rosettes.

Eastward in the Baylor Mountains and Beach Mountain, the joint pattern changes significantly in the same manner as the fault pattern. Here, two joint sets of nearly equal magnitude trend northeast and northwest, in the same directions as the faults. In the Red Valley north of the Hillside fault, where minor faults trend north to north-northwest, a prominent joint set in the same direction is recorded by the rosettes (pl. 15).

Subdivision of the recorded joints according to tectonic units was made primarily to test the possibility of significant differences between jointing in rocks of different ages, but the results are inconclusive. Although there are differences in the patterns of rosettes in rocks of various ages in the same units of area, these seem less likely to be caused by differences in age than by differences in amounts of data, or by differences in susceptibility to jointing of the rocks themselves. In many areas, for example, the rosette for the Permian rocks shows many joints in all directions with poorly defined maxima, whereas rosettes for the Van Horn Sandstone and the Cretaceous rocks show much better defined maxima. This is partly because more observations were made on the extensively exposed Permian rocks, partly because the Permian carbonate rocks fractured more diversely than the dominant sandstones of the other two units. The dominant joint trends in rocks of different ages in the same unit areas thus appear to be nearly alike.

This suggests that the dominant joint pattern in all the rocks might be less closely related to the earlier orogenies than it is to the upheaval of the mountain blocks in late Tertiary and Quaternary time. It seems unlikely, however, that rocks which have been in process of accumulation and deformation since Precambrian time could have remained without fractures until such a late period. Moreover, evidence so far presented indicates that faulting and flexing along a west-northwest trend has recurred many times in the history of the area. It would thus appear that joints related to this trend, and perhaps others, formed long before the latest upheaval, and were renewed in successively younger rocks that were laid down unconformably over the older.

REGIONAL INTERPRETATION AND SYNTHESIS

The structure of the Sierra Diablo and surrounding regions is dominated by a network of faults (pl. 15, fig. 8) that formed in later Cenozoic time. The faults are a product of the stress pattern which existed at the time, and would seem to be capable of mechanical analysis on that basis. Such an analysis is made difficult, however, by the extensive prior tectonic history of the region. At least part of the faulting resulted from reactivation of earlier faults and flexures, which were created by forces different from those which prevailed during later Cenozoic time. Once created, these earlier faults and flexures became zones of weakness which could be utilized afterwards by new forces with new orientations.

The fault network of the region consists principally of two sets of faults and related features, one trending northward, the other west-northwestward, which cross or intersect in a complex manner (fig. 8). The northward-trending set dominates, and may be most closely related to the stresses existing during later Cenozoic time; the west-northwestward-trending set is mainly subordinate, and may have formed principally by reactivation of earlier zones of weakness.

The northward-trending structures extend far northwestward beyond the Sierra Diablo into New Mexico, and perhaps westward into Chihuahua, but they die out southward in Trans-Pecos Texas. Throughout their extent they largely control the modern topography, attesting the relative recency of their formation. They thus outline the Salt Basin and the mountains which adjoin it, such as the Sierra Diablo. Along the edges of the Salt Basin the latest faults of Pleistocene age are of northerly trend. In the Guadalupe and Delaware Mountains the principal northward-trending structure is an arch, fractured along its crest by longitudinal faults and joints (King, P. B., 1948, p. 109), but in the Sierra Diablo and adjacent mountains, the principal structures are fault blocks which have been little arched or flexed. The northward-trending structures of Trans-Pecos Texas and New Mexico are seemingly products of a regional tension, whose axis of least stress was oriented approximately east and west.

Along the edges of the Sierra Diablo the northward-trending structures break across the west-northwestward-trending structures, as though these largely originated earlier. Within the range the dominant faults and joints trend west-northwest, and northward-trending structures are scantily represented, if at all (pl. 15). Nevertheless, west-northwestward-trending structures significantly truncate or offset northward-trending structures in other places, especially in the Apache Mountains east of the Sierra Diablo. Also, the Salt Basin is peculiarly segmented, apparently by west-northwestward-trending faults that extend short distances into the ranges which border it (fig. 8). Each segment is offset left laterally from the ones on either side, suggesting a possible strike-slip displacement along the west-northwestward-trending faults which bound them. Nevertheless, no such displacements can be observed where these faults enter the adjoining ranges. It seems more likely that the northward-trending structures, during their formation, reactivated an earlier west-northwestward-trending grain, and were modified by it.

Evidence has been presented (p. 102–103, 105–106, 111–115) that the west-northwestward-trending structures were intermittently displaced between late Precambrian and late Cenozoic time. Faults of this trend that are of late Precambrian age can be proved with certainty at only a few places, yet the fact that they exist at all suggests that a grain of this trend originated in the Precambrian basement early in the history of the region and controlled the structures formed during later tectonic episodes, in strata of younger ages laid down over the basement. Many of the faults of west-northwesterly trend that are of late Precambrian age have left-lateral strike-slip displacements of a mile or less; but no strike-slip displacement can be proved on faults of similar trend in the younger rocks, and on some of the faults there is evidence against such a displacement. The conglomerate of the Powwow Member of the Hueco Limestone on the north side of the Hillside fault was derived from a source just south of the fault, and demonstrates that no strike-slip displacement occurred along it during Permian time or later.

Seemingly, then, the forces which caused the subsequent flexing and faulting of the west-northwestward-trending structures were of a different kind and orientation from those of late Precambrian time, and were merely guided by the lines of weakness already established. Some of the structures, as those formed during the pre-Hueco deformation of later Pennsylvanian time, were products of a mild compressional folding. Succeeding structures may have been dominantly tensional and the incidental products of dominantly vertical movements that created major positive and negative areas. During Permian time such vertical movements differentiated the positive area of the Diablo platform from the negative area of the Delaware basin on the northeast; during Cretaceous time similar movements differentiated the positive area from a geosynclinal area on the southwest.

The discussion so far indicates the local causes for the west-northwestward-trending structures. Are they also a product of more fundamental regional causes, and are they merely a segment of a large regional feature? Some geologists (Hill, 1902, p. 173; Ransome, 1915, p. 295; Baker, 1935a, p. 211–214; Moody and Hill, 1956, p. 1223–1224; Albritton and Smith, 1957) ascribe them to the "Texas lineament," a supposed major structure that is believed to extend across south-central North America from the Pacific to the Gulf Coast. The original definition of this structure by Ransome (op. cit.) is of interest:

> [It] coincides in general with the southwest boundary of the Colorado Plateaus and with the valley of the Rio Grande. It is along this general line that the uplifted masses of Paleozoic rocks of the Colorado Plateau province, as in the Franklin Mountains near El Paso, look out to the south over the Cretaceous terrain of the Mexican Plateau. Mr. R. T. Hill has called attention to this feature in several of his papers and points out that in the Trans-Pecos Region it coincides with a zone of faulting which is older than the north-south faults to which the bolder topographic features are due. The entire, rather vaguely defined and perhaps in part imaginary, zone from the Pacific to the Gulf of Mexico may be called the Texas lineament.

Subsequent proponents of the Texas lineament do not mention Ransome's final unflattering, but probably just, characterization of this feature.

Baker (1935a, p. 212) extends the Texas lineament as described by Ransome "from Point Conception on the Pacific coast of southern California to Cape San Roque, the easternmost point of South America, the zone determining the northeastern coast line of South America and passing through the island of Cuba"; he proposes that it be renamed the "Hill intercontinental lineament." Moody and Hill (1956, fig. 11) believe that the lineament is a zone of "wrench faults" with left-lateral strike-slip displacement. Albritton and Smith (1957, p. 515) conclude that "after more than half a century, the idea of the Texas lineament remains in the class of plausible hypothesis."

The substance of these proposals seems to be that the alleged lineament forms a zone between more stable and less stable parts of the continental crust—between a mainly cratonic area on the north, as in the Colorado Plateau, and a mobile area on the south, in the southern part of the Basin and Range province and the ranges of Mexico. In places, as in the Transverse Ranges of California, the zone contains faults with left-lateral strike-slip displacement. In others, as in Arizona and Trans-Pecos Texas, the zone marks the passage from a dominantly thrust-faulted terrain on the south to a dominantly block-faulted terrain on the north. Moreover, the Transverse Ranges of California are alined with the lengthy Murray fracture zone of the Pacific Ocean basin on the west, which probably involves a strike-slip displacement of the oceanic crust (Menard, 1955, p. 1164–1167).

Whether any persistent throughgoing structures exist along the lineament in the continental crust is doubtful. Even conceding transverse faults in gaps between the ranges of the southern part of the Basin and Range province, which would now be concealed from detection by unconsolidated deposits, no lengthy structures, due to more than local causes, can be proved. No rift features comparable to those along active faults with strike-slip displacement occur east of California.

It would therefore appear that the Texas lineament marks rather vaguely a boundary between parts of the continental crust of North America that have possessed different degrees of mobility through geologic time, that these differences in mobility have influenced the development of varied local structures, such as those of west-northwest trend in the Sierra Diablo region, but that the differentiation has not been of sufficient magnitude to produce any throughgoing structures comparable to the great faults of California or the fracture zones of the Pacific Ocean basin.

ECONOMIC GEOLOGY

Metallic and nonmetallic mineral deposits of the Sierra Diablo region are varied. Some of these deposits have yielded or continue to yield profitable production, and others may be capable of later exploitation; but many are too small or of too low a grade to be of economic interest. The region has also been extensively drilled with varying success for water, and in a few places unsuccessfully for oil and gas. Most of these resources have been described in various earlier publications, and are merely summarized here.

COPPER AND SILVER [6]

Vein deposits containing metallic sulfide minerals occur in a number of places in the Precambrian rocks in the eastern part of the foothills of the Sierra Diablo, and to a lesser extent in the Carrizo Mountains. Ore has been produced intermittently from several mines since 1880, and the veins in other places have been explored by many prospects. The principal metals of the deposits are copper and silver, but some deposits also contain zinc and lead. Some rich pockets of ore were discovered during the early days of mining, but most of the ores of the district are of low grade, averaging about 2½ to 3 percent of copper.

The most prolific mine in the district is the Hazel, which lies near the foot of the Sierra Diablo 10 miles northwest of Van Horn (sec. 14, Block 66, Twp. 7). It is one of the oldest mines in Texas, and the largest proucer of copper in the State. Moderate amounts of ore have also been produced from the Blackshaft and Sancho Panza mines a few miles to the southwest, but production from the remaining mines and prospects has been much less. Total production of the district is difficult to estimate because records are fragmentary, and are generally lacking for the period before 1900. A possible approximation is 140,000 tons of ore, yielding 2,700,000 pounds of copper and 4,000,000 ounces of silver.

The copper and silver deposits occur in four principal associations, of which only two have yielded production:

1. Deposits of Hazel type lie in the northern part of the district, near the foot of the scarps of the southeastern angle of the Sierra Diablo. These deposits are in vertical fissure veins or mineralized fractures, lying in gently dipping compact red sandstone of the Hazel Formation. The veins are commonly indicated in surface outcrops by bleaching of the red sandstones immediately adjacent. They consist of zones a few feet to 40 feet wide of bleached, brecciated, and sliced country rock, interlaced with a gangue of barite and other minerals, which contain sulfides of copper, silver, and other metals. The deposits of Hazel type are not haphazardly located, but occur along two fracture zones. The Hazel fracture zone, about 3½ miles in length, trends nearly east and west and contains deposits of the Hazel mine, Marvin-Judson prospect, and Mohawk mine (pls. 1, 15). The Pecos fracture zone, about 2 miles in length, trends north-northeast and contains the deposits of the Pecos mine and Eureka prospect.

2. Deposits of Blackshaft type occur in a belt about 1½ miles long just north of the Millican Hills, and have been worked in the Blackshaft, St. Elmo, and Sancho Panza mines (pl. 1). Deposits of Blackshaft type are in crushed, sheared, and silicified limestone, phyllite, and igneous rock of the Allamoore Formation, and in associated fault gouge, which together form a bed a few feet thick along a low-angle thrust fault, enclosed by the Hazel Formation. The bed is folded into an irregular east-plunging syncline, so that it dips steeply in the southeastern part and very gently in the northwestern part, where it crops out over a wide area and is susceptible to opencut mining. The crushed and sheared rock of the Allamoore Formation has been veined and replaced by gangue minerals and metallic sulfides, principally of copper, although there are scattered rich silver-bearing pockets.

3. Other deposits have been prospected in the Allamoore Formation of the Millican Hills and the Carrizo Mountain Formation of the Carrizo Mountains. In the workings of all these prospects mineralization seems to have taken place in narrow unsystematic veins and veinlets, with little replacement of limestone or other host rocks. Prospecting so far has failed to yield any sizable ore bodies, and no ore is known to have been produced from the deposits.

4. Another type of deposit occurs only at the Dallas mine on the west side of Beach Mountain (pl. 1). Here, a fault of pre-Ordovician (pre-Bliss) age has thrown the Van Horn Sandstone down against the Allamoore Formation, and the limestone of the Allamoore adjacent to the fault has been veined and mineralized. No ore is known to have been produced from this deposit.

Although these deposits occur in varied structural situations, the deposits themselves are of such a similar makeup as to suggest that they all formed from a common cause at the same time. The deposits are dominantly in Precambrian rocks, and similar deposits are only scantily developed in the adjacent Paleozoic and Cretaceous rocks. In all the deposits, narrow previously formed zones of weakness in the country rock were later veined and replaced by gangue and metallic minerals brought in by hydrothermal solutions. The zones of weakness in the Blackshaft type of deposits were formed during Precambrian time; those of the Dallas mine originated between Precambrian(?) and Ordovician time; the age of the zones of weakness of the Hazel type of deposits is unknown.

Regional considerations suggest that the metallic ore deposits of the district were emplaced in the zones of weakness during Tertiary time. Paleozoic and Cretaceous rocks contain mineral deposits in the Eagle and Quitman Mountains not far to the southwest in Trans-Pecos Texas, and similar deposits are widely distributed in adjacent parts of Chihuahua and New Mexico.

[6] See King, P. B., and Flawn, P. T. (1953, p. 149–168), which contains detailed descriptions of the mines and prospects and references to earlier publications.

Tertiary intrusive and volcanic rocks are also common throughout the region. The ore deposits in the district may be principally in the Precambrian rocks, not because the deposits are old, but because the Precambrian rocks were lower and nearer the source of hydrothermal solutions, and because the Precambrian rocks have been much more deformed and fractured than the Paleozoic and later rocks which overlie them.

TUNGSTEN AND BERYLLIUM

The Mine Canyon stock in the northeastern part of the Sierra Diablo (sec. 20, Block 66, Twp. 5) has been sporadically prospected for many years for tungsten and other metals. The most extensive work was done in 1940 and 1941, by William Rossman of Pecos, Tex., who put more than a thousand feet of adits and shafts into the slopes of Cave Peak.

The light rhyolite breccia of the stock has been somewhat mineralized throughout, as indicated by extensive iron staining of weathered surfaces. Most of the introduced minerals occur in narrow veinlets which trend westward, northwestward, and northward; the veinlets are 3 inches or less thick, and fray out into joints within 50 or 100 feet along the strike. According to S. G. Lasky (written commun., 1941), the dominant mineral is pyrite, but there is also chalcopyrite, fluorite, and huebnerite (iron-manganese tungstate); in addition, Richardson (1914, p. 9) reports the presence of wolframite. None of the outcrops or workings on Cave Peak show sufficient quantities of tungsten minerals to make the deposit of economic interest.

In 1948 the outcrops and workings on Cave Peak were sampled for beryllium by W. T. Holser, as part of an investigation of nonpegmatitic occurrences of this metal in the United States (Warner and others, 1959, p. 140–143). Analyses of samples indicate that the veinlets and rocks adjoining them in places contain as much as 0.1 percent BeO, but mostly much less, and that none occurs in the other rocks of the area.

TALC [7]

Talc was discovered in the Allamoore Formation south of the Sierra Diablo in 1952, and has since been mined and prospected in the Streeruwitz, Bean, and Millican Hills and on Tumbledown Mountain, for a distance along the strike of 17 miles.

The talc occurs in phyllite units that are interbedded with the limestone and volcanic units of the formation. On the geologic map (pl. 1) the phyllite units are grouped with the limestone units, but they were shown separately in an earlier publication (King, P. B., and Flawn, P. T., 1953, pls. 2, 3). The phyllite units are generally less than 100 feet thick, but are as much as 300 feet thick in places; individual units vary in thickness along the strike as a result of crumpling and flowage of the incompetent rock. The amount of talc in the units varies from place to place. The mineral may have formed from an original fine-grained magnesium-bearing tuff or marl. Carbonate rocks adjacent to the phyllite units contain little magnesium, and are mainly limestone rather than dolomite, but dolomite forms inclusions in the talc bodies. Large masses of pure ceramic-grade foliated to fibrous talc as much as 150 feet thick occur in places, but in others the talc bodies contain layers or irregular masses of chert and carbonate rock.

Six companies are operating in the district, and through 1958 these had produced a total of 120,000 tons of talc; in 1960 they produced 60,000 tons. In 1960 a processing mill was installed at Allamoore. About 90 percent of the talc produced in the district is sold for ceramic purposes and is used for manufacture of wall tile, the remainder being marketed as an insecticide carrier.

CRUSHED STONE [8]

Crushed stone is produced by Gifford-Hill Co. of Dallas, Texas, at its Holley plant 2½ miles east of Allamoore (sec. 27, Block 67, Twp. 8). The plant and workings are in the northwestern part of the Carrizo Mountains just southwest of the Texas and Pacific Railway, between the railroad and U.S. Highway 80. The plant was opened in 1926, and has been in nearly continuous operation since that date.

The stone used for crushing is the metarhyolite that intrudes the Carrizo Mountain Formation. In the workings this is pink or reddish, siliceous, and considerably more massive and blocky than elsewhere in the area. As elsewhere, it contains broken and elongated phenocrysts of quartz and feldspar, and some layering, defined by different colors and varying composition, but the rock does not split readily along the layering. Large reserves of metarhyolite remain in the neighborhood, although most of it is more foliated, and hence more slabby and less massive than that which is now quarried.

The crushed metarhyolite has been used to ballast the line of the Texas and Pacific Railway between Dallas and Sierra Blanca, and has also been used to a more limited extent in highway construction.

MARBLE AND BRUCITE

In the Sierra Diablo region, marble occurs sporadically in limestone units of the Precambrian Allamoore

[7] See King, P. B., and Flawn, P. T., (1953, p. 170–172) and Flawn (1958, p. 104–105).

[8] See King, P. B., and Flawn, P. T., (1953, p. 172–173).

Formation, but its main occurrence is in the Permian Hueco Limestone in contact metamorphic zones adjacent to igneous intrusives of Tertiary age. A zone of marble in the Hueco, 200–400 feet wide, encircles the Marble Canyon stock, and a slightly narrower zone extends part of the way around the periphery of the Mine Canyon stock; a zone 3–25 feet thick overlies the sill of Sierra Prieta on its south side.

Marbles derived from the Hueco Limestone are white, uniformally crystalline and massive, seldom retaining any relic bedding structures, although they are obscurely jointed. Analyses indicate that they vary in composition from nearly pure $CaCO_3$ to mixtures of $CaCO_3$ with $MgCO_3$ and $Mg(OH)_2$. The latter forms the mineral brucite, and in some specimens amounts to as much as 30 percent of the rock. The magnesium-bearing marbles were obviously derived from the more dolomitic layers of the original limestone.

The marbles of the Sierra Diablo region have been little developed until recently. A "marble quarry" was shown on the east side of the Marble Canyon stock on the topographic map of the Van Horn quadrangle, which was surveyed in 1904 and 1905, but only a little surface stripping was done during this period, and very little marble was taken out (Richardson, 1914, p. 9). In the winter and spring of 1961 and 1962 this deposit was being reopened and prospected by the Texas Construction Materials Co. of Houston, Tex., with plans for production of dimension stone and for use of broken material in terrazzo tile. The brucite which occurs in many of the marbles is a possible source of metallic magnesium, but it is intermixed with the carbonate minerals of the marble.

NITRATE AND TURQUOISE

A few very minor mineral deposits have been recorded in the Sierra Diablo region. Nitrate has been prospected on an overhanging cliff of Van Horn Sandstone, 7 miles northwest of Van Horn (sec. 24, Block 67, Twp. 8), but it is a superficial coating produced from disintegration of bat guano (Mansfield and Boardman, 1932, p. 66–68). Thin films of turquoise were reported by Richardson (1914, p. 9) in some of the copper prospects in the Carrizo Mountain Formation of the Carrizo Mountains west of Van Horn, but probably in very small amounts, as none was observed there during the present investigation.

GROUND WATER

In the Sierra Diablo region, ground water has been explored by drilling from the time of the first American settlements to the present, but with results which have varied according to the geologic conditions at different localities. Geologic conditions which govern accumulation of ground water in the region have been summarized by Richardson (1914, p. 9). Richardson (1914; 1904, p. 89–95) and Baker (1935b, p. 373–380) have reported on the earlier results of drilling for water. Later results of drilling have been investigated by the Texas Board of Water Engineers, in cooperation with the U.S. Geological Survey, and have been reported on in part (Broadhurst and others, 1951, p. 37, 97; Hood and Scalapino, 1951; Follett, 1954, p. 6–15).

The principal source of ground water in the region is the unconsolidated deposits of Cenozoic age in the intermontane basins, especially in the Salt Basin and to a lesser extent in Eagle Flat. Water in the Salt Basin varies widely in quality, as illustrated by two analyses published by Richardson (1914, p. 9), one from Van Horn, the other from the Figure Two Ranch which contain, respectively, 425 and 2,366 parts per million of dissolved solids.

The analysis of water from Van Horn is representative of that in the southern part of the Salt Basin, where alluvial slopes extend out from the mountains on either side to a central axis, along which Wildhorse Creek drains northward. Water was discovered at Van Horn shortly after construction of the Texas and Pacific Railway, and has proved to be of the best quality of any along the line west of the Pecos River. It is obtained from unconsolidated deposits at a depth of about 600 feet in several wells drilled by the railroad and by the town of Van Horn; the municipal wells yield 100,000 gallons per day (Broadhurst and others, 1951, p. 37).

Since World War II, ground water in the southern part of the Salt Basin has been further exploited by drilling in the Lobo Flats district about 12 miles south of Van Horn and in the Wildhorse Valley district about 8 miles northeast of Van Horn (each a little beyond the edge of the map area, pl. 1). In both districts a dozen or more wells supply sufficient water to irrigate areas of more than 10 square miles (Hood and Scalapino, 1951; Leonard A. Wood, written commun., 1959); a few square miles are also irrigated by wells on the east side of the Salt Basin 5 miles northeast of the northeast corner of the Baylor Mountains. Wells in the Wildhorse Valley district yield 800 to 1,200 gallons per minute from unconsolidated deposits at depths of 200 to 600 feet. The most productive areas are seemingly nearest Wildhorse Creek, and wells several miles on each side of it have yielded insufficient water for practical irrigation. Two wells in the southern part of the district (sec. 19, Block 63) were drilled into limestone bedrock when they failed to obtain water in the unconsolidated deposits; one of these is reported to have yielded 350 gallons per minute at 1,000 feet and 400 gallons per minute at 1,500 feet.

Ground water at Van Horn, in the Lobo Flats district, in the Wildhorse Valley district, and elsewhere in the southern part of the Salt Basin is evidently derived from water moving northward through the unconsolidated deposits in a manner comparable to the surface drainage of Wildhorse Creek and its tributaries. These streams drain extensive areas in the high relatively well watered Davis Mountains (fig. 1). These mountains evidently provide a large recharge area, so that ground water in the southern part of the Salt Basin is probably capable of continued exploitation.

The analysis of water from the Figure Two Ranch, mentioned above, is representative of that in the main part of the Salt Basin, where alluvial slopes extend only a few miles out from the mountains on each side, with a nearly level alkaline floor 5 miles or more wide between them. On the floor, ground water is reached at a depth of 30 feet of less, and is taken out by ranch wells for watering stock. As indicated by the analysis, it is of poor quality, all of it being so saline or gypseous that it would be valueless for irrigation purposes. It is unlikely that water of better quality could be discovered in the unconsolidated deposits at any depth in the main part of the Salt Basin, for this has been an area of concentration of mineral salts throughout the history of the basin as a topographic feature.

The unconsolidated deposits of Eagle Flat, the intermontane basin south of the Sierra Diablo, have been less extensively drilled for water than the Salt Basin. Besides scattered ranch wells, wells about 1,000 feet deep have obtained water at Hot Wells and Torbert on the line of the Southern Pacific railroad in the southern part of the report area (pl. 1), and at the town of Sierra Blanca west of the report area (Baker, 1935b, p. 374–375). The wells at Sierra Blanca yield 36,000 gallons of water per day which contains 1,655 ppm of dissolved solids (Broadhurst and others, 1951, p. 97); hence, the yield is smaller and of poorer quality than at Van Horn. As noted by Baker (op. cit.) ground water at Hot Wells and Torbert stands less than 100 feet higher than at Van Horn, suggesting that the ground water, like the surface water, drains from Eagle Flat into the Salt Basin. Reserves of water in Eagle Flat are probably much less than those in the Salt Basin, as the drainage area tributary to it is smaller and is largely country with scanty rainfall. Along the northern border of Eagle Flat, in the southern foothills of the Sierra Diablo, where Precambrian rocks lie near the surface, ranch wells obtain small supplies of water from the overlying unconsolidated deposits; some of the earlier of these wells were noted by Richardson (1914, p. 9).

The mountain areas, including the large Sierra Diablo and the smaller Baylor Mountains and Beach Mountain, are formed largely of various formations of carbonate rock, which are less likely to contain accumulations of ground water than the surrounding unconsolidated deposits. A few successful wells have been drilled, mainly in the alluvium of the valleys, but many others have proved to be dry. One of the deeper unsuccessful wells, drilled at the Slaughter Ranch in the northern part of the Sierra Diablo, is reported to have been sunk to a depth of more than a thousand feet in Permian carbonate rocks. In the Sierra Diablo and the other mountain areas the chief supplies of water will probably continue to be from artificial surface reservoirs (locally termed "tanks"), many of which have been constructed, as shown on the topographic base map (pls. 1, 9).

OIL AND GAS

Possibilities for accumulations of oil or gas in the Sierra Diablo region appear to be remote.

Possibilities are least likely in the southern half of the region, south of the Victorio flexure. Here, Precambrian and Precambrian(?) rocks lie either at the surface or within a thousand feet of the surface (pls. 15, 16). Moreover, in much of this part of the region Permian Hueco Limestone rests directly on Precambrian and Precambrian(?) rocks, with the earlier Paleozoic sequence removed by pre-Hueco erosion.

Possibilities are somewhat greater north of the Victorio flexure, as the Precambrian and Precambrian(?) rocks lie at greater depth beneath the surface, and as both the Permian and pre-Permian Paleozoic sequences are more completely preserved (pls. 15, 16). Two wells have been drilled in this structural situation about 10 miles north of the northwest corner of the report area to depths of 4,518 and 4,794 feet (A. R. Jones, 1 E. W. Mowry in sec. 36, Block 70, Twp. 2; General Crude Oil, 1 Merrill & Voyles in sec. 8, Block 69, Twp. 2) (Haigh and others, 1953, p. 78–81), both of which passed through a complete sequence of Paleozoic formations beneath the Permian, but apparently without showings of oil or gas.

Possibilities are greatest northeast and east of the Sierra Diablo region, within the former Delaware basin area, where both Permian and Pennsylvanian strata attain great thickness, as shown by both surface exposures and drill records (King, P. B., 1948, p. 12–13). In the Apache Mountains east of the Sierra Diablo, several wells have drilled through these strata into lower Paleozoic formations, including the Middle Ordovician Simpson Group (Maley, 1945; M. E. Upson, in DeFord and others, 1951, p. 50–52). This group is productive of oil in the West Texas basin farther east, but is missing in most parts of the Sierra Diablo region on the west. In the Salt Basin, between the Apache Mountains and the Baylor Mountains (sec. 5, Block 86) the West & Armour, 1 Davis Investment et al. test was completed in 1960 at a depth of 8,201 feet, but reports are conflicting as to the rocks penetrated—whether the well entered "Ellenburger(?)," that is, El Paso Limestone, at total depth (Horak and others, 1961, p. 834), or whether it failed to reach the base of the Permian. It is not known whether showings of oil or gas were found in this well.

DESCRIPTIONS OF STRATIGRAPHIC SECTIONS AND FOSSIL COLLECTIONS

STRATIGRAPHIC SECTIONS AND FOSSIL COLLECTIONS OF ORDOVICIAN, SILURIAN, AND DEVONIAN ROCKS

SECTION 1. SIXMILE MOUNTAIN

The following is a section of the basal part of the El Paso Limestone and of the Bliss Sandstone, at the south end of Beach Mountain, on the west side of Sixmile Mountain (with BM 5315 at top), near SW cor. sec. 10, Block 66, Twp. 8. The section was measured by P. B. King and J. Brookes Knight in 1931; fossils were observed in the field but were not collected.

Top of mountain; no higher beds exposed.

El Paso Limestone:

Division B:	Feet
19. Limestone, granular; possibly slightly sandy, but not mottled; in 1- to 4-in. beds; contains small chert masses. Forms a great cliff, the full height of which was not ascended. Estimated thickness	250
18. Limestone, buff, sandy, thin-bedded; thinly laminated in some beds; gastropod imprints observed	28
17. Sandstone, buff, friable	1
16. Limestone, buff, sandy; in 6-in to 1-ft beds; contains lenses of nonsandy limestone	45
Division A:	
15. Sandstone, coarse-grained, calcareous, white; weathers gray; forms massive ledge	21
14. Sandstone, calcareous, thin-bedded; forms a slope	32
13. Limestone, brown, sandy	26
12. Sandstone, fine-grained, calcareous, buff to white; top bed glauconitic. Cystid stems abundant in lower part. Mostly forms thin ledges, but locally projects in a cliff	31
11. Limestone, brown, sandy; in 1-ft beds, weathers pitted	24
10. Sandstone, fine-grained, white; in 6-in to 3-ft beds; mostly thinly laminated, but crossbedded in part. Forms prominent rounded ledges	36
9. Sandstone, somewhat calcareous, brown; with widely spaced laminae. Five feet above base of unit is a layer of brown sandy thin-bedded limestone, partly nodular and mottled, whose base is crowded with gastropod casts	36

Disconformity.

Bliss Sandstone:	Feet
8. Sandstone, brown; in 1- to 3-in. beds; with partings of sandy marl or marly shale, the upper of which are greenish. Sandstone beds contain *Scolithus;* an open-coiled euomphalid gastropod and various trails observed on bedding surfaces	55
7. Sandstone, fine-grained to gritty; in 6-in. beds; parts crossbedded, other parts containing *Scolithus;* forms ledges	7
6. Sandstone, brown, marly	1
5. Sandstone, fine-grained to gritty; in 1- to 2-ft beds; thinly laminated to thinly crossbedded, with abundant *Scolithus* in upper part; forms ledges	16
4. Sandstone, gray to brown, coarse-grained to conglomeratic; contains quartz pebbles	2
3. Covered	7
2. Sandstone, gritty, laminated to crossbedded; with thin seams of quartz pebbles; mainly gray but partly pink, due to content of red detritus derived from Van Horn sandstone	26
1. Conglomerate, gray; composed of rounded quartz and chert pebbles in a coarse poorly sorted sand matrix	.5

Angular unconformity.

Van Horn Sandstone at base of section.

Summary of section 1

El Paso Limestone:		
Part of division B exposed	324	
Division A	206	
Part of El Paso Limestone exposed		530
Bliss Sandstone		114.5

SECTION 2. YATES RANCH

The following is a section of the basal part of the El Paso Limestone and of the Bliss Sandstone on the west side of Beach Mountain, on a spur half a mile east of Yates Ranch, near SW cor. sec. 3, Block 66, Twp. 8. The section was measured by J. Brookes Knight and Josiah Bridge in 1938; fossils were observed in the field but not collected.

Summit of spur; higher beds not measured.

El Paso Limestone:

Division B:	Feet
34. Dolomite	15
33. Limestone, dolomitic; contains poorly preserved fossils; forms a ledge	4
32. Limestone, dolomitic, thin-bedded; forms a slope	23
Division A:	
31. Sandstone, dolomitic; forms a massive ledge	7
30. Marl, sandy, yellow; forms a slope	5
29. Sandstone, dolomitic; forms a massive ledge	27
28. Dolomite, yellow; contains poorly preserved gastropods and cephalopods; forms ledges	27
27. Limestone, dolomitic, yellow; contains silicified gastropods; forms a ledge	4
26. Limestone, mottled, dolomitic, yellow	7

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	Feet
El Paso Limestone—Continued	
Division A—Continued	
25. Limestone, mottled gray; forms thin ledges. Bedding surfaces covered with brown dolomitic fucoidal markings; contains gastropods and cephalopods	45
24. Limestone, marly, dolomitic; forms a slope	7
23. Sandstone, calcareous; forms a ledge	2
22. Sandstone, marly; forms a slope	4
21. Sandstone, dolomitic, light-gray, massive; forms a prominent ledge. Fucoidal markings abundant near base and faint *Scolithus*? tubes occur near top	45
20. Limestone, sandy, marly, dolomitic; forms a slope	12
19. Limestone, sandy, dolomitic; forms a ledge	3
18. Sandstone, marly	10
17. Sandstone; contains *Lytospira;* forms a ledge	3
16. Marl; forms a slope	7
15. Sandstone, dolomitic; forms a ledge	2
14. Sandstone, dolomitic, marly; forms a slope	12
13. Sandstone; contains poorly preserved fossils; forms a ledge	1
12. Mainly covered on slope; a few ledges and much float of coarse brownish-red sandstone	14
Disconformity.	
Bliss Sandstone:	
11. Sandstone, coarse, reddish, thin-bedded; contains rare *Scolithus,* as well as *Lytospira* and linguloid brachiopods near top	31
10. Sandstone, coarse, reddish; contains abundant *Scolithus;* forms prominent ledges	15
9. Sandstone, with many conglomerate layers	15
8. Sandstone	3
7. Conglomerate	20
6. Sandstone	20
5. Conglomerate	1
4. Sandstone, thin-bedded; contains rare *Scolithus*	11
3. Conglomerate	2
2. Sandstone, thin-bedded; contains rare *Scolithus*	12
1. Conglomerate, coarser than any rocks above	1
Angular unconformity.	
Van Horn Sandstone at base of section.	

Summary of section 2

El Paso Limestone:	
Part of division B exposed	42
Division A	244
Part of El Paso Limestone exposed	286
Bliss Sandstone	113

SECTION 3. DALLAS MINE

The following is a section of the basal part of the El Paso Limestone and of the Bliss Sandstone, on the northwest side of Beach Mountain, on the slope east of Tumbledown Mountain above the abandoned Dallas mine, near the center of the western part of section 28, Block 66, Twp. 7. The section was measured in 1936 by J. Brookes Knight and reviewed in 1938 in company with Josiah Bridge. Fossil identifications are by P. E. Cloud, Jr., and Josiah Bridge (written commun., 1954). (See also Cloud and Barnes, 1948, p. 67–68.)

	Feet
El Paso Limestone:	
Division A:	
6. Dolomite; forms ledges; continues up the slope of mountain	(?)
5. Sandstone, coarse, pinkish, somewhat dolomitic; in part crossbedded. Contains faint markings on bedding surfaces	36
4. Limestone, brownish, slightly sandy, dolomitic; in 1- to 2-ft beds; interbedded with marl	75
3. Sandstone, pink, dolomitic; forms a massive ledge. *Piloceras* observed at top, and elsewhere worm borings and fucoidal markings	18
Disconformity.	
Bliss Sandstone:	
2. Sandstone, light-brown to red-purple; in 3-in. to 2-ft beds; with thin shaly partings, containing abundant *Scolithus* and obscure fucoidal markings. A fragment of *Clarkoceras, Lytospira* sp., *Ophileta* sp., *Helicotoma* cf. *H. uniangulata* (Hall), gastropod cross sections, and archaeostracan crustaceans were collected 5–8 ft below top (TF 437; Oe 4, USGS 2751; X 3, USGS 3589); *Hystricursus*? sp. and *Lytospira gyrocera* from same general level (B 173); *Lingulepis* sp. and gastropod cross sections 27 ft below top (TF 438)	88
1. Sandstone, quartzitic, with rare *Scolithus.* Some beds are red, because of content of detritus derived from Van Horn	17
Angular unconformity.	
Van Horn Sandstone at base of section. A short distance to the southwest the Bliss overlaps the Dallas fault and lies on Allamoore Formation beyond it.	

Summary of section 3

El Paso Limestone:	
Part of division A exposed	129
Bliss Sandstone	105

SECTION 4. NORTH SIDE OF BEACH MOUNTAIN

The following is a section of Montoya Dolomite, El Paso Limestone, and Bliss Sandstone on the north side of Beach Mountain, on a blunt spur projecting north-northwest from elevation point 5,590, in the east half of sec. 22, Block 66, Twp. 7. This section was originally measured by King in 1931. It was measured again in 1936 by Knight, who revisited it with Josiah Bridge in 1938, when further collections and observations were made. The section of El Paso Limestone and Bliss Sandstone was remeasured in great detail by P. E. Cloud, Jr., and V. E. Barnes in 1944 and 1945 (Cloud and Barnes, 1946, p. 352–361).

In the text given here, description of the Montoya Dolomite is from Knight's section, and descriptions of the El Paso Limestone and Bliss Sandstone are abridged from the published section of Cloud and Barnes; however, lists of fossils collected by Knight, Bridge, and others are added at the appropriate places. Unit numbers for the El Paso and Bliss are the same as those in the published section of Cloud and Barnes, which were given in descending order, or the reverse of the usual arrangement. The Bliss Sandstone is further illustrated by section 4a, by Knight, measured at nearly the same place as the main section, and by section 4b, by King, measured about half a mile to the southwest, in the southwestern part of sec. 22, on the opposite, or upthrown side of a fault. Fossil identifications are by P. E. Cloud, Jr., but they include some earlier determinations by Josiah Bridge (written commun., 1954).

Top of mountain; no higher beds exposed.

Montoya Dolomite:

Aleman(?) Cherty Member or Fusselman(?) Dolomite: *Feet*

8. Dolomite, light-gray, unfossiliferous; without chert; forms upper cliff on mountain. This unit might be Fusselman Dolomite rather than Montoya, but until fossil evidence for such an assignment is available, it is retained in the Montoya — 110

Aleman Cherty Member:

7. Dolomite, thin-bedded, purplish-pink to light-gray; without chert; forms a slope between cliffs above and below. *Dinorthis* (*Plaesiomys*) large n. sp. collected (Om 1, USGS 2761) — 28
6. Limestone, dolomitic, hackly, light-gray to pink; without chert — 25
5. Limestone, dolomitic, massive, pinkish-gray; with chert bands — 25
4. Limestone, dolomitic, massive, pinkish-gray; without chert. Poorly preserved corals and brachiopods observed — 58
3. Limestone, dolomitic, gray to slightly pink, very cherty; parts very thin bedded — 40

Upham Member:

2. Limestone, dolomitic, light-gray to slightly pink; forms massive 3- to 7-ft beds that stand in a cliff. Contains a few dolomitized poorly preserved brachiopods, including *Lepidocyclus* — 95

Cable Canyon(?) Sandstone Member:

1. Sandstone, massive, pinkish, saccharoidal, dolomitic. Forms a cliff and breaks off in huge blocks. A few poorly preserved cup corals observed — 35

Disconformity.

El Paso Limestone:

Division C:

1. Dolomite and limestone, earthy, nodular, brownish-gray; with interbedded 4- to 14-in. layers of compact dolomite; forms a gently sloping bench between the ledges and cliffs above and below. Small *Maclurites*, poorly preserved high-spired gastropods, sponges, and a probable *Buttsoceras* collected 7-12 ft above base (TF 327; Oe 14, USGS 2760) — 50

El Paso Limestone—Continued

Division B: *Feet*

2. Dolomite, fine-grained, brown to grayish-brown; in 1-in to 3-ft beds; some interbedded shaly dolomite; mostly forms steep slopes and ledges; some small chert nodules in lower part, and minor chert and siliceous masses elsewhere. *Ceratopea* sp., *Hormotoma* sp., and large gastropods collected 45 ft above base (TF 441); *Lophonema* sp. and longicone siphuncles 85 ft above base (Oe 12, USGS 2758); *Ceratopea ankylosa* Cullison 142–144 ft above base (TF 326); *Lophonema?* sp., *Hormotoma* spp., *Ceratopea* aff. *C. anklosa* Cullison, and *C.* spp.? near top (Oe 13). *Ceratopea* and *Hormotoma* observed elsewhere — 160
3. Covered on bench; probably argillaceous dolomite — 20
4. Dolomite, fine-grained, grayish-brown to brown; well bedded, but forming thick ledges; a thin intraformational conglomerate 51 ft above base, a few layers of chert nodules. Dolomite is markedly sandy in lower 48 ft. Two genera of high-spired gastropods collected 48 ft above base (TF 439). *Ceratopea* observed 85 ft above base — 101
5. Dolomite; similar to overlying beds, but with sand only in a thin layer 12 ft above base. Contains some chert nodules. *Hormotoma* and other small gastropods observed — 24
6. Dolomite; coarser grained than beds above or below; light-pink to brownish — 2.5
7. Dolomite; like beds above, except in lower 8 ft, which is fine grained, grayish brown; yields a weak petroliferous odor when broken. Some beds contain chert, in part oolitic; others contain scattered sand grains. A siphuncle of a probable *Mcqueenoceras* observed 12 ft above base; *Hormotoma* sp. and another siphuncle 37 ft above base — 184.5
8. Dolomite, very fine grained, grayish-brown; irregularly bedded in layers as much as 3 ft thick; forms lower part of a prominent bluff. Chert lenses in lower part and minor chert elsewhere. Dolomite contains abundant sand grains in lower 3 ft — 53
9. Dolomite, mostly very fine grained, gray to brownish-gray; irregularly bedded in layers as much as 3 ft thick; considerably less cherty than beds beneath. *Ceratopea tennesseensis* Oder and piloceratid siphuncles collected 80 ft above base (TF 436); *Ceratopea* cf. *C. tennesseensis* Oder and *C.* cf. *C. keithi* Ulrich 95 ft above base (TF 324); *C.* cf. C. *tennesseensis* Oder, *C.*, sp., and an endoceratid siphuncle 118 ft above base (TF 325); and from several beds in about the

El Paso Limestone—Continued

Division B—Continued — *Feet*

same part of the section *Ceratopea* aff. *C. tennesseensis* Oder and *C. jenkinensis* Cullison, and *C.* spp. (Oe 11, USGS 2757) — 120

10. Dolomite, very fine grained to dense, gray to brownish-gray; irregularly bedded in layers as much as 3 ft thick. Chert forms abundant nodules and masses in lower half, and some beds higher up. A siphuncle of *Mcqueenoceras* type and a large *Ceratopea* observed 9 ft above base; *Calathium, Ceratopea*, sp., a *Mcqueenoceras* siphuncle, and another endoceratid siphuncle collected 18 ft above base (TF 322); *Callathium* sp., *Helicotoma*? sp., a small gastropod, *Mcqueenoceras* sp., and a piloceratid? siphuncle from same general level (Oe 10, USGS 2756); *Calathium*, a *Ceratopea*, gastropods, and a fragment of a cephalopod from chert at top (TF 323) — 85
11. Dolomite, fine-grained, brownish, yellowish, or pinkish, thin-bedded; in 1- to 20-in. beds; interbedded with dolomitic and argillaceous limestone in upper 18 ft; forms benches. Some chert lenses in lower part and a thin bed of cherty sandstone near middle. *Archaeoscyphia* cf. *A. annulata* Cullison, and a fragment of a probable *Pynoceras* collected 18–20 ft above base (TF 320); *Archaeorthis costellata* Ulrich and Cooper and cystid plates at top (TF 321; Oe 9, USGS 2755). *Hormotoma, Ceratopea*, siphuncles of brevicone cephalopods, *Archaeorthis, Finkelnburgia*, and *Calathium* were observed at various other levels — 50
12. Dolomite, fine- to medium-grained, vuggy; calcitic in upper part; yellowish gray to light gray; in 1- to 30-in. beds; some scattered sand grains in lower part. *Xenelasma syntrophiodes* Ulrich and Cooper, a sponge, *Hormotoma* sp., and *Polhemia*? collected 4–6 ft above base (TF 319); *Calathium* sp., *Hormotoma* sp., *Ceratopea* sp., and *Mcqueenoceras* sp. at about the same level (Oe 8, USGS 2754). *Orospira*? and *Hormotoma* were also observed — 13

Division A:

13. Sandstone, dolomitic, fine- to medium-grained; quartz grains well-rounded, some feldspar grains — 4
14. Dolomite, moderately sandy, very fine grained, gray; in 1-in. to 2-ft beds; quartz grains well rounded and frosted. *Polhemia*, small brevicone cephalopods, and syntrophioid brachiopods like *Diaphelasma* observed 3 ft above base — 8
15. Dolomite, sandy and shaly; dolomitic sandstone; yellowish to brownish gray, with a greenish shaly layer at top. Gastropods suggesting *Euconia* and *Polhemia* observed near middle — 11

El Paso Limestone—Continued

Division A—Continued — *Feet*

16. Sandstone, dolomitic, yellowish to pinkish, medium- to fine-grained, crossbedded; in beds as much as 5 ft thick; forms a prominent persistent ledge. Some feldspar grains — 29
17. Siltstone, dolomitic; interbedded with fine to coarse sandstone; yellowish to pinkish; in beds as much as 4.5 ft thick; forms a ledge. Some glauconite at base — 21
18. Dolomite, silty and sandy, fine-grained, yellowish- to brownish-gray; weathers earthy — 15
19. Dolomite, partly calcitic, very fine grained, yellowish- to brownish-gray; in 1-in. to 4-ft beds; forms a prominent ledge in lower part. Some glauconite in middle. Cystid plates and columnals observed 29 ft above base — 40
20. Limestone, dolomitic, fine-grained, gray to yellowish-gray; in 1-in to 1-ft beds. Contains abundant chert in lower 3 ft. A sponge like *Archaeoscyphia, Diaphelasma, Allopiloceras* sp., and a trilobite were collected 12 ft above base (TF 318) — 17
21. Limestone, fine-grained, gray, nodular; interbedded with calcareous shale — 6
22. Limestone, medium- to fine-grained, gray; with dolomitic streaks; weathers to thin beds; abundant glauconite in lower part. Piloceratid siphuncles abundant in lower 3 ft. *Lytospira*, "*Euconia*," *Ophileta* (*Ozarkispira*) cf. *O. rotuliformis* (Meek), *Diaphelasma* cf. *D. Oklahomense* Ulrich and Cooper, and other brachiopods collected 2 ft above base (TF 315; Oe 7, part; B 39, USGS 3590); *Ophileta* (*Ozarkispira*) *rotuliformis* Meek, *Lytospira*? *Hormotoma* small sp., *Bucanella* sp., *Euconia* sp., *Pelagiella*? sp., *Holopea*-like gastropod, a raphistomoid gastropod. *Endocycloceras* sp., and *Hystricurus* sp. from 9 ft above base (Oe 7, USGS 2753; C 39, USGS 3591); *Diaphelasma oklahomense* Ulrich and Cooper, *Syntrophina* sp., *Ophileta* (*Ozarkispira*) cf. *O. rotuliformis* (Meek), *Ophileta* sp., *Hormotoma* sp., a raphistomoid gastropod, and a small cyrtendoceratid cephalopod from higher up (TF 317) — 16
23. Dolomite, fine-grained, brownish-gray; in beds a few inches thick; interbedded with gray limestone. *Clarkella* sp., *Syntrophina* sp., *Ophileta* (*Ozarkispira*) cf. *O. rotuliformis* (Meek), and *Homotoma* sp. were collected 9–11 ft above base (TF 433), and poorly preserved *Rhombella*? *and Lecanospira*? were observed at the same level. Cystid plates, *Tetralobula* sp., *Ozarkispira* sp., *Lytospira*? *Piloceras* sp., *Allopiloceras* sp., and *Kirkoceras*? were collected 15–17 ft above base (TF 434) — 26

El Paso Limestone—Continued

Division A—Continued *Feet*

24. Sandstone, dolomitic, medium- to coarse-grained, crossbedded, yellowish-gray to pink; forms a prominent ledge ---------- 9
25. Siltstone, and very fine grained dolomitic sandstone ---------- 12
26. Dolomite, silty and sandy; interbedded with siltstone, sandstone, and green shale; forms a light-colored slope. At base is a 4- to 10-in. bed of reddish sandy dolomite, containing rounded pebbles and cobbles of sandstone, the largest 10 in. in diameter. Lies with abrupt contact on Bliss Sandstone -- 38

Disconformity.

Bliss Sandstone:

27. Sandstone, fine- to coarse-grained; contains pebbly layers in lower half; pinkish or yellowish; friable to quartzitic, slightly calcareous throughout; in 1-in. to 2-ft beds. Is interbedded with argillaceous sandstone and shale, the latter of greenish or purplish color. The well-indurated sandstone layers contain vertical *Scolithus* tubes. *Lingulepis*, *Lingulella*, a possible *Lytospira*, and archaeostracan crustaceans were colcollected 98–105 ft above base (TF 432); many beds show impressions or molds of various unidentified gastropods ---------- 125

Angular unconformity.

Van Horn Sandstone at base of section.

Section 4a

[Section of Bliss Sandstone measured at approximately the same place as lower part of preceding, by J. Brookes Knight, 1936]

El Paso Limestone:

Division A:

4. Sandstone, fine-grained, friable, dolomitic; with obscure winding tubules on bedding; forms a ledge ---------- 10

Disconformity.

Bliss Sandstone:

Calcareous division:

3. Sandstone; a little more massive and dolomitic than beds below, with finer grained sand; gray to yellow; no *Scolithus* ---------- 28

Main body of formation:

2. Sandstone; forms ledges on slope. Some layers, which are more quartzitic than remainder, contain *Scolithus;* others are crossbedded. Between the sandstone layers are partings of soft marly sandstone. Sandstones and marls are light gray, brown, and purplish red; some marls are green ---------- 72
1. Sandstone, pebbly and gritty, gray to reddish-brown, crossbedded. At base is a quartz-pebble conglomerate which lies with sharp contact on Van Horn Sandstone ---------- 22

Angular unconformity.

Van Horn Sandstone at base of section.

Section 4b

[Section of Bliss Sandstone measured about half a mile southwest of preceding section on opposite, or upthrown side, of a fault, by P. B. King, 1931]

El Paso Limestone:

Division A: *Feet*

7. Sandstone, friable; with partings of greenish marly shale; becomes calcareous 10–15 ft above base ---------- 30

Disconformity.

Bliss Sandstone:

Calcareous division:

6. Sandstone, quartzitic, brown, thinly laminated; forms a ledge ---------- 2
5. Sandstone, friable, buff; in 1-ft beds; full of calcareous tubular structures ---------- 13
4. Limestone, buff, sandy ---------- 5

Main body of formation:

3. Sandstone, gray, friable; in 1- to 3-in. beds; all contain *Scolithus* ---------- 37
2. Sandstone, less resistant than beds above or below ---------- 26
1. Sandstone gritty, quartzitic; weathers brown; brown; crossbedded on a small scale. Contains seams of rounded quartz pebbles as much as half an inch in diameter ---------- 10

Angular unconformity.

Van Horn Sandstone at base of section.

Summary of section 4

Montoya Dolomite:		
Aleman(?) Cherty Member or Fusselman limestone(?)	110	
Aleman Cherty Member	177	
Upham Member	95	
Cable Canyon(?) Sandstone Member	35	
Total Montoya Dolomite		417
El Paso Limestone:		
Division C	50	
Division B	813	
Division A	252	
Total El Paso Limestone		1,115
Bliss Sandstone:		
Main section	125	
Section 4a	125	
Section 4b	93	

SECTION 5. UNCONFORMITY LOCALITY

The following is a section of the basal part of the El Paso Limestone and of the Bliss Sandstone in the southern part of Baylor Mountains, on a prominent bluff that faces into a reentrant valley north of Sulphur Creek, near the middle of the south line of sec. 22, Block 65, Twp. 7. This bluff is prominently in view from Texas Highway 54 to the south and is illustrated in figure 5*A*. The bluff of El Paso and Bliss is overlapped on the west by the Hueco Limestone, whose base stands several hundred feet lower, and which contains talus blocks derived from unit 8 and other resistant beds of the Ordovician sequence; the place was hence referred to during the field investigation as the "unconformity locality," and that title is retained here. The section was measured by J. Brookes Knight in 1936; fossil identifications are by P. E. Cloud, Jr., (written commun., 1954).

Top of section; higher beds of El Paso Limestone occur to northeast, but the whole Ordovician sequence is overlapped on the west by Hueco Limestone.

El Paso Limestone:

Division A: *Feet*

14. Limestone, dolomitic — (?)
13. Sandstone, crossbedded, light-brown to pink, dolomitic; forms a ledge — 12.5
12. Limestone, marly and sandy, mottled, light-gray — 25
11. Limestone, dolomitic; interbedded with marly layers; contains poorly preserved gastropods — 22
10. Not exposed in line of section; to east is yellow sandy limestone, slightly mottled, containing poorly preserved *Ophileta*, with interbedded marl layers — 25
9. Limestone, dolomitic, slightly sandy; in 1-ft beds; contains *Piloceras* — 16
8. Limestone, dolomitic, slightly sandy, thin-bedded, dark-gray; weathers brown. *Piloceras* and other cephalopods collected (Oe 2). Forms top of a projecting promontory that overlooks valley to the south — 20

Disconformity.

Bliss Sandstone:

Calcareous division:

7. Sandstone, coarse, crossbedded; interbedded with finely sandy dolomitic limestone, and marl — 15
6. Limestone, dolomitic, finely sandy, yellowish-gray; in part with ramifying mottlings; interbedded with marl — 28

Main body of formation:

5. Sandstone, quartzitic; in 6-in to 1-ft beds; interbedded with softer more argillaceous sandstone and blue-green shaly sandstone. Many of the sandstone layers are crossbedded and ripple marked, and the quartzose layers contain *Scolithus*. *Lingulepis* n. sp. and *Lytospira*? collected from near base (Oe 1, USGS 2748; Oe 5, USGS 2765; Oe 6, USGS 2752) — 30
4. Sandstone, shaly, brown, white, and green; forms a slope. One thin bed contains *Scolithus* — 10
3. Sandstone, quartzitic, brown; in 1-ft beds; contains *Scolithus* — 20
2. Sandstone, quartzitic, red-brown, purplish, and white; forms somewhat thinner layers than beds above; interbedded with white and green marly sandstone. The quartzitic sandstone layers are crossbedded in part, contain *Scolithus*, and have fucoidal markings on bedding — 25
1. Sandstone, coarse, crossbedded, reddish to white; contains quartz pebbles in lower 3 ft. *Scolithus* occurs 4 ft above base, and in a few beds higher up. To east, basal beds contain rounded cobbles 3 in. across, mostly of vein quartz, but a few of schist and quartzite — 17

Angular unconformity.

Van Horn Sandstone at base of section.

Summary of section 5

	Feet	
El Paso Limestone:		
Part of division A exposed		120.5
Bliss Sandstone:		
Calcareous division	43	
Main body of formation	102	
Total Bliss Sandstone		145

SECTION 6. SOUTHEASTERN BAYLOR MOUNTAINS

The following is a section of Fusselman Dolomite, Montoya Dolomite, beds of Middle(?) Ordovician age, and the upper part of the El Paso Limestone on the southeast face of Baylor Mountains 1 mile south-southwest of the portal of Red Tank Canyon in the northwestern part of sec. 6, Block 122. A generalized section was measured in this vicinity by P. B. King and R. E. King in 1928, but the sequence was studied in more detail later by H. J. Howe (1959, p. 2312–2313, 2328), when two sections were measured about half a mile apart, termed "B–1 and B–2." The descriptions of the Montoya and Fusselman Dolomites given here are from Howe's section B–1 (1959, fig. 29, p. 2328); that of the beds of Middle(?) Ordovician age is from his section B–2 (written commun., 1959); some observations by P. B. King and R. E. King have been added. Fossil identifications are by H. J. Howe.

Hueco Limestone at top of section.

Angular unconformity.

Fusselman Dolomite: *Feet*

10. Dolomite, very fine grained, very light gray; weathers brownish orange and sugary. Massive, except for basal few feet, which is faintly laminated — 70

Disconformity(?).

Montoya Dolomite:

Aleman Cherty Member:

9. Dolomite, microgranular, faintly thinly laminated, brownish-gray; weathers light olive gray. About 40 percent of unit consists of elongated irregular white chert nodules that weather light brown — 18
8. Dolomite, very fine grained, thick-bedded to very thick bedded, light-gray; weathers brownish orange. Near top, contains *Hypsiptycha*, *Streptelasma*, and favositids; *Paleophyllum thomi* (Hall) zone is well developed lower down; near base, contains *Thaerodonta* and *Lepidosyclus* — 24
7. Dolomite, very fine grained, light-gray. About 15–20 percent of unit consists of chert nodules, elongated parallel to bedding — 15

Montoya Dolomite—Continued

Aleman Cherty Member—Continued *Feet*

6. Dolomite, very fine grained, thick-bedded to very thick bedded, light-gray; weathers brownish orange; contains sparse chert nodules. Horn corals are scattered throughout and *Lepidocyclus* was observed near top ---- 40
5. Dolomite, microgranular, homogeneous to faintly laminated, light-gray; about 30 percent of unit consists of light-gray elongated chert nodules ---- 20
4. Dolomite, microgranular, light-gray. "Key chert" horizon occurs at top; remaining part of unit consists of about 10 percent elongated chert nodules. "Key chert" contains *Lepidocyclus manniensis* (Foerste), *L. laddi* Wang, *L. capax* (Conrad), *L.* sp., *Onniella* sp.,*Thaerodonta* sp., *Plaesiomys bellistriatus* Wang., *Rhynchotrema* sp., *Austinella* sp., *Glyptorthis* sp., and fragments of other fossils ---- 30

Upham Member:

3. Dolomite, like unit 1; contains very common fossil fragments, and *Onniella* sp., *Thaerodonta* sp., *Lepidocyclus* sp., and *Glyptorthis* sp ---- 29
2. "Key chert," containing 15–20 percent small irregular chert nodules, arranged in closely spaced layers ---- 6
1. Dolomite, fine-grained to very fine grained, thick-bedded to very thick bedded, light-gray; weathers brownish orange. Contains *Receptaculites* and *Halysites*, nearly obliterated by dolomitization ---- 66

Cable Canyon(?) Sandstone Member:

h. Dolomite, sandy ---- 2

Disconformity.

Beds of Middle(?) Ordovician age:

g. Sandstone, fine-grained, brown; forms a ledge ---- 10
f. Shale and argillaceous dolomite ---- 17
e. Sandstone, dolomitic ---- 3
d. Shale and argillaceous dolomite ---- 26
c. Sandstone, fine-grained, brown; forms a ledge ---- 10

El Paso Limestone:

Division C:

b. Shale and argillaceous dolomite, probably equivalent to division C of geologic section 4 ---- 40

Division B:

a. Limestone, dolomitic, finely crystalline; weathers light gray and contains a few irregular chert masses; in beds a few feet thick; forms conspicuous ledges. Contains *Ceratopea* near top ---- 200

Similar strata below base of section, forming less conspicuous ledges, dipping more steeply and cut by closely spaced joints; one or more faults downthrown toward the southeast probably duplicate the sequence.

Summary of section 6

	Feet
Fusselman Dolomite	70
Montoya Dolomite:	
Aleman Cherty Member	147

Summary of section 6—Continued

	Feet
Montoya Dolomite—Continued	
Upham Member	101
Cable Canyon(?) Sandstone Member	2
Total Montoya Dolomite	250
Beds of Middle(?) Ordovician age	66
Part of El Paso Limestone exposed	240

SECTION 7. NORTHEASTERN BAYLOR MOUNTAINS

The following is a section of beds of Devonian age, Fusselman Dolomite, Montoya Dolomite, and beds of Middle(?) Ordovician age on the southeast spur of the high point of Baylor Mountains (BM 5568), a mile northeast of the portal of Red Tank Canyon, in the northwestern part of sec. 9, Block 65, Twp. 7. The section was measured by J. Brookes Knight in 1938, but notes made by Knight and the writer during earlier years have been incorporated. Fossils were not collected, but were observed during measurement of section.

Section 7a illustrates further features of the beds of Middle(?) Ordovician age and the upper part of the El Paso Limestone at a locality half a mile to the northeast, near the center of sec. 2, Block 65, Twp. 7; it was furnished through the courtesy of C. C. Branson (written commun. 1950), who measured it in 1947. Fossils noted in the section were identified by G. A. Cooper.

Hueco Limestone at top of section.

Angular unconformity.

Beds of Devonian age: *Feet*

14. Limstone, dolomitic, gray-brown, buff, or pink, thin-bedded or nodular; contains very abundant irregular nodules and lenses of black or brown chert; preserved beneath Hueco Limestone only on southwestern of two spurs of the mountain ---- 30–50

Disconformity(?).

Fusselman Dolomite:

13. Beds like those below, occurring on southwestern of two spurs of mountain; not preserved on northeastern spur where main part of section was measured. Approximate thickness ---- 25
12. Dolomite, fine-grained light-gray; weathers salmon gray and pitted; forms massive ledges several feet thick. A few beds are indistinctly mottled, and some in upper part are thin bedded and hackly. No chert or fossils observed ---- 275

Disconformity(?).

Montoya Dolomite:

Aleman Cherty Member:

11. Limestone, dolomitic, light-gray; contains thick chert lenses ---- 20
10. Limestone, dolomitic, light-gray, thin-bedded; contains sparse chert nodules and lenses. Poorly preserved *Lepidocyclus*, *"Orthis,"* and other brachiopods observed ---- 75

	Feet
Montoya Dolomite—Continued	
Aleman Cherty Member—Continued	
9. Limestone, dolomitic, gray, thin-bedded; contains abundant ramifying chert masses	28
8. Limestone, dolomitic, gray; contains moderately abundant chert nodules and lenses. Poorly preserved brachipods observed	55
7. Limestone, dolomitic, light-gray; in 6- to 18-in. beds; contains many silicified *Lepidocyclus*, *"Orthis,"* other brachiopods, and cup corals	50
6. Limestone, dolomitic, very cherty	10
Upham Member:	
5. Limestone, dolomitic, gray; thinner bedded than below	18
4. Limestone, dolomitic, very cherty; forms a ledge. Probably the same as lower "key chert" interval, unit 2 of section 6	3
3. Limestone, dolomitic, gray; in 3- to 5-ft beds; mottled, with mottlings projecting in relief on weathered surfaces. *Maclurites*, *Lepidocyclus*, *Favosites*, halysitid corals, cup corals, and *Receptaculites* observed. Base concealed on spur, but exposed in ravine to north	40
Cable Canyon (?) Sandstone Member:	
2. Sandstone, brown, crossbedded	7–25
Disconformity.	
Beds of Middle (?) Ordovician age:	
1. Limestone, earthy, yellow, pink, and brown; without sandstone beds; exposed in ravine north of spur	(?)
Base of section covered by alluvium.	

Section 7a

[Section of beds of Middle (?) Ordovician age and upper part of El Paso Limestone measured half a mile northeast of preceding section; by C. C. Branson, 1947]

	Feet
Montoya Dolomite at top of section, with a 2-ft bed of sandstone at base.	
Disconformity.	
Beds of Middle (?) Ordovician age:	
9. Dolomite, yellow, very sandy; contains frosted sand grains, with a green shale parting a little above base	8
8. Shale, green, with thin layers of buff fucoidal sandstone	4
7. Siltstone, fine-grained, buff, well-bedded; contains frosted sand grains	5
6. Sandstone, saccharoidal, crossbedded; white, with greenish areas	7
5. Sandstone, dolomitic, silty, yellow	18
4. Limestone, shaly and silty, platy, yellow	26
3. Sandstone, calcareous, nodular; contains frosted sand grains, also *Desmorthis*? and cystid plates	18
El Paso Limestone:	
Division C:	
2. Dolomite, calcitic, sandy, knotty, buff to yellow, sparsely fossilferous, poorly exposed	59
El Paso Limestone—Continued	
Division B:	
1. Dolomite, dense, slightly cherty and sandy, gray to pink; contains scattered frosted sand grains	50
Base of section covered by alluvium.	

Summary of section 7

Beds of Devonian age		30–50
Fusselman Dolomite		300
Montoya Dolomite:		
Aleman Cherty Member	238	
Upham Member	61	
Cable Canyon (?) Sandstone Member	7–25	
Total Montoya Dolomite		306–324
Beds of Middle (?) Ordovician age (in section 7a)		86
El Paso Limestone (in section 7a):		
Division C	59	
Part of division B exposed	50	
Part of El Paso Limestone exposed		109

SECTION 8. HAWKINS TANK

The following is a section of the basal part of the El Paso Limestone, and of the Bliss Sandstone and Van Horn Sandstone, in a group of hills between the northwest corner of the Baylor Mountains and Sierra Diablo scarp, west of Texas Highway 54. The section was measured on a conical butte half a mile southwest of Hawkins Tank, near the center of the north line of sec. 10, Block 54½, but some observations made on adjacent hills have been added. The section was measured by P. B. King in 1936; fossils were noted in field, but have not been formally identified.

	Feet
Top of butte; higher beds exposed in some of hills farther east, probably including parts of division B of El Paso Limestone, but could not be placed in sequence; many of hills are capped by Hueco Limestone, which oversteps all the earlier strata down to the Hazel Formation.	
El Paso Limestone:	
Division A:	
21. Limestone, sandy, marly, brown	7
20. Limestone, gray; forms ledges	4
19. Limestone, marly, brown; forms a slope	5
18. Limestone; forms thin ledges, with marl partings	12
17. Limestone, evenly layered, gray; in 6-in. beds; contains abundant silicified fossils, including *Piloceras*, *Ophileta*, *Lytospira*, *Hormotoma*, and possible sponges (Oe 3)	4
16. Limestone, nodular, marly; forms a slope	13
15. Limestone, forming a slope below and passing into prominent ledges above; lower part sandy, brown or gray-brown, thin bedded; upper part gray, in 1-ft beds, mottled or lumpy, containing spongy light-brown chert that forms networks of tubules on bedding, and nodules of compact bluish chert	28

	Feet
El Paso Limestone—Continued	
Division A—Continued	
14. Sandstone, fine-grained, calcareous, brown or buff; in 6-in to 1-ft beds; in part laminated, in part crossbedded; forms massive ledges	17
Disconformity.	
Bliss Sandstone:	
Calcareous division:	
13. Sandstone, finer grained than below; slightly calcareous, buff or brown; forms ledges a foot thick, separated by slopes	40
12. Sandstone, coarse, quartzose, slightly calcareous and glauconitic; weathers brown; in massive ledge	3
11. Sandstone, thin-bedded, soft, buff	6
10. Sandstone, coarse, quartzose, calcareous; weathers brown	3
Main body of formation:	
9. Sandstone, quartzitic, noncalcareous, gray; forms ledges	4
8. Sandstone, thin-bedded, friable, buff	13
7. Sandstone, quartzitic; in part crossbedded; weathers brown; in 1- to 3-ft beds with marly partings; forms ledges	10
6. Sandstone, thin-bedded, quartzose, apparently glauconitic	16
5. Sandstone, quartzitic, gray; weathers red brown; forms two groups of ledges; in part crossbedded and in part containing *Scolithus*	10
4. Sandstone, medium-grained, quartose, white or buff; mostly in beds a few inches thick, but with some 1-ft beds near middle. Beds contain dark laminae and many contain *Scolithus*	50
Angular unconformity.	
Van Horn Sandstone:	
3. Sandstone, coarse, arkosic, red-purple to maroon-red; in massive rounded 5- to 10-ft ledges, with scattered pebbles, and interbedded conglomerate layers made up of closely packed well-rounded pebbles and cobbles as much as 6 in. in diameter, of same composition as those in unit 1. Toward top, sandstone is irregularly decolorized to brown adjacent to joints. Thickness exposed, to base of slope	100
2. Poorly exposed across flat, toward hill to northwest; dip changes from less than 5° in unit above to 20° in unit below, and several faults may occur, but interval is probably small	(?)
1. Conglomerate, coarse; interbedded with friable coarse maroon-red sandstone. Conglomerate consists of closely packed well-rounded pebbles and cobbles of vein quartz, mafic volcanic rocks, chert, limestone, massive red rhyolite, and schistose lineated metarhyolite	50
Angular unconformity.	
Hazel Formation, fine-grained red sandstone at base of section.	

Summary of section 8

		Feet
El Paso Limestone:		
Part of division A exposed	90	
Part of El Paso Limestone exposed		90
Bliss Sandstone:		
Calcareous division	52	
Main body of formation	103	
Total Bliss Sandstone		159
Van Horn Sandstone		>150

SECTION 9. POINT OF MOUNTAINS

The following is a section of the Montoya Dolomite, and parts of the overlying Fusselman Dolomite and underlying El Paso Limestone, on a projecting salient of the Sierra Diablo escarpment 1½ miles northwest of Figure Two Ranch, on a ridge projecting northeast from a flat-topped butte capped by Hueco Limestone, near the center of the southern part of sec. 9, Block 66, Twp. 5. The section was measured by P. B. King in 1931; fossils were noted in the field, but have not been formally identified.

	Feet
Hueco Limestone at top of section.	
Angular unconformity (Barnett Shale and beds of Devonian age are preserved beneath the unconformity at nearby localities).	
Fusselman Dolomite:	
11. Dolomite, white to light-gray, finely crystalline; with veins, patches, and vugs of crystalline calcite. A poorly preserved favosite coral noted. Forms obscure massive beds, which dip steeply and stand in a wall-like ridge. Approximate preserved thickness	100–200
Disconformity (?).	
Montoya Dolomite:	
Aleman Cherty Member:	
10. Limestone, dolomitic; in 3- to 4-ft beds; weathers to drab gray jagged surfaces. Contains abundant nodules, knotted lenses, and long beds of light-gray to brown chert, weathering rusty. Brachiopods observed	38
9. Limestone, dolomitic; thinner bedded than below and above	30
8. Limestone, dolomitic; in 2- to 3-ft beds; weathers to dark gray jagged surfaces. Toward top, nodular layers of brown chert several inches thick are interbedded. Contains abundant brachiopods	21
7. Limestone, dolomitic; in 1- to 2-ft beds; weathers to dark gray jagged surfaces, with a few chert nodules. Contains abundant brachiopods, in part silicified, including *Lepidocyclus* and "*Orthis*"	21
Upham Member:	
6. Limestone, dolomitic, finely crystalline, dark-gray; in 2- to 3-ft beds containing knotted nodules and lenses of brown chert	20
5. Limestone, dolomitic; weathers jagged and pitted; forms a slope. Contains brachiopods and corals	11

	Feet
Montoya Dolomite—Continued	
Upham Member—Continued	
4. Limestone, dolomitic, finely crystalline, dark-gray; weathers to drab-gray pitted surfaces. Forms massive beds and prominent ledges, cut by vertical joints. Contains abundant corals, especially in upper part, including *Streptelasma* and halysitid corals	37
Cable Canyon (?) Sandstone Member:	
3. Sandstone, marly, thin-bedded, buff; bedded with thin quartzitic layers	30
2. Sandstone, saccharoidal, pale-brown; weathers dark brown; in thick beds breaking out in large blocks	25
Disconformity.	
El Paso Limestone:	
Division C:	
1. Limestone, marly, mottled, yellow; obscured in part by sandstone blocks from above. Exposed thickness about	10–15
Base of section cut off by fault; rocks of Devonian and Mississippian age on downthrown side to northeast.	

Summary of section 9

Part of Fusselman Dolomite exposed		100–200
Montoya Dolomite:		
Aleman Cherty Member	110	
Upham Member	68	
Cable Canyon (?) Sandstone Member	55	
Total Montoya Dolomite		233
Part of El Paso Limestone exposed		10–15

SECTION 10. APACHE SPRING

The following is a section of the Fusselman Dolomite and the upper part of the Montoya Dolomite on the ridges north of Apache Spring. The section is in two parts. Section 10a, of the Montoya Dolomite and the lower part of the Fusselman Dolomite, was measured on the ridge half a mile north of the spring, in the southeastern part of sec. 4, Block 66, Twp. 5. It is imperfectly tied by a cherty unit in the Fusselman Dolomite with the lower part of section 10b, which was measured on the ridge just northwest of the spring, in the northeastern part of sec. 7, Block 66, Twp. 5. The section was measured by J. Brookes Knight and Josiah Bridge in 1938; fossils were collected and identified in the field, but are not now available for reexamination.

Section 10b

	Feet
Hueco Limestone at top of section.	
Angular unconformity.	
Fusselman Dolomite:	
11. Dolomite, massive, without chert. *Stromatopora* observed near base	85
10. Limestone, forming ledges and cliffs. Contains silicified fossils near top, including *Favosites*, several species of cup corals, and *Stromatopora* (X 9)	60
9. Limestone, in part cherty; contains *Favosites* and cup corals (X 8)	37
8. Limestone, dolomitic; without chert	37
7. Limestone, somewhat dolomitic, medium-bedded; in part brecciated, with numerous chert masses. Contains brachiopods and the trilobite *Dalmanites* (X 7)	38
6. Limestone, massive; forms a coral reef. Corals include several species of *Favosites, Halysites,* and cup corals (X 6)	37
5. Limestone, dolomitic; contains brecciated chert, also *Favosites, Halysites,* and cup corals (X 5)	18
4. Dolomite, without chert	8
3. Limestone, dolomitic, very cherty; contains *Halysites* and other corals (X 4)	25
2. Dolomite, white; forms ledges	50
1. Dolomite, white; weathers light buff; without chert or fossils; forms prominent ledge in ravine at northeast base of spur	21
Base of section concealed by alluvium.	

Section 10a

Top of spur; higher beds not measured.	
Fusselman Dolomite:	
k. Dolomite; weathers to pitted surfaces; silicified along joints	6
j. Dolomite; not so massive as bed below. Walking of beds between sections 10b and 10a indicates that cherty units 3 and 5 of the former should lie in this unit about 30 ft above base	100
i. Dolomite, finely crystalline massive, light-gray; weathers to light-buff pitted surfaces	38
Disconformity (?).	
Montoya Dolomite:	
Aleman Cherty Member:	
h. Covered	6
g. Limestone, dolomitic; with abundant chert layers; forms ledges	14
f. Limestone, dolomitic; contains rounded chert nodules 2–3 in. in diameter; forms a slope	4
e. Limestone, dolomitic, very cherty; forms prominent ledges	22
d. Limestone, dolomitic; with sparse chert layers. At top, contains a branching colonial coral, *Lepidocyclus*, "*Orthis*," and other brachiopods	20
c. Limestone, dolomitic; silicified *Streptelasma* at base	21
b. Limestone, dolomitic, gray; without chert; forms ledges; contains poorly preserved silicified brachiopods	21
Upham Member:	
a. Limestone, dolomitic; contains some chert bands and nodules; forms a massive cliff at base of exposure	32
Base of section concealed by alluvium.	

Summary of section 10

Fusselman Dolomite:		
In section 10b	416	
In section 10a	144	
Approximate total Fusselman Dolomite in overlapping sections		420

Summary of section 10—Continued

	Feet
Montoya Dolomite:	
Aleman Cherty Member	108
Part of Upham Member exposed	32
Part of Montoya Dolomite exposed	140

ORDOVICIAN AND SILURIAN FOSSILS, NOT COLLECTED ALONG COURSES OF STRATIGRAPHIC SECTIONS

The following fossils were collected from Ordovician and Silurian rocks but not in any measured section:

X 1 and X 2 (*USGS 3594, 3595, 3596, and 3597*).—El Paso Limestone, lower part of division B. Inlier within the Sierra Diablo northeast of Cox Mountain; low hills between the two county roads, in northwestern part of sec. 14 and northeastern part of sec. 15, Block 54½. A sequence 340–400 ft thick is exposed, between sandstone beds at or near the top of division A on the southeast, and unconformably overlying Hueco Limestone on the northwest (Cloud and Barnes, 1946, p. 71), but the nature of the exposures are such that no section could be measured. Two sets of collections are available: The first set (X 1 and X 2) consists of a lot from the lower beds and another lot from the higher, made by J. Brookes Knight in 1938. The second set X2a–X2e) consists of five lots from the same succession of beds, made by Josiah Bridge, J. Brookes Knight, and others, later in the same field season. In addition, collections TF 329 to TF 335 were made in 1944 by Cloud and Barnes (1946, p. 71), but the fossils identified from them are not reproduced here. Identifications are by P. E. Cloud, Jr. (written commun., 1954). Each set of collections is given in descending stratigraphic order.

X 2. Higher beds to northwest, near saddle. *Calathium* sp., *Orospira* sp., *Barnesella*?, *Hormotoma* sp., bellerophontid? sp., other gastropods, endoceratid cephalopods, *Xenelasma*? sp., *Tritoechia*?

X 1. Lower beds, between saddle and county road. *Calathium* sp., *Ceratopea* n. sp., *C.* sp.?, *Hormotoma* sp., *Orospira* cf. *O. elegantula* Cullison, gastropod gen. and sp.? orthoid brachiopods gen. and sp.?, trilobite gen. and sp.?

X 2 e. Near saddle, at top of sequence from which collections were made. Brachiopod gen. and sp.?

X 2 d. Gastropod unident.; *Mcqueenoceras* siphuncle; coiled nautiloid aff. *Curtoceras*, *Tarphyceras*, and *Eurystomites; Hystericurus*?, *Jeffersonia* sp., archaeostracan crustacean? gen. and sp.?

X 2 c. *Calathium*, *Barnesella* sp. aff. *B. lecanospiroides* Bridge and Cloud, *Bolbocephalus*? sp., *Jeffersonia* sp. aff. *J. missouriensis* Cullison.

X 2 b. Pelmatozoan columnal, *Orospira*? sp., *Diparelasma*? sp.

X 2 a. Near county road, not far above sandstone exposure. *Ceratopea* n. sp., *Orospira* sp., gastropod gen. and sp.? orthoid gen. and sp.?

X 15 (*USGS 3599*).—El Paso Limestone, upper part of division B, which is here overlain unconformably by Hueco Limestone. Northeastern Baylor Mountains, half a mile northeast of stratigraphic section 7a, on northeast side of next ridge. Collected by J. B. Knight in 1938; identified by P. E. Cloud, Jr. (written commun., 1954).

Ceratopea cf. *C. ankylosa* Cullison, *Hormotoma* sp., *Raphistoma* sp.

X 10 (*USGS 3598*).—Montoya Dolomite, probably Aleman Cherty Member. Inlier of steeply dipping strata projecting amidst outcrops of Hueco Limestone, in Victorio Canyon 2 miles west-southwest of summit of Victorio Peak, near eastern center of sec. 14, block 43. Collected by J. B. Knight, 1938; identified by P. E. Cloud, Jr., Jean Berdan, and Helen Duncan (written commun., 1954).

Streptelasmatid corals, one specimen probably related to *S. foerstei* group; "*Rafinesquina*" sp.; *Hypsiptycha* sp.; *Lepidocyclus* sp.; dinorthid brachiopods gen. and sp.?

Om 2 (*USGS 2762*).—Montoya Dolomite, Aleman Cherty Member. West slope low ridge on west side of Baylor Mountains, a quarter of a mile east of Texas Highway 54, near center of sec. 6, Block 66, Twp. 8. Collected by P. B. King and J. Brookes Knight, 1936; identified by Helen Duncan and Jean Berdan (written commun., 1954).

Streptelasmatid corals, in part probably related to *S. foerstei* group.

Om3 (*USGS 2763*).—Montoya Dolomite, Aleman Cherty Member. East slope of Baylor Mountains a quarter of a mile south of eastern portal of Red Tank Canyon, in east-central part of sec. 4, Block 122. Collected by J. B. Knight, 1936; identified by P. E. Cloud, Jr., Jean Berdan, and Helen Duncan (written commu., 1954).

Palaeophyllum thomii (Hall); *Foerstephyllum*? sp. undet.; streptelasmatid corals, in part probably related to *S. prolongatum* group; *Platystrophia* sp.; *Dinorthis* (*Austinella*) sp.; *Hypsiptychia* sp.; *Lepidocyclus* sp., trepostomatous bryozoans.

Om 4 (*USGS 2764*).—Fusselman(?) Dolomite; light-gray bedded limestone, several hundred feet higher stratigraphically than Om 3, in same sequence. Originally mapped as upper part of Montoya Dolomite, but later interpreted as a calcitic facies of Fusselman. Southeast slope of Red Tank Canyon, a quarter of a mile above its eastern portal, in west-central part of sec. 4, Block 122. Collected by J. B Knight, 1936; identified by Helen Duncan, and Jean Berdan (written commun., 1954).

Streptelasmatid coral gen. and sp.?

STRATIGRAPHIC SECTIONS AND FOSSIL COLLECTIONS OF MISSISSIPPIAN AND PENNSYLVANIAN ROCKS

SECTION 11. MINE CANYON

The following is a section of part of the Barnett Shale exposed in a ravine about half a mile north of the portal of Mine Canyon, in the southwestern part of sec. 12, Block 66, Twp. 5. The section was measured by J. Brookes Knight in 1931. Fossils collected from units 2, 3, and 4 have been identified by Mackenzie Gordon, Jr., and E. L. Yochelson, and are discussed on pages 41–42.

Hueco Limestone at top of section.
Unconformity.

	Feet
Barnett Shale:	
9. Limestone, white, impure	5
8. Shale, green	10
7. Shale, purplish-brown; interbedded with shaly limestone	10
6. Limestone, buff, shaly, friable; contains poorly preserved fossils	10

Barnett Shale—Continued	*Feet*
5. Shale, purplish, carbonaceous; interbedded with thin limestone beds that contain poorly preserved fossils	20
4. Shale like that above, but containing limestone lenses and concretions as much as 3 ft in diameter; these and similar limestone lenses beneath contain well-preserved fossils	10
3. Shale, dark-gray; contains pyrite and selenite, also phosphatic nodules; lenticular limestone beds near top	20
2. Shale, purplish, carbonaceous; limestone concretions and lenses at top and 20 ft below top	50
1. Shale, black, massive, to base of exposure	(?)
Base concealed by alluvium.	
Part of Barnett Shale exposed	135+

SECTION 12. MARBLE CANYON

The following is a section of part of the beds of Pennsylvanian age exposed along the base of the Sierra Diablo escarpment south of Marble Canyon, along the east edge of sec. 21, Block 66, Twp. 5. The section was measured by P. B. King and R. E. King in 1928, and fossils were collected from units 5 and 6 by J. Brookes Knight and P. B. King in 1931. Identification of these fossils by Mackenzie Gordon, Jr., and E. L. Yochelson is given on page 45.

Hueco Limestone at top of section.	
Angular unconformity.	
Beds of Pennsylvanian age:	*Feet*
10. Limestone, gray, thin-bedded; forms a slope	22
9. Limestone, light-gray, granular; forms a ledge	22
8. Limestone, light-gray, thin-bedded; forms a slope	24
7. Limestone, light-gray, granular; forms a ledge	25
6. Slope on which bedrock is concealed; *Spirifer*, cup corals, and other fossils on surface	5
5. Limestone; forms a ledge; contains bellerophontids and cup corals	3
4. Covered	11
3. Limestone, light-gray, granular; contains crinoid columnals	22
2. Covered	6
1. Limestone, light-gray, granular; forms a ledge	30
Base concealed by alluvium.	
Part of beds of Pennsylvanian age exposed	170

STRATIGRAPHIC SECTIONS AND FOSSIL COLLECTIONS OF PERMIAN ROCKS

The sections and fossil lists which follow describe fossils which were collected and identified during both the earlier and later phases of this investigation. As many revisions of fossil terminology and taxonomy have been made between the times of the earlier and later investigations, the names for the same fossils are likely to vary from one collection to another. It has not been feasible to revise the earlier identifications to agree with the later, but the earlier listings are given here because they are of some descriptive and historical interest.

From collections made during the earlier phases of the investigation, brachiopods were identified by R. E. King (1931) and fusulinids by Dunbar and Skinner (1937). Collection numbers are preceded by REK for the brachiopods so identified and by D & S for the fusulinids so identified. These collections are deposited at Peabody Museum, Yale University.

Fossils in collections made during the later phases of the investigation were identified by paleontologists of the U.S. Geological Survey (P. E. Cloud, Jr., and E. L. Yochelson, written commun., 1954; L. G. Henbest, written commun., 1955). They are indicated by accession numbers prefixed by USGS, and the Foraminifera by additional accession numbers prefixed by "F." In addition, the field labels of J. Brookes Knight and the writer are also generally indicated. These collections are deposited with the U.S. Geological Survey.

SECTION 13. WYLIE MOUNTAINS

The following is a section of the Hueco and Victorio Peak Limestones in the Wylie Mountains, beginning in the southeast corner of the report area, and proceeding eastward across the mountains about 10 miles. Sections of the Hueco Limestone on the west face of the Wylie Mountains were measured by P. B. King and R. E. King in 1928, and by P. B. King and J. Brookes Knight in 1931, at which time scattered observations were also made on higher strata farther east. Subsequently, the whole mountain area has been mapped and described by Hay-Roe (1957). Fossils collected in 1928 were identified by R. E. King (1931) and Dunbar and Skinner (1937); those collected in 1931 were identified by E. L. Yochelson (written commun., 1959); those collected by Hay-Roe were identified by R. V. Hollingsworth and D. A. Drake (Hay-Roe, 1957). Some collections from the same area were made earlier by G. B. Richardson and identified by G. H. Girty (Richardson, 1914, p. 5).

The section given here is compiled from these sources. Data on the Powwow Member of the Hueco Limestone combine observations by King and his associates and by Hay-Roe. Units 3–7 of the main body of the Hueco Limestone are generalized from the sections by P. B. King and R. E. King and by P. B. King and J. Brookes Knight, which were measured on the slope west of elevation point 5039 (sec. 3, Block 64). The section of Victorio Peak Limestone is from Hay-Roe, with the addition of some observations by P. B. King and J. Brookes Knight.

Seven Rivers Formation in eastern foothills of Wylie Mountains, and farther east.

Conformity (?).

Victorio Peak Limestone:

Dolomite member: *Feet*

12. Dolomite, granular; with calcite vugs; pale brownish gray; weathers deeply pitted; in thick massive beds. Contains abundant species of *Parafusulina* (identified by R. V. Hollingsworth), which are said to be of Leonard type in lower part and of Guadalupe type in the upper part. Most of these weather to cavities, but part are silicified. Forms eastern third of Wylie Mountains ---------- 1,100

Marl member:

11. Marl, dolomitic; poorly exposed because of slumping of overlying beds; wedges out along strike south of mountains ---------- 15

Limestone member:

10. Limestone and dolomite, yellowish- to brownish-gray; weathers to light-gray pitted surfaces; in 4- to 6-in. beds; contains rare poorly preserved fossils. In 1931, bellerophontid gastropods as much as 3 in. in diameter were collected in basal beds, and in higher beds a large coarsely ribbed spiriferoid (USGS 7052) ---------- 470

Basal member:

9. Marl, dolomitic, thin-bedded, yellow-gray to pale-brown; with thin ledge-making dolomite layers, interbedded with red silty shale and crossbedded limestone-pebble conglomerate. Forms a light-colored slope-making band between the ledges that extends southward across the mountains ---------- 30–60

Unconformity.

Hueco Limestone:

Main body of formation:

8. Limestone, similar to that below, forming summits of western third of Wylie Mountains. Thickness indeterminate on outcrop because of numerous closely spaced faults of small displacement. Amount given is obtained by subtracting measured thickness of lower beds from total thickness of main body of formation (1,240 ft) in Cosden Petroleum Cockrell 1 well at east edge of mountains (sec. 7, Block 80) ---- 450

7. Limestone, dense, dark-gray to gray-brown; in 6-in to 2-ft beds; forms ledges 5–30 ft thick, separated by slopes, in which platy limestone and shale are interbedded. Many of the limestone beds contain short chert nodules and lenses. Spicules, fusulinids, productids, gastropods, and echinoid spines observed in various layers. Forms summit of west face of Wylie Mountains south of elevation point 5039 ---------- 173

Hueco Limestone—Continued

Main body of formation—Continued *Feet*

6. Limestone. In upper part thinner bedded and darker gray than beds above and below, forming thin ledges on slope; in lower part, some thicker, lighter gray ledges. A few beds in upper part contain small chert nodules. Fossils are abundant in many beds, but are mostly visible in cross section, and are partly destroyed by dolomitization. From collections of 1928 have been identified *Staffella* sp., *Pseudoschwagerina texana* Dunbar and Skinner, *Productus inca?* d'Orbigny, and *Productus invesi?* Newberry (D & S 141, 142; REK 508). Collection of 1931 contains *Polypora* sp., *Composita* sp., and *Omphalotrochus sp.* (USGS 7005x); echinoid spines, a pinnid pelecypod, and bellerophontid gastropods also observed ---------- 211

5. Limestone, dolomitic, fine-grained to dense, gray to dark-gray; in 1- to 4-ft beds; forms ledges and cliffs. Some beds are laminated and a few are brecciated. Some poorly preserved echinoid spines and bellerophontid gastropods observed ------- 196

4. Limestone, partly dolomitic, gray to pink; weathers gray; in 1- to 3-ft beds; forms ledges and slopes, with a covered interval at base --------- 75

3. Limestone, gray to gray-brown; mainly in 6-in. to 1-ft beds; forms slopes and thin ledges below, where there are many marl partings, but passing into a strong ledge at top, which is prominent at about midheight on west face of mountains. A few beds contain chert nodules and lenses. Fossils are abundant, but are mostly poorly preserved and fragmented. *Productus hessensis* King and *Composita subtilita* (Hall) have been been identified from collection of 1928 (REK 507). Collection of 1931 includes echinoid spines; the brachiopods *Composita* cf. *C. subtilita* (Hall), and *Dictyoclostus* (n. subgen.) cf. *D. hessensis* (King), *D. wolfcampensis* (King); the gastropods *Omphalotrochus?* sp. and a bellerophontid; and the pelecypod *Avi-*

Hueco Limestone—Continued

	Feet
Main body of formation—Continued	
culopecten sp. (USGS 7005); staffellid foraminifers also observed	139
Powwow Member:	
2. Marl and nodular limestone, buff, poorly consolidated. Abundant staffellid foraminifers, *Composita*, productid brachiopods, euomphalid gastropods, pectenoid pelecypods, and echinoid spines and plates observed. Also contains the ostracodes *Ellipsella? distenda* Kellett, *Healdia?* sp., *Paraparchites humerosus* Ulrich and Bassler, and *P. magnus* Kellett, and the foraminifer *Globovalvulina* sp. (identified by D. A. Drake)	20
1. Sandstone, siltstone, and shale, arkosic and conglomeratic, poorly consolidated, dark-red-brown to orange. Thickness varies abruptly within short distances, as a result of deposition on an irregularly eroded surface of underlying rocks	20–150

Angular unconformity.
Metamorphic rocks of Carrizo Mountain Formation at base of section.

Summary of section 13

Victorio Peak Limestone		1,615–1,645
Hueco limestone:		
Main body of formation	1,244	
Powwow Member	40–170	
Total Hueco Limestone		1,284–1,414

SECTION 14. BASS CANYON

The following is a section of the Hueco Limestone in the southern Carrizo Mountains, on the south slope of Bass Canyon, about 1¼ miles south of the south edge of the report area (sec. 18, Block 66, Twp. 9). A section at this locality is given by Baker (1927, p. 9), and a section of the main body of the formation was measured by P. B. King and R. E. King in 1928; the area was later mapped by Flawn (in King, P. B., and Flawn, P. T., 1953, p. 67 and pl. 1). In the section given here, the description of the Powwow Member is by Baker and that of the main body of the formation by P. B. King and R. E. King. Fossils were identified by R. E. King (1931).

Top of ridge; no higher beds preserved.
Hueco Limestone:

	Feet
Main body of formation:	
8. Limestone, dark-gray; in 1-ft beds; interbedded with thin-bedded yellow-brown limestone	255
7. Limestone, dark-gray, thin-bedded	70
6. Limestone, dark-gray, thick-bedded; forms prominent ledges. Contains *Productus hessensis* King and *Composita subtilita* (Hall) (REK 510); staffellid foraminifers, echinoid spines, and gastropods also observed	100

Hueco Limestone—Continued

	Feet
Main body of formation—Continued	
5. Limestone, poorly exposed	13
Powwow Member:	
4. Sandstone, calcareous, micaceous, fissile	5
3. Sandstone, irregularly banded red and gray	20
2. Sandstone, coarse, conglomeratic, gray; lying unevenly on unit below	8
1. Sandstone and conglomerate, micaceous, dark-purplish-red, containing angular fragments of quartz and schist. (This unit was assigned by Baker to the Van Horn sandstone; observations by King, confirmed by Flawn, indicate that it is part of the Powwow member, although Flawn has found true Van Horn sandstone below the Hueco a mile or two to the northeast.)	250

Angular unconformity.
Carrizo Mountain Formation at base of section.

Summary of section 14

Hueco Limestone:		
Part of main body of formation exposed	438	
Powwow Member	283	
Part of Hueco Limestone exposed		721

SECTION 15. THREEMILE MOUNTAIN

The following is a section of Hueco Limestone on Threemile Mountain, at the east end of the high ridge northwest of Van Horn, in the southeastern part of sec. 13, Block 66, Twp. 8. The main part of the section (units 1–14) was measured up the east face of the mountain to the top of a spur, the higher beds being added from the summit of the mountain, 750 ft to the northwest, which is separated from the spur by minor faults, downthrown to the west. The section was measured by J. Brookes Knight in 1931, and some additional notes and fossil collections were made in 1938. Larger fossils were identified by P. E. Cloud, Jr., and E. L. Yochelson; foraminifers were identified by L. G. Henbest (written commun., 1954, 1955). Besides the fossil collections from Threemile Mountain listed here, others were made by G. B. Richardson in 1907, which were identified by G. H. Girty (USGS 7184; field loc. 37), and by J. W. Beede and others for the Texas Bureau of Economic Geology, which were identified by R. E. King (1931, REK Te).

Top of mountain; no higher beds preserved.
Hueco Limestone:

	Feet
Main body of formation:	
19. Limestone, thinner bedded and darker than below; near top, cross sections of pelecypods observed	38
18. Limestone, massive, gray; weathers pitted	12
17. Limestone, thin-bedded, light-gray; a few beds 2–3 ft thick	38
16. Limestone, dark-gray; contains some chert and fossils	17

Hueco Limestone—Continued

Main body of formation—Continued *Feet*

15. Limestone, dark-gray; forms a slope; contains chert and a few echinoid spines, and near base, large bellerophontids ---------- 23
14. Limestone, thin-bedded; forms top of southeastern spur ---------- 10
13. Limestone, massive, gray; contains chert and bellerophontids ---------- 55
12. Limestone, thin-bedded; weathers yellowish; succeeding unit. Contains echinoid spines and other fossils ---------- 25
11. Limestone, forming a ledge; contains bryozoans ---------- 18
10. Limestone, forming slopes and ledges; contains bryozoans and large echinoid spines ---------- 11
9. Limestone, gray, massive; with thin marl partings near base and bands of chert nodules near top. This and adjacent beds contain *Wewokella* (*Talpaspongia*) *clavata* (R. H. King), other sponges and their spicules, *Syringopora* sp. and other compound corals; echinoid spines and plates; *Fenestella* sp., *Fistulipora* sp., *Polypora* sp., and other bryozoans; the brachiopods *Composita* cf. *C. subtilita* (Hall), *Crurithyris*? sp., *Dictyoclostus wolfcampensis* (King), various dielasmids including *Dielasma* aff. *D. bovidens* (Morton), *Hustedia mormoni* (Macrou), and *Meekella*? sp.; the pelecypods *Alloris ma*? sp., *Aviculopecten* sp., *Aviculopinna* sp., *Pseudomonotis* sp., and *Septimyalina* sp.; the gastropods *Bellerophon parvicristatus* Yochelson and other bellerophontids, *Euconispira* cf. *E. missouriensis* (Swallow), a loxonematacean, *Meekospira* sp., *Naticopsis* sp., *Omphalotrochus obtusispira* (Shumard), *Stegocoelia*? sp., *Straparollus* (*Euomphalus*) *cornudanus* (Shumard), and a subulitid; the scaphopod *Plagioglypta*? sp.; and ostracodes (USGS 6937, 14437; field labels 11, C 14). The beds also contain the foraminifers *Stafella* sp., and *Ozawainella* sp. (F. 2718c, 9812), and Dunbar and Skinner report the presence of *Schwagerina bellula* Dunbar and Skinner (D & S 90) ---------- 30
8. Limestone, marly; forms a slope; poorly exposed except in ravines. Contains bellerophontids ---------- 35
7. Limestone, gray; forms a ledge ---------- 6
6. Marl and marly limestone; containing bellerophontids ---------- 19
5. Limestone, thick-bedded, gray to light-gray; with marl partings; forms a ledge. Contains bellerophontids ---------- 20

Powwow Member:

4. Limestone, marly; forms a slope; poorly exposed except in ravines. Fossils occur in the marls and are scattered on the slope, derived from this bed and those just above. They include fenestrate and branching bryozoans; the brachiopods *Dictyoclostus wolfcampensis* (King), *Composita* cf. *C. subtilita* (Hall), and *Dielasma* cf. *D. bovidens* (Morton); the gastropods *Straparollus* (*Euomphalus*) *cornudanus* (Shumard), *Omphalotrochus obtusispira* (Shumard), and a large bellerophontid; and the scaphopod *Plagioglypta*? sp. (USGS 14430; field label C 7) ---------- 22
3. Sandstone, arkosic, conglomeratic, yellow; mostly forms a slope, but with ledges toward the top ---------- 77
2. Sandstone, arkosic, red; contains scattered chert pebbles near base and a layer of limestone-pebble conglomerate in a red arkosic matrix at top ---------- 37
1. Conglomerate, gray; formed of limestone pebbles and cobbles, probably derived from El Paso Limestone to north. This unit is a very local deposit, and thins rapidly westward ---------- 70

Angular unconformity.

Van Horn Sandstone in massive red ledges at base of section.

Summary of section 15

Hueco Limestone:

Part of main body of formation exposed	357
Powwow Member	206
Part of Hueco Limestone exposed	563

OTHER FOSSIL COLLECTIONS FROM HUECO LIMESTONE IN THREEMILE MOUNTAIN AREA

The following fossils were collected by P. B. King and J. Brookes Knight from the Hueco Limestone in the Threemile Mountain area, but not in any measured section:

USGS 14438, F 9813 (*field label C 15*).—About 4 miles west of Threemile Mountain, on south side of ridge, south of elevation point 5083 (southwestern part of sec. 16, Block 66, Twp. 8). Lower part of main body of Hueco Limestone contains undetermined bryozoans; the brachiopods *Dictyoclostus wolfcampensis* (King), *D.* (n. subgen.) *huecoensis* (King), and *Composita*? sp.; and the gastropods *Omphalotrochus*? sp., *Stegocoelia*? sp., *Straparollus* (*Euomphalus*) *cornudanus* (Shumard); large bellerophontids, and a subulitid. The limestone is crowded with small foraminifers of the *Spandelina* group and *Staffella* sp. and with juvenaria of fusulinids, probably including *Schubertella*.

USGS 14426 (*field label C 3*).—About 3¾ miles west-northwest of Threemile Mountain, on an outlier whose summit is elevation point 5079 (near center of sec. 9, Block 66, Twp. 8). Limestone and interbedded marls of main body of Hueco 25–50 ft above Powwow Member contain echinoid spines, the brachiopods *Dictyoclostus wolfcampensis* (King) and *Composita* cf. *C. subtilita* (Hall); and the gastrophod *Omphalotrochus obtusispira* (Shumard). Staffellid foraminifers and productid gastropods were observed in the field, but are not represented in the collection.

SECTION 16. BEACH MOUNTAIN

The following are two sections of the Hueco Limestone on the eastern flank of Beach Mountain. Section

16a was measured at the east end of a mesalike outlier whose summit is elevation point 5021 (near center of south line of sec. 6, block G). Section 16b was measured about three-quarters of a mile farther east, in a block downfaulted farther than rocks of the preceding, and extends southwestward from outcrops of Montoya Dolomite to the crest of the ridge (southwestern part of sec. 6, Block 65, Twp. 8). The sections were measured by J. Brookes Knight in 1931. Fossils were observed in the field, but none were collected. Small collections, which were made in the same area by G. B. Richardson in 1907, have been identified by G. H. Girty (USGS 7182, 7182a; field locs. 25, 27).

Section 16a

	Feet
Top of outlier; no higher beds preserved.	
Hueco Limestone:	
Main body of formation:	
10. Limestone, dolomitic, blue-gray, thin-bedded; forms 1- to 3-ft ledges; contains minute mollusks	70
9. Limestone, dolomitic, yellow-gray, splintery; forms 5- to 15-ft ledges; contains poorly preserved silicified fossils, including bellerophontids	105
8. Limestone, dolomitic, yellow-gray; in 1- to 2-ft beds; interbedded with dolomitic marl; forms a slope	100
7. Limestone, dolomitic, yellow-gray; forms a ledge; contains staffellid foraminifers and large productids	3
6. Slope, with a thin ledge of dolomitic limestone near middle; probably mostly marl	15
5. Limestone, dark blue-gray, mottled; forms a ledge; cross sections of small gastropods observed	3
Powwow Member:	
4. Marl, sandy, poorly consolidated; yellow, below nearly white at top	8
3. Sandstone, fine-grained, marly, red; contains pebbles near base	25
2. Slope without exposures; pebbles on surface	17
1. Conglomerate, made up of limestone pebbles derived from underlying Ordovician rocks	2
Angular unconformity.	
Montoya Dolomite at base of section.	

Section 16b

	Feet
Top of ridge; no higher beds exposed.	
Hueco Limestone:	
Main body of formation:	
6. Limestone, dolomitic, gray; in 3- to 5-ft beds, becoming thinner bedded, darker, and less dolomitic upward. In the thinner darker beds cross sections of small mollusks are visible; the topmost ledge contains poorly preserved gastropods, including *Euconispira*, euomphalids, and bellerophontids, as well as *Composita*, cup corals, and echinoid spines	140

Section 16b—Continued

	Feet
Hueco Limestone—Continued	
Main body of formation—Continued	
5. Limestone, dolomitic; gray, in 3- to 5-ft beds; forms receding ledges. A euomphalid gastropod observed near top; irregular siliceous masses lower down may in part be much altered fossils	50
4. Limestone, dolomitic, splintery; forms thin ledges on slope, with a 2-ft ledge near middle that contains poorly preserved bellerophontid gastropods	35
3. Slope, with a thin ledge of splintery yellow-gray dolomitic limestone at top	10
Powwow Member:	
2. Slope, poorly exposed. Some outcrops of red marl at top, but most of surface is covered by limestone pebbles and reddish wash	30
1. Conglomerate, sandy, yellow, composed of limestone pebbles derived from underlying Ordovician rocks	3
Angular unconformity.	
Monotoya Dolomite at base of section, on northeast.	

Summary of section 16

Hueco Limestone:		
Section 16a:		
Part of main body of formation exposed	269	
Powwow Member	52	
Part of Hueco limestone exposed		348
Section 16b:		
Part of main body of formation exposed	235	
Powwow Member	33	
Part of Hueco Limestone exposed		268

SECTION 17. HIGH POINT OF BAYLOR MOUNTAINS

The following section of the Hueco and Bone Spring Limestones was measured on the eastern face of Baylor Mountains, up a southeast-trending spur, whose summit is the high point of the mountains, at BM 5568 (northeastern part of sec. 1, Block 122, and southern part of sec. 3, Block 65, Twp. 7). A section was measured here by P. B. King and R. E. King in 1928, and again by J. Brookes Knight in 1931. The section given is that of Knight, but some notes made in 1938 have been added, and the fossils collected in 1928 are placed in their approximate positions in the section. Fossils collected in 1928 were identified by R. E. King (1931), and those collected in 1931 by P. E. Cloud, Jr., and E. L. Yochelson (written commun., 1954).

	Feet
Top of mountain; no higher beds exposed.	
Bone Spring Limestone:	
17. Limestone, dolomitic, light-gray, massive; has an original dip to north, and forms great cliffs north of summit BM 5568	200
16. Limestone, fine-grained, light-gray, thin-bedded; contains fossil fragments. Forms a cliff whose summit is BM 5568; wedges out northward beneath, and partly intergrates with unit above	110

Bone Spring Limestone—Continued	*Feet*
15. Shale, calcareous or marly, yellow to pink; with some ledges of dark-gray limestone a foot or two thick, in part fossilferous	55
14. Limestone, dark-gray, thin-bedded, cherty, very fossiliferous. From a collection made in 1928 at about this level, R. E. King identified the brachiopods *Rhipidomella mesoplatys baylorensis* King (type), *Streptorhynchus pyramidale*? King, *Productus ivesi* Newberry, *Productus schucherti* King, *Linoproductus cora angustus* King, *Marginifera sublaevis* King, *Aulostegas triagonalis* King, *Spirifer* (*Neospirifer*) *pseudocameratus* Girty, *Hustedia meekana* (Shumard), and *Composita mira* (Girty) (REK 503)	10
13. Limestone, dolomitic, irregularly bedded; with siliceous bands that contain fossils	45
12. Limestone, dolomitic, gray, massive; contains sponges at base	10
11. Limestone, granular, light-gray, thick-bedded, cherty; contains many silicified brachiopods	15
10. Limestone, light-gray, thin-bedded and laminated; interbedded with siliceous shale. Many cherty bands are fossiliferous and contain hexactinellid sponge spicules; the bryozoans *Fistuliopora* sp., *Acanthocladia* sp., and *Polypora* sp.; the brachiopods *Buxtonia* (*Kochiproductus*) *victorioensis* King, *Chonetes* sp., *Composita* sp., *Dictyoclostus* (*Chaoiella*) *guadalupensis* (Girty), *Hustedia* sp., *Linoproductus* (*Cancrinella*) sp., "*Marginifera*" sp., "*Martinia*" sp., *Meekella* sp., orthotetacean indet., "*Spirifer*" sp., and *Stenocisma* sp.; a nuculoid pelecypod; the gastropods *Apachella* sp., *Babylonites* sp., *Euphemites* cf. *E. imperator* Yochelson, *E.* sp., and *Knightites* (*Retispira*) sp.; the scaphopod *Plagioglypta* sp.; and the trilobite *Delaria*? sp. (USGS 7048; field label 24 A). From a collection made in 1928 at about the same level, R. E. King identified the brachipods *Rhipidomella mesoplatys baylorensis* King, *Meekella difficilis* Girty, *Marginifera manzanica* Girty, *Prorichthofenia likharewi* King, *Camarophoria venusta* Girty, *Hustedia meekana* (Shumard), and *Composita subtilita* (Hall) (REK 502)	50
9. Limestone, dolomitic; contains abundant molds of fusulinids in parallel orientation; weathers very jagged; forms ledges that alternate with 2- to 3-ft layers of marl. To north, the dolomitic layers wedge out into light-gray platy fossiliferous limestone	110
8. Limestone, dolomitic, thin-bedded; contains poorly preserved large fusulinids, crinoid columnals, and cup corals; weathers very jagged; some interbedded marl near top	55
7. Limestone, dolomitic, massive; in part brecciated; weathers very jagged; forms a lens; contains poorly preserved large fusulinids and other fossils	20
6. Limestone, dolomitic; resembles beds below, but forms receding ledges	40
5. Limestone, dolomitic, light-gray, thick-bedded; weathers jagged; forms cliffs; contains poorly preserved crinoid columnals near top	165
4. Limestone, dolomitic, light- to dark-gray; in 1- to 4-ft beds; weathers jagged in part; forms a slope. Some beds contain molds of fusulinids that are larger than those below	110
Unconformity (?).	
Hueco Limestone:	
Main body of formation:	
3. Limestone, dolomitic, light-gray, thinly and evenly bedded, splintery; forms cliffs in upper part. Most beds contain molds of small fusulinids, and a bed 25 ft above base contains nodules of probable algal origin	308
2. Limestone, dolomitic, light gray-brown; in 2- to 5-ft beds; weathers somewhat pitted; forms a ledge; contains vugs, cavities, and fusulinid molds	10
Powwow (?) Member:	
1. Poorly exposed on slope; in ravines are outcrops of limestone-pebble conglomerate in gray-brown dolomitic matrix	35
Angular unconformity.	
Beds of Devonian age, and Fusselman Dolomite at base of section (see section 7).	

Summary of section 17

Part of Bone Spring Limestone exposed		995
Hueco Limestone:		
Main body of formation	318	
Powwow (?) Member	35	
Total Hueco Limestone		353

OTHER FOSSIL COLLECTIONS FROM BONE SPRING LIMESTONE NEAR HIGH POINT OF BAYLOR MOUNTAINS

The following fossils were collected from the Bone Spring Limestone by P. B. King in 1931, on the ridge west of the high point of the Baylor Mountains; the collections are not in the measured section, but their stratigraphic positions can be approximated.

USGS 7053.—Ridge west of high point of Baylor Mountains, near elevation point 5535 (northeastern part of sec. 2, Block 122), from black limestone above middle reef beds (approx. unit 15 of section 17). Contains the coral *Lophophyllum* sp.; the bryozoan *Fistulipora* sp.; the brachiopods *Chonetes* sp., *Linoproductus* (*Cancrinella*) sp., "*Marginifera*" spp., *Dictyoclostus* (*Chaoiella*) *guadalupensis* (Girty), productids indet., *Stenocisma*? sp., *Neospirifer* sp., and *Rhipidomella* sp.; the pelecypods *Astartella* sp. and a pectenoid; and a bellerophontid gastropod.

USGS 7009.—North end of ridge west of high point of Baylor Mountains (southeastern part of sec. 4, Block 65, Twp. 7), from top of middle reef beds (approx. unit 14 of section 17, or at about same level as collection REK 503). Contains the bryozoans *Fistulipora* sp. and *Striatopora* sp.; the brachiopods *Leptodus* sp., *Rhipidomella* sp., and a productid; the pelecypods *Astartella* sp., "*Cypricardinia*" sp., a nuculoid, and *Pteria*? sp.; and the gastropods *Apachella* sp., *Euphemites* sp., *Glabrocingulum* sp., and a pleurotomarian.

SECTION 18. NORTHEASTERN BAYLOR MOUNTAINS

The following section of the Hueco and Bone Spring Limestones was measured in the northeastern part of the

Baylor Mountains northwestward up the first ridge southwest of elevation point 4888 (north-central part of sec. 48, Block 65, Twp. 6), with higher beds on elevation point 4888 added (south-central part of sec. 37, Block 65, Twp. 6), which are downfaulted with respect to the main section. The section was measured by J. Brookes Knight in 1931, but some additional observations were made in 1938. Fossils were identified by P. E. Cloud, Jr., and E. L. Yochelson (written commun., 1954).

Top of ridge; no higher beds exposed.	
Bone Spring Limestone:	*Feet*
18. Limestone, dark-gray, fine-grained to dense; chert nodules in 6-in to 2-ft beds; weathers to smooth gray surfaces and forms cliffs. Resembles limestone at high point of Baylor Mountains (unit 16, section 17). Thickness given is approximately that on elevation point 4888; on ridges at northeast, near northeast end of mountains, these limestones are several times thicker	100
17. Limestone, thin-bedded, black; forms a slope. On southeast slope of summit 4888, about 150 ft stratigraphically above unit 14, a thin lens of bioclastic limestone (or "molluscan ledge") contains a prolific dominantly molluscan fauna (USGS 6983, USGS 14475; field labels 27, C 33). This includes the corals *Amplexus* sp., *Cladochonus* sp., and *Lophophyllum* sp.; the bryozoans *Acanthocladia* sp., *Cystodictya* sp., *Fenestella* sp., *Fistulipora* sp., *Meekopora* sp., *Polypora* sp., *Rhombopora* sp., *Septopora* sp., *Stenopora* sp., and *Striatopora* sp.; the brachiopods *Avonia* sp., *Buxtonia* (*Kochiproductus*) *victorioensis* King, *Chonetes* sp., (large), *Composita* sp., *Enteletes* cf. *E. dumblei* Girty, *Hustedia mormoni* (Marcou), *Leptodus* sp., *Meekella difficilis* Girty, orthotetacean indet., *Rhipidomella* sp., *Squamularia* sp., and *Wellerella* sp.; and the trilobite *Delaria*? sp. The mollusks include the pelecypods *Acanthopecten* sp., *Astartella nasuta* Girty, *Aviculopecten* sp., *Edmondia* sp., Myalinid indet., *Nucula* sp., *Nuculana* spp., *Paleoneilo* sp., *Parallelodon* sp., *Permophorus* sp., *Pseudomonotis* sp., *Pteria*? sp., *Schizodus* sp., *Solenoyma* sp., and *Streblopteria* sp.; the gastropods *Anomphalus* sp., *Babylonites* sp., *Bellerophon deflectus* Chronic, *Glyptospira* sp., *Knightites* (*Retispira*) sp., cf. *Loxonema* sp., *Naticopsis* sp., *Orthonema* sp., pleurotomarian indet., *Stegocoelia*? sp., "*Strobeus*" sp., sublitid indet., *Trachydomia* sp., "*T.*" sp., and "*Worthenia*" sp.; the chiton "*Gryphochiton*" sp.; the scaphopod *Plagioglypta* sp.; and an orthoceratid cephalopod and an ammonite	200
16. Limestone, granular, dark-gray, evenly bedded; contains some poorly preserved fossils. Forms top of ridge southwest of summit 4888	20
15. Limestone, platy and siliceous, gray and black; forms a slope. Some 1-ft beds of gray granular limestone interbedded in lower part	85
Bone Spring Limestone—Continued	*Feet*
14. Limestone, granular, gray, thick-bedded; contains a large *Enteletes* and other fossils	14
13. Limestone, dolomitic, gray, massive. Contains the bryozoan *Fistulipora* sp.; the brachiopods *Meekella* sp., *Prorichthofenia* sp., and *Wellerella* sp. (large); a pseudozygopleuran and a pleurotomarian gastropod, and an indeterminate nautiloid (USGS 7000; field label 25 B). Sponges were observed near base	45
12. Limestone, black, thin-bedded; with an irregular upper contact	5
11. Limestone, dolomitic, light-gray, massive; contains large fusulinids	35
10. Limestone, granular, light-gray, thin-bedded, fossiliferous; mostly forms float on a slope	20
9. Limestone, dolomitic, massive, in part brecciated; forms a reefy mass; contains rare fossils	35
8. Limestone, slabby, black; forms a slope	25
7. Limestone, dolomitic; brecciated below, massive above; forms a reefy mass. Contains many silicified fossils, and near base, large fusulinids	40
6. Limestone, platy to thin-bedded; light-gray below and black above; forms a slope; several 2-ft beds of granular limestone interbedded near base	110
5. Limestone, dolomitic, light-gray, thin-bedded to platy; with a 10-ft ledge of granular fossiliferous limestone interbedded 17 ft above base. This contains the brachiopods *Prorichthofenia* sp. and "*Marginifera*" sp., the gastropod *Warthia waageni* Yochelson, and the scaphopod *Plagioglypta* sp. (USGS 7000a; field label 25 AA). At about the same level, large indeterminate fusulinids were collected (F 9822; field label C 24 B)	66
4. Limestone, dolomitic, siliceous, gray, thin-bedded and laminated; forms a slope	15
3. Limestone, dolomitic, granular, light-gray; forms a ledge, with a slope beneath	8
Erosional unconformity.	
Hueco Limestone:	
2. Limestone, dolomitic, bedded, in part brecciated; forms massive ledges. Some 1–ft beds of light-gray compact limestone are interbedded about 15-ft below top. The dolomitic beds contain numerous small or slender fusulinids, mostly preserved as molds and partly filled by quartz, which are indeterminate in the laboratory (F 3908; field label C 24 A). The unit varies in thickness, due to the unconformities at the top and base of the Hueco; a thickness of 100 ft was measured nearby to the east in 1938, but the unit pinches out entirely between the Bone Spring and El Paso a short distance to the south	80
1. Conglomerate, dolomitic; contains angular pebbles of limestone, dolomite, and chert, derived from underlying Ordovician formations	15
Angular unconformity.	
El Paso Limestone (division A) at base of section.	
Summary of section 18:	
Part of Bone Spring Limestone exposed	**823**
Total Hueco Limestone	**95**

SECTION 19. NORTHWESTERN BAYLOR MOUNTAINS

The following is a section of the Hueco and Bone Spring Limestones on a northwestern hill of the Baylor Mountains, whose summit is elevation point 4364, lying about half a mile east of Texas Highway 54 (southeastern part of sec. 42, Block 65, Twp. 6). The section is based on observations by P. B. King and J. Brookes Knight in 1931 and 1936. The units are incompletely described, and their thicknesses are estimated; the section is included mainly to indicate the relative positions of the fossil collections. Larger fossils were identified by P. E. Cloud, Jr., and E. L. Yochelson, and foraminifers by L. G. Henbest (written commun., 1954, 1955).

	Feet
Top of hill; no higher beds preserved.	
Bone Spring Limestone:	
6. Limestone, dolomitic; weathers brown and jagged; similar to unit beneath, but somewhat thinner bedded. Contains algae, crinoid stems, and abundant large fusulinids, rather poorly preserved as a result of dolomitization. Fossils are better preserved at this level a mile to the southeast, where the rock is a calcirudite in which many of the fusulinid shells are completely preserved, although most show the effects of attrition. Rounded pellets of limestone are abundant, some of which contain fossils that belong to a different facies from that represented by the matrix. This rock probably is a lithified beach sand, derived from nearby reefs. It contains the foraminifers *Climacammina* sp., *Tetrataxis* sp., *Staffella* sp., *Pseudofusulina setum* (Dunbar and Skinner), *Parafusulina imlayi* Dunbar var., fusulinids of the *P. attenuata-P. bakeri* series, *P. schucherti* Dunbar and Skinner, and *P.*? sp. (F 2720; field label Pb 16)	50
5. Limestone, dolomitic; weathers brown and jagged; thick bedded to massive, with some marl partings. Poorly preserved sponges, *Geyerella*, *Leptodus*, and productids observed, and some thin layers contain fusulinids	100
4. Slope-making beds, mainly covered by blocks that have slumped from above. Appears to be mostly thin-bedded cherty fossiliferous limestone, but shale and marl are exposed in places near base. A fossiliferous limestone near top locally yields an extensive fauna, which includes indeterminate fusulinids; the corals *Cladochonus* sp. and *Lophophyllum* sp.; the bryozoans *Batostomella* sp., *Fistulipora* sp., and *Striatopora* sp.; echinoid plates; the brachiopods *Chonetes* (*Chonetinella*) *victorianus* (Girty), *Crurithyris* sp., *Dielasma* spp., *Enteletes* cf. *E. dumblei* Girty, *Hemiptychina* sp., *Hustedia mormoni* (Marcou), *Leptodus* sp., *Meekella* sp., *Neospirifer* sp., orthotetacean indet., *Rhipidomella* sp., and *Wellerella* sp.; the pelecypods *Acanthopecten* sp. and *Parallelodon* sp.; the gastropods *Anomphalus* sp., *Babylonites* sp., *Bellerophon deflectus* Chronic, *Donaldina*? sp., *Platyceras* sp., pseudozygopleuran indet., *Stegocoelia*? sp., *Straparollus* (*Euomphalus*) cf. *S.* (*E*). *kaibabensis* Chronic, *Trachydomia* sp., and "*T.*" sp.; the scaphopod *Dentalium* sp.; and an ammonite (USGS 7002b; field label 26). Ledges near the base of the slope contain indeterminate fusulinids; the sponges *Fissispongia* n. sp., n. gen. aff. *F.*, and *Girtyocoelia dunbari* R. H. King; the bryozoan *Fistulipora* sp.; the brachipods *Composita* sp., *Enteletes* sp., *Neospirifer* sp., productid indet., *Prorichthofenia* sp., *Squamularia* sp., and *Wellerella* sp.; the pelecypods *Parallelodon* sp., pectenoid indet., and *Pseudomonotis* sp.; and the gastropods *Bellerophon* sp. and *Euphemites* sp. (USGS 7002a)	175
Unconformity (angular and erosional at nearby localities).	
Hueco Limestone:	
3. Limestone, dolomitic, massive; interbedded with thin-bedded limestone and bedded chert; forms ledges. In lower part contains the brachiopods *Meekella*? sp., "*Productus*" sp., *Leptodus* sp., and *Hustedia hessensis* King (USGS 7002)	100
3. Limestone, dolomitic, gray-brown; weathers pitted	50
1. Limestone, dolomitic, thin-bedded; crumpled in places; contains some small fusulinids. This unit wedges out entirely against the El Paso Limestone at the south end of the ridge, where unit 2 lies on the El Paso; a mile to the southwest, units 2 and 3 are also missing, so that unit 4 lies on the El Paso. Thickness to base of slope in northern part of hill	100
Angular unconformity.	
El Paso Limestone at base of section; exposed only at south end of hill.	

Summary of section 19

Part of Bone Spring Limestone exposed	325
Total Hueco Limestone	150–250

SECTION 20. EAGLE FLAT

The following is a section of the Hueco Limestone at the east end of the high ridge north of Texas and Pacific Railway, about a mile northwest of Eagle Flat section house (center of south line of sec. 1, Block 69, Twp. 8). The Powwow Member was measured on the slope at the eastern end, where it is exposed in a gully; the main body of the formation was measured about half a mile to the northwest on the north side of the ridge, beginning about 500 feet east of an abandoned prospect pit, the higher beds (units 22–24) being added from a ridge top to the west. The section was measured by J. Brookes Knight in 1931. Fossils were identified by P. E. Cloud, Jr., and E. L. Yochelson (written commun., 1954).

Top of ridge; no higher beds exposed.

Hueco Limestone:

	Feet
Main body of formation:	
24. Limestone, dark-gray, thin-bedded; contains small gastropods	8
23. Limestone, forming a ledge	3
22. Limestone, thin-bedded, splintery; weathers gray; contains echinoid spines and a few other fossils	25
21. Limestone, thin-bedded to slabby, gray to light-gray; weathers yellow; mostly forms a slope, but with 2-ft ledges at intervals. Contains a few echinoid spines in upper part	71
20. Limestone, moderately thin-bedded; forms cliffs; 2 or 3 cherty beds; contains mollusks like those in unit 18	16
19. Limestone, gray; forms a slope, with a few ledges toward top	22
18. Limestone, dark-gray, cherty; forms a cliff, containing abundant mollusks in upper part, including bellerophontids	20
17. Limestone, thin-bedded; forms a slope	18
16. Limestone, dark-gray, cherty, massive; forms a cliff; contains echinoid spines and a few other silicified fossils	18
15. Limestone, dark-gray, thin-bedded; forms a slope; contains abundant echinoid spines 8 ft above base	16
14. Limestone, dense, dark-gray; weathers mouse gray; forms a massive cliff; contains abundant ramifying chert nodules and silicified fossils. The latter include echinoid spines, the brachiopods *Composita* cf. *C. subtilita* (Hall) and *Dictyoclostus wolfcampensis* King; and the gastropods bellerophontid indet., *Knightites* (*Retispira*) sp., *Naticopsis* sp., *Omphalotrochus* sp., and *Straparollus* (*Euomphalus*) *cornudanus* (Shumard) USGS 7008; field label 1 A)	28
Powwow Member:	
13. Limestone, forming a slope	8
12. Limestone, forming a ledge; contains large chert nodules	3
11. Marl, forming a slope; interbedded with thin limestone layers	14
10. Limestone, containing large bellerophontids	3
9. Limestone, gray; interbedded with marl, containing abundant fossils, which include the bryozoans *Fenestella* sp., *Polypora* sp., and *Rhombopora* sp.; the brachiopods *Cleiothyridina* sp., *Composita* sp., *Dictyoclostus wolfcampensis* (King), and dielasmids including *Dielasma* aff. *D. bovidens* (Morton); myalinid and pseudomonotid pelecypods; the gastropods *Bellerophon parvicristatus* Yochelson, and other abundant but poorly preserved bellerophontids, *Euconispira* cf. *E. missouriensis* (Swallow), *Knightites* (*Knightites*) sp., a loxonematacean, *Naticopsis* sp., and *Straparollus* (*Euomphalus*) *cornudanus* (Shumard); and the scaphopod *Plagioglypta*? sp., (USGS 7028; field label 5)	27
8. Limestone, sandy, yellow, fossiliferous	2

Hueco Limestone—Continued

	Feet
Powwow Member—Continued	
7. Shale, sandy, yellow; mostly covered	18
6. Conglomerate, red	2
5. Shale, red, sandy	6
4. Conglomerate, gray; formed of schist and chert pebbles	7
3. Shale, red, sandy	6
2. Conglomerate, yellow; formed mainly of limestone from Allamoore Formation, but including a few pebbles of schist and greenstone	16
1. Conglomerate, arkosic, red; formed of pebbles of schist and greenstone	13

Angular unconformity.

Metarhyolite of Precambrian age at base of section.

Summary of section 20

Hueco Limestone:	
Part of main body of formation exposed	245
Powwow Member	125
Part of Hueco Limestone exposed	370

SECTION 21. STREERUWITZ HILLS

The following sections of the Hueco Limestone are in the Streeruwitz Hills, on closely adjacent mesas, lying 2½ to 3½ miles northwest of the Eagle Flat section house. They were measured by J. Brookes Knight in 1931, but additional fossils were collected from each section in 1938. Section 21a is at the southeastern end of the eastern mesa (center of sec. 26, Block 57), and section 21b is about three-quarters of a mile to the northwest, at the west end of the western mesa (east-central part of sec. 27, Block 57). Larger fossils were identified by P. E. Cloud, Jr., and E. L. Yochelson, and foraminifers by L. G. Henbest (written commun., 1954, 1955).

Section 21a

Top of mesa; no higher beds exposed.

Hueco Limestone:

	Feet
Main body of formation:	
8. Limestone, massive; forms ledge at top of mesa	10
7. Limestone, thin-bedded; forms a slope	15
6. Limestone, dark-gray, massive; forms cliff	20
Powwow Member:	
5. Limestone, dense, splintery, light-gray, thin-bedded; contains much chert and is interbedded with shale. Upper beds form thin ledges on slope. The limestones contain the foraminifers *Bradyina*? sp., a spandelinid, *Schubertella kingi*? Dunbar and Skinner, *Triticites* or *Pseudofusulina* sp., and *Schwagerina knighti* Dunbar and Skinner; cup corals; the bryozoan *Septopora* sp.; echinoid spines; the brachiopods *Composita* cf. *C. subtilita* (Hall), *Dictyoclostus* cf. *D. wolfcampensis* (King), "*Dielasma*" sp., and *Hustedia* sp.; the pelecypods *Allorisma* sp. and *Pseudomonotis* sp.; the gastropods *Omphalotrochus obtusispira* (Shumard), *Knightites* (*Retis-*	

Section 21a—Continued

	Feet
Hueco Limestone—Continued	
Powwow Member—Continued	
pira) sp., and large bellerophontids; the scaphopod *Plagioglypta*? sp.; and plant fragments (USGS 7003, 7003a, 14431, F 9808; field labels 2 E, C 8)	47
4. Shale, marly; with a thin ledge of splintery limestone near middle, containing quartz geodes. Contains small fusulinids; the bryozoans *Fistulipora* sp., *Polypora* sp., *Septopora* sp., and *Streblotrypa* sp.; echinoid spines; the brachiopods *Cleiothyridina* sp.; *Composita* cf. *C. subtilita* (Hall), *Crurithyris*? sp., *Dictyoclostus wolfcampensis* (King), "*Dielasma*" sp., and *Wellerella* sp.; the pelecypods *Nucula* sp. and a myalinid; the gastropods *Bellerophon huecoensis* (Yochelson) and other bellerophontids, *Euconispira* cf. *E. missouriensis* (Swallow), *Naticopsis* sp., and *Straparollus* (*Euomphalus*) *cornudanus* (Schumard); a nautiloid; and the scaphopod *Plagioglypta*? sp. (USGS 7003b; field label 2D)	30
3. Limestone, shaly, splintery, red	10
2. Shale, calcareous, red	8
1. Conglomerate, arkosic, massive; formed of pebbles of limestone, greenstone, and schist, derived from Precambrian formations	8

Angular unconformity.
Greenstone of Precambrian age at base of section.

Section 21b

Top of mesa; no higher beds exposed.

	Feet
Hueco Limestone:	
Main body of formation:	
6. Limestone, alternating beds of which are gray, coarse-grained, and slabby, and pink to yellow, dense, and splintery. Both types contain echinoid spines and other fossils	20
5. Limestone, pink-weathering, buff, fossiliferous	8
Powwow Member:	
4. Limestone, gray; cherty toward top; interbedded with marl. Contains the forminifers *Bradyina*? sp., *Ozawainella* sp., *Staffella* sp., and spandelinids; the sponge *Wewokella* (*Talpaspongia*) *clavata* (R. H. King) and spicules; echinoid spines; the brachiopods *Composita* cf. *C. subtilita* (Hall) and *Dictyoclostus wolfcampensis* (King); and the gastropod *Straparollus* (*Euomphalus*) *cornudanus* (Shumard), and others (USGS 14432, F 9809; field label C 9)	60
3. Limestone, dense, pinkish; weathers yellow brown; interbedded with marl; forms ledges and slopes; fossiliferous at top	66
2. Limestone, shaly, pink; with a bed of splintery limestone at top	4
1. Conglomerate, calcareous; formed of pebbles of limestone of Allamoore Formation	3

Angular unconformity.
Allamoore Formation at base of section.

Summary of section 21

		Feet
Hueco Limestone:		
Section 21a:		
Part of main body of formation exposed	45	
Powwow Member	103	
Part of Hueco Limestone exposed		148
Section 21b:		
Part of main body of formation exposed	28	
Powwow Member	133	
Part of Hueco Limestone exposed		161

SECTION 22. McADOO RANCH

The following is a section of the Hueco Limestone near the west end of the south-facing escarpment of the Sierra Diablo, on the east side of a gap in the ridge, 2 miles southwest of the Gordon (formerly McAdoo) Ranch (center of north line of sec. 29, Block 52½). The section was measured by J. Brookes Knight in 1931. Many fossils were observed in the field but not collected; the small collections which were made were identified by P. E. Cloud, Jr. (written commun., 1954).

Top of ridge; no higher beds exposed.

	Feet
Hueco Limestone:	
Main body of formation:	
12. Limestone, gray, slabby; contains chert and calcite vugs; marly partings in lower part. Contains a bellerophontid and *Straparollus* (*Euomphalus*) *cornudanus* (Shumard) (USGS 7013b; field label 8 C)	45
11. Limestone, forming a ledge; bellerophontids and other fossils observed	5
10. Limestone, gray; weathers pitted; in 4-ft beds, alternating with thinner beds; in part forms cliffs, in part ledges and slopes. Some beds contain chert nodules and small quartz geodes; a bed about 25 ft above base contains large masses of white chert. Fossils rare; echinoid spines observed	110
Powwow Member:	
9. Limestone, slabby, gray to pinkish-gray. Contains a dasycladacean alga, probably *Mizzia* (USGS 7013a; field label 8 B). Staffellid foraminifers observed	10
8. Limestone, slabby, pink; with a thin bed of arkosic sandstone in middle; minute fossils observed	11
7. Limestone, pinkish-gray; in 4-ft ledges; separated by arkosic sandstone	22
6. Limestone, dense, pink; weathers yellow; in 1-ft ledges, separated by greater thicknesses of slabby arkosic sandstone. A limestone bed near middle contains a dasycladacean alga (USGS 7013; field label 8 A); minute gastropods and staffellid foraminifers observed	14
5. Sandstone, arkosic, pinkish-gray, poorly consolidated; mostly forms a slope	20
4. Covered by talus; probably like adjoining units	20

Hueco Limestone—Continued

Powwow Member—Continued *Feet*

3. Sandstone, arkosic, pinkish-gray, conglomeratic; forms a ledge 7
2. Covered by talus; probably like adjoining units 25
1. Sandstone, arkosic, coarse, yellowish-gray, poorly consolidated 5

Angular unconformity.
Van Horn Sandstone at base of section.

Summary of section 22

Hueco Limestone:

Part of main body of formation exposed 160
Powwow Member 134

Part of Hueco Limestone exposed 294

SECTION 23. WEST OF OLD CIRCLE RANCH

The following is a section of the Hueco Limestone on the south-facing escarpment of the Sierra Diablo, on the east side of a wide gap in the ridge, 3¾ miles west of the Old Circle Ranch (northeastern part of sec. 2, Block 56). The section was measured by J. Brookes Knight in 1931. Fusulinids were collected, and were examined by Dunbar and Skinner (1937), but they were not identified.

Top of ridge; no higher beds exposed.
Hueco Limestone:

Main body of formation: *Feet*

6. Limestone, gray, massive; contains euomphalid gastropods and large echinoid spines 5
5. Limestone, gray; with indistinct bedding; forms a cliff. Fusulinids collected at top and base (D & S 92, 93; field labels 9 B, 9 C); other fossils rare or obscure 35
4. Limestone, gray; in 2- to 5-ft beds; contains abundant fusulinids (D & S 91; field label 9 A) 35
3. Limestone, gray; forms a massive ledge 10

Powwow Member:

2. Limestone, sandy, pink; contains calcite vugs 8
1. Marl, arkosic; mostly yellow, becoming red below, with thin beds of yellow limestone and conglomeratic limestone, and with beds of arkosic conglomerate in lower part, whose pebbles have been reworked from those in the Van Horn Sandstone 80

Angular unconformity.
Van Horn Sandstone at base of section.

Summary of section 23

Hueco Limestone:

Part of main body of formation exposed 85
Powwow Member 88

Part of Hueco Limestone exposed 173

SECTION 24. OLD CIRCLE RANCH

The following is a section of the Hueco Limestone on the escarpment overlooking Deer Creek from the west, half a mile northwest of Old Circle Ranch (southwest corner of sec. 23, Block 53½). The section was measured by J. Brookes Knight in 1931. Fusulinids were collected, and were examined by Dunbar and Skinner (1937), but they were identified only in part.

Top of escarpment; no higher beds exposed.
Hueco Limestone:

Main body of formation: *Feet*

11. Limestone, light-gray, thin-bedded; forms ledges; a few beds contain fusulinids (D & S 98; field label 10 D) 50
10. Limestone, containing large calcite vugs and some chert; forms upper part of massive cliff. Contains fusulinids at top (D & S 97; field label 10 C), and large echinoid spines 35
9. Limestone, light-gray; forms lower part of massive cliff. Contains *Schwagerina linearis* Dunbar and Skinner (D & S 96; field label 10 B), poorly preserved productids, and at top, large echinoid spines and a euomphalid 25
8. Limestone, partly covered; forms a slope; float contains abundant fusulinids 20
7. Limestone, light-gray; forms a massive ledge 16
6. Limestone, compact, light-gray to pink; forms a massive cliff in lower half. Fusulinids abundant in lower part, including *Schwagerina linearis* Dunbar and Skinner, and *S. emaciata* (Beede) (D & S 95; field label 10 A) 52
5. Limestone, compact, gray; with some chert nodules 15
4. Limestone, poorly exposed; forms a slope 10
3. Limestone, compact, massive, gray; contains chert nodules 11

Powwow member:

2. Shale, arkosic, light-yellow-gray; with thin ledges of conglomerate in lower half 31
1. Conglomerate, arkosic, yellow 5

Angular unconformity.
Red sandstone of Hazel Formation at base of section.

Summary of section 24

Hueco Limestone:

Part of main body of formation exposed 234
Powwow Member 36

Part of Hueco Limestone exposed 270

SECTION 25. HAZEL MINE

The following is a section of the Hueco Limestone on the southeastern angle of the Sierra Diablo escarpment, half a mile north-northeast of the Hazel mine (southeastern part of sec. 41, Block I). The Powwow Member was measured on the southeastward-projecting ridge below the upper cliffs, the higher beds up the northeast side of the ridge through a cleft in the cliffs, thence westward to the ridge summit. The section was measured by J. Brookes Knight and P. B. King in 1931. No fossils were collected, although they were observed in the field.

Top of ridge; no higher beds exposed.

Hueco Limestone:

Main body of formation: *Feet*

10. Limestone, dolomitic; somewhat thinner bedded and lighter gray than beds below; forms ledges and slopes above the main cliffs ---- 130
9. Limestone, dolomitic, dark-gray; in even beds 3–5 ft thick; contains fusulinid molds; forms cliffs. Basal part is pinkish-gray and contains some chert ---- 150
8. Limestone, dolomitic, light-gray; contains abundant fusulinid molds ---- 5
7. Limestone, dolomitic, light-gray; forms cliffs; contains poorly preserved fossils ---- 31
6. Limestone, light-gray; with many calcite vugs; contains poorly preserved bellerophontids, and in upper foot, staffellid foraminifers ---- 12
5. Limestone, dense, light-gray; weathers yellow; contains fossil fragments ---- 3

Powwow Member:

4. Sandstone, arkosic, calcareous, yellow, poorly exposed on slope ---- 5
3. Limestone, sandy, yellow ---- 3
2. Conglomerate, yellow; interbedded with gray sandy marl in upper part. Conglomerate at base consists of closely packed coarse pebbles and cobbles of limestone and of red sandstone from Hazel formation. Conglomerate above consists of smaller pebbles of red sandstone and resistant foreign rocks, with scattered seams of limestone pebbles, set in an arkosic sandstone matrix ---- 85
1. Conglomerate, red, arkosic; made up of pebbles of red sandstone, quartzite, and igneous rocks ---- 5

Angular unconformity.

Red sandstone of Hazel Formation at base of section.

Summary of section 25

Hueco Limestone:

Part of main body of formation exposed ---- 331

Powwow Member ---- 98

Part of Hueco Limestone exposed ---- 429

SECTION 26. BAT CAVE

The following is a section of the Hueco Limestone on the escarpment of the Sierra Diablo at Bat Cave, on the south side of an eastward offset of the escarpment 1¾ miles north-northeast of the Pecos Mine (northeastern part of sec. 13, Block 54½). The section was measured by J. Brookes Knight in 1936. Fusulinids and other foraminifers were identified by L. G. Henbest (written commun., 1955); other fossils were observed in the field, but were not collected.

Top of escarpment; no higher beds exposed.

Hueco Limestone:

Main body of formation: *Feet*

7. Limestone, dolomitic, gray, thin-bedded; with some interbedded very light gray layers and much interbedded calcitic limestone in upper part. Poorly preserved fusulinids observed in lower part. A bed 100 ft above base contains better preserved foraminifers, including *Staffella* sp., *Schubertella kingi* Dunbar and Skinner, *Pseudofusulina?* sp., and *Schwagerina bellula* Dunbar and Skinner (F 2703; field label Ph 18). Near the top occur *Climacammina* sp., *Schubertella kingi* Dunbar and Skinner, *Triticites* aff. *T. subventricosus* Dunbar and Skinner, and *Schwagerina* sp. (F 2719; field label Ph 19); with these were observed poorly preserved *Omphalotrochus* ---- 165
6. Limestone, dolomitic, gray, thin-bedded; contains fusulinid molds ---- 150
5. Limestone, dolomitic, gray, thick-bedded; forms lower part of a slope; contains unidentifiable small fusulinids (F 2696; field label Ph 12) ---- 75
4. Limestone; calcitic below, dolomitic toward top; gray, thin-bedded; forms a great cliff. Fusulinids abundant in lower part and scarcer toward top. At base contains the fusulinids and other foraminifers *Schubertella kingi?* Dunbar and Skinner, *Pseudo fusulina powwowensis?* (Dunbar and Skinner), *Parafusulina linearis* (Dunbar and Skinner) var., and *Schwagerina bellula?* Dunbar and Skinner (F 2693; field label Ph 15). Near middle contains *Geinitzina* sp., *Schubertella kingi?* Dunbar and Skinner, *Parafusulina linearis* (Dunbar and Skinner) var., and *Pseudoschwagerina texana* Dunbar and Skinner (F 2714; field label Ph 16) ---- 195
3. Limestone, marly, gray; forms ledges; contains abundant fusulinids in lower half. Contains the fusulinids and other foraminifers *Osagia incrustata* Twenhofel (algal-foraminiferal colonies), a tolypamminid, *Trepeilopsis* sp., textulariids, *Spandelina* sp., *Endothyra* sp., *Tetrataxis* sp., a millerellid, *Staffella* sp., *Ozawainella?* sp., *Pseudofusulina powwowensis* (Dunbar and Skinner, ?*Schwagerina bellula* Dunbar and Skinner, *Parafusulina linearis* (Dunbar and Skinner), and *Pseudoschwagerina beedei* Dunbar and Skinner (F 2690; field label Ph 14) ---- 20

Powwow Member:

2. Limestone, dolomitic, sandy, massive; contains quartz pebbles in lower part. Upper part contains many small unidentifiable fusulinids (F 2711; field label Ph 13) ---- 90
1. Conglomerate, yellow; made up of limestone pebbles, with a dolomitic matrix toward top ---- 48

Angular unconformity.

Red sandstone of Hazel Formation at base of section.

Summary of section 26

Hueco Limestone:

Part of main body of formation exposed ---- 605

Powwow Member ---- 138

Part of Hueco Limestone exposed ---- 743

FOSSIL COLLECTIONS FROM HUECO LIMESTONE NEAR SHEEP PEAK

No stratigraphic sections were measured on Sheep Peak, or near it, but the fossils listed below were collected from the Hueco Limestone on the peak, and in surrounding areas. Collections were made by J. Brookes Knight in 1936 and 1938; fusulinids and other foraminifers were identified by L. G. Henbest and larger fossils by P. E. Cloud, Jr., and E. L. Yochelson (written commun., 1955, 1954).

USGS 8560, F 2712 (field label Ph. 25).—Hueco Limestone, lower part of main body of formation, north slope of Sheep Peak (northeastern part of sec. 18, Block 53½). Contains the fusulinids ?*Schwagerina bellula* Dunbar and Skinner, *Parafusulina* cfr. *P. linearis* (Dunbar and Skinner), and ?*Pseudoschwagerina beedei* Dunbar and Skinner; the brachiopods *Meekella* sp. and *Linoproductus* sp.; and the gastropod *Straparollus* (*Euomphalus*) sp. indet.

USGS 8559 (field label Ph 24).—Hueco Limestone, basal part of main body of formation, lying directly on red sandstone of Hazel Formation, the Powwow Member being missing at the locality. Knoll 1½ miles north-northwest of Sheep Peak (northwestern part of sec. 13, Block 53½). Contains the brachiopod *Linoproductus* sp.

USGS 8560a, F 2701 (field label Ph 28).—Hueco Limestone main body of formation. Three miles east-northeast of Sheep Peak on south side of valley of Deer Creek, south of Cox Mountain fault, in bed of a dry creek (center of sec. 15, Block 54½). Contains the fusulinids and other foraminifers *Geinitzina* sp., *Spandelinoides* sp., *Schubertella* sp., *Triticites subventricosus* Dunbar and Skinner, *Pseudofusulina*? sp., and *Pseudoschwagerina beedei* Dunbar and Skinner.

USGS 8560a, F 2695 (field label Ph. 29).—Hueco Limestone, main body of formation. Four miles east-northeast of Sheep Peak on ridge north of valley of Deer Creek, north of Cox Mountain fault (center of sec. 14, Block 54½). Contains the fusulinids and other foraminifers *Climcammina* sp., *Geinitzira* sp., *Spandelina* sp., *Tetrataxis* sp., *Schubertella kingi* Dunbar and Skinner, *Schwagerina bellula* Dunbar and Skinner, *Triticites* spp., *Parafusulina linearis*? (Dunbar and Skinner), and *Pseudoschwagerina texana* Dunbar and Skinner var.

USGS 8560a, F 2704 (field label Ph 27).—Hueco Limestone, main body of formation. Four and a quarter miles east of Sheep Peak and 1¼ miles south of Bat Cave, on rim of Sierra Diablo escarpment, in upfaulted block south of Cox Mountain fault (center of east line of sec. 17, Block 54½). Contains the fusulinids and other foraminifers *Endothyra*? sp., *Schubertella kingi*? Dunbar and Skinner, *Triticites* aff. *T. subventricosus* Dunbar and Skinner, and *Schwagerina* sp.

USGS 14474 (field label C 32).—Hueco Limestone, main body of formation. Four miles west-northwest of Sheep Peak at north end of low ridge, south of Sheep Peak fault (center of west line of sec. 13, Block 52½). Contains the gastropod *Stegocoelia* n. subgen. n. sp.

USGS 14424 (field label C 1).—Hueco Limestone, main body of formation. Three miles west-northwest of Sheep Peak at crest of ridge, north of Sheep Peak fault (northeastern part of sec. 13, Block 52½). Contains the brachiopod *Composita* cf. *C. subtilita* (Hall); a parallelodontid pelecypod; and the gastropods *Bellerophon parvicristatus* Yochelson, *Meekospira* sp., a murchisonid, *Naticopsis* sp., *Peruvispira* sp., *Stegocoelia*? sp., *Straparollus* (*Euomphalus*) *cornudanus* (Shumard), and *Worthenia* sp.

SECTION 27. SECOND SECTION SOUTH OF VICTORIO PEAK

The following is a section of the Hueco and Bone Spring Limestones on the escarpment of the Sierra Diablo at the upper end of the Victorio flexure 2¼ miles south of Victorio Peak (southwestern part of sec. 19, Block 43). The section was measured by J. Brookes Knight in 1938. Larger fossils were identified by P. E. Cloud, Jr., and E. L. Yochelson and fusulinids and other foraminifers by L. G. Henbest (written commun., 1954, 1955).

	Feet
Top of ridge above escarpment; no higher beds exposed.	
Bone Spring Limestone:	
19. Limestone, dolomitic; forms a cliff; approximate thickness	200
18. Shale, yellow; interbedded with limestone and limestone-pebble conglomerate, both very fossiliferous. Unit dips steeply northward and thins abruptly, being little more than 75 ft thick a quarter of a mile to the north. Contains the sponge *Heliospongia vokesi* R. H. King; colonial, semicolonial, and cup corals; the brachiopods *Buxtonia* (*Kochiproductus*) *victorioensis* King, *Dictyoclostus* (*Chaoiella*) *guadalupensis* (Girty), *Enteletes* sp., "*Marginifera*" cf. "*M.*" *walcottiana* (Girty), and *Stenocisma* cf. *S. inequalis* (Girty); and the gastropod *Bellerophon deflectus* Chronic. Fusulinids and other foraminifers include textulariids, *Spandelina* sp., *Geinitzina* sp., *Textrataxis* spp., *Staffella* sp., *Pseudoschwagerina uddeni* (Beede and Knicker), *Parafusulina schucherti*? Dunbar and Skinner, *P. attenuata*? Dunbar and Skinner, and *P.* spp. (USGS 14454, F 9827; field label C 25 C). The fusulinids are exceedingly abundant, but their tests are commonly abraded or broken, after lithification but before incorporation in the sediment. Hueco and Bone Spring fusulinids have been mixed by redeposition, the specis of *Pseudoschwagerina* representing the former, and the two species of *Parafusulina* representing the latter	215
17. Limestone, dolomitic, massive	45
16. Slope, with limestone float blocks that contain *Leptodus* and other fossils of Bone Spring aspect	50
15. Limestone, dolomitic; forms slopes and ledges; contains poorly preserved fusulinids as well as larger fossils	150
14. Limestone, dolomitic, massive; forms a cliff	30
13. Limestone, dolomitic, gray; forms ledges on slope; contains silicified fossils of Bone Spring aspect	30
12. Slope; no exposure	45
11. Limestone, massive, lenticular, reefy; in part brecciated; contains a few silicified fossils	20
10. Limestone, thin-bedded; contains nodules of gray chert	5

Bone Spring Limestone—Continued *Feet*

9. Limestone, conglomeratic or bioclastic, gray, thin-bedded; forms ledges. Contains cup corals and a few silicified brachiopods of Bone Spring aspect, including *Enteletes*. Fusulinids and other foraminifers include textulariids, *Geinitzina* sp., *Spandelina* sp., *Spandelinoides* sp., *Tetrataxis* spp., *Staffella*? sp., ?*Schubertella kingi* Dunbar and Skinner, *Pseudoschwagerina laxissima*? (Dunbar and Skinner), *Paraschwagerina* sp., *Pseudoschwagerina uddeni* (Beede and Knicker), and ?*Schwagerina compacta* (White) (USGS 14453, F 3806; field label C 25 B). Most of the identified species of fusulinids are characteristic of the Hueco, rather than of the Bone Spring, but the bioclastic nature of the rocks suggests possible redeposition — 65

Unconformity (?).

Hueco Limestone:

Main body of formation:

8. Limestone, dolomitic, granular, gray-buff, very massive; contains molds of very small fusulinids — 100
7. Limestone, dolomitic, gray-buff, massive; weathers to fairly smooth surfaces; forms cliffs. Contains molds of very small fusulinids in upper half — 140
6. Limestone, marly, and marl; interbedded with ledge-making layers of slightly dolomitic limestone. Lower part of unit contains a small cup coral cf. *Caninia* sp.; the annelid *Spirorbis* sp.; and the brachiopods *Dictyoclostus* (n. subgen.) cf. *D. hessensis* (King), *D. wolfcampensis* (King), *Aulosteges*?, *Waagenoconcha* n. sp., *Linoproductus* sp., "*Marginifera*" n. sp. aff. "*M.*" *lasallensis* (Worthen), *Composita* sp., and *Neospirifer* spp. The same strata contain the fusulinids and other foraminifers *Climacammina* sp., *Spandelina* sp., *Geinitzina* or *Spandelina* sp., *Endothyra*? sp., *Tetrataxis* sp., *Schubertella kingi*? Dunbar and Skinner, *Pseudofusulina uddeni*? (Dunbar and Skinner), *Pseudofusulina* sp. confr. *P. uddeni* (Dunbar and Skinner) and *Parafusulina* aff. *P. linearis* (Dunbar and Skinner) (USGS 14452, F 9823; field label C 25 A). The last species occurs in a limestone very different litholigically from that containing the other species; field relations between the two rock types are unknown — 135
5. Limestone, thin-bedded; contains many fusulinids, productid brachiopods, and bellerophontid gastropods — 18

Powwow Member:

4. Sandstone; marly in upper part; some layers fine grained and red, others coarse grained and yellow; forms a slope — 70
3. Sandstone, red, fine-grained; with a few ledges of coarse conglomeratic yellow sandstone — 40
2. Sandstone, coarse to conglomeratic, yellow; mostly poorly exposed on slope, which is covered by pebbles weathered from conglomerate — 70

Hueco Limestone—Continued

Powwow Member—Continued *Feet*

1. Conglomerate, sandy; forms ledges at base and top. Contains angular to rounded pebbles and cobbles, consisting of red sandstone from Hazel Formation, but including dolomitic and calcitic limestone, quartz, quartzite, and rhyolite — 68

Angular unconformity.

Red sandstone of Hazel Formation at base of section.

Summary of section 27

Part of Bone Spring Limestone exposed		855
Hueco Limestone:		
Main body of formation	393	
Powwow Member	248	
Total Hueco Limestone		641

SECTION 28. FIRST SECTION SOUTH OF VICTORIO PEAK

The following is a section of the Hueco, Bone Spring, and Victorio Peak Limestones, about 1½ miles south of Victorio Peak (from the southeastern to northwestern parts of sec. 19, Block 43). The section begins on the southeast near the northernmost outcrop of red sandstone of the Hazel Formation and extends northwestward across successive ledges and slopes to the summit of the peak marked by elevation point 6353. The section was measured by P. B. King and R. E. King in 1928. Brachiopods in the collections made were identified by R. E. King (1931) and fusulinids by Dunbar and Skinner (1937).

Top of peak 6353; no higher beds exposed.

Victorio Peak Limestone: *Feet*

25. Limestone, light-gray, massive; forms a cliff. The unit is approximately equivalent to the lower part of the Victorio Peak Limestone on nearby Victorio Peak, although its lower part appears to interfinger in that direction with shale and marl of Bone Spring Limestone — 130

Intergradation.

Bone Spring Limestone:

24. Limestone, gray; forms two thick cliff-making units and some minor ledges, separated by thinner beds of buff sandy marl. The limestone units wedge out northward into marl not far north of peak 6353. Marls north of the peak contain the brachiopods *Enteletes dumblei* Girty, *Chonetes permianus* Shumard, *Productus ivesi* Newberry, *P. schucherti* King, *Marginifera cristobalensis* Girty, *M. manzanica* Girty, *Aulosteges magnicostatus* Girty, *Lyttonia nobilis americanus* (Girty), *Camarophoria venusta* Girty, *Spirifer* (*Neospirifer*) *pseudocameratus* Girty, and *Composita mira* (Girty) (REK 484) — 170
23. Limestone, finely crystalline, gray; weathers white; in 1-ft beds — 16
22. Marl, buff, sandy — 50
21. Limestone, dolomitic, finely crystalline, gray; in 1- to 2-ft beds; contains irregular chert nodules. Weathers to light-gray smooth surfaces and forms a receding slope — 303

Bone Spring Limestone—Continued

	Feet
20. Limestone, black, thin-bedded	20
19. Limestone, dolomitic, finely crystalline; in 1- to 2-ft beds. Weathers to gray-brown granular surfaces and forms massive ledges	63
18. Limestone, black, platy; weathers gray; interbedded with drab shale above. A conglomeratic layer in lower part contains *Productus ivesi* Newberry (REK 489)	175
17. Limestone, dolomitic, finely crystalline, gray; with faint bedding planes, moderately closely spaced; weathers drab gray. Thickens northward along outcrop to as much as 150 ft	45
16. Shale, drab; weathers buff; with thin seams of shaly sandstone and some beds of fossiliferous limestone	54
15. Limestone, finely crystalline; contains siliceous masses and poorly preserved slicified fossils	1
14. Shale, drab; weathers buff; some interbedded thin limestone layers. Fossils in the limestone layers, and weathered from the shale, include the fusulinids *Parafusulina schucherti* Dunbar and Skinner and *Parafusulina* sp., and the brachiopods *Rhipidomella mesoplatys baylorensis* King, *Enteletes dumblei* Girty, *Derbya nasuta* Girty, *Chonetes biplicatus* King, *Marginifera sublaevis* King, *M.? whitei King*, *Prorichthofenia uddeni* (Böse), *Spirifer marcoui infraplicata* King, *Squamularia guadalupensis* (Shumard), and *Spiriferina laxa*? Girty (REK 485, D & S 127)	17
13. Limestone, dolomitic, drab to orange-brown; crowded with fusulinids in upper part	75
12. Limestone, dense to granular, gray; weathers gray brown; in 2-ft beds, separated by beds of shale The limestone beds are crowded with fossils, which are silicified on the surface. Collections from several beds include the brachiopods *Rhipidomella hessensis* King, *Enteletes dumblei* Girty, *E. liumbonis* King, *Streptorhynchus pygmaeum* Girty, *Meekella attenuata* Girty, *Chonetes spinoliratus diabloensis* King, *Productus dartoni* King, *P. ivesi* Newberry, *Marginifera sublaevis* King, *M? whitei* King, *Strophalosia hystericula* Girty, *Prorichthofenia likharewi* King, *P. teguliferoides* King (types), *Lyttonia nobilis americanus* (Girty), *Pugnoides elegans* (Girty), *Spiriferina angulata* King (type), *Hustedia hessensis* King, and *Composita subtilita* (Hall) (REK 47 8,419)	75

Unconformity(?).

Hueco Limestone:

Main body of formation:

	Feet
11. Limestone: dolomitic in part; finely granular; gray-brown; faintly bedded; forms 10- to 20-ft ledges; contains irregular chert masses	243
10. Limestone, dolomitic, dense, faintly bedded; weathers to a rough surface, containing irregular chert masses	27
9. Limestone, dense, thin-bedded, gray; weathers light gray; contains spherical to lenticular chert masses. *Composita* and other silicified fossils observed	74
8. Limestone, dense, thin-bedded, gray, cherty; contains many fusulinids	17
7. Limestone, finely crystalline, dark gray; weathers buff; in 1-ft beds; contains the fusulinid *Schwagerina linearis* Dunbar and Skinner, and the brachiopods *Productus dartoni* King (type), *Productus semistratus* Meek, *Linoproductus cora* (d'Orbigny), and *Composita mira* (Girty) (REK 460, D & S 99)	27

Powwow Member:

	Feet
6. Shale; drab to gray, passing into red below; much concealed by talus	48
5. Shale, sandy, maroon-red	27
4. Sandstone, coarse to conglomeratic, brown	17
3. Shale, sandy, maroon-red	27
2. Shale, sandy, brown; interbedded with thin sandstone layers	4
1. Sandstone, coarse, conglomeratic, brown; contains subangular to rounded pebbles, mostly limestone and chert, but with a few of quartz, rhyolite, and schist; no pebbles of red sandstone from rock beneath	2

Angular unconformity.

Red sandstone of Hazel Formation at base of section.

Summary of section 28

Part of Victorio Peak Limestone exposed		130
Bone Spring Limestone		1,064
Hueco Limestone:		
Main body of formation	388	
Powwow Member	125	
Total Hueco Limestone		513

COLLECTIONS FROM HUECO AND BONE SPRING LIMESTONES ON VICTORIO FLEXURE WEST OF VICTORIO CANYON

No stratigraphic sections were measured of the Permian rocks on the Victorio flexure west of sections 27 and 28, or west of the front of the Sierra Diablo, but fossils were collected at various localities in the Hueco Limestone and lower part of the Bone Spring Limestone, which are listed below. The collections were made in 1936 and 1938, mainly by J. B. Knight, but in part by P. B. King; fusulinids and other foraminifers were identified by L. G. Henbest, and larger fossils by P. E. Cloud, Jr., and E. L. Yochelson (written commun., 1954, 1955).

USGS 8544 (*field label Pb 13*).—Bone Spring Limestone, limestone layers above unit of limestone-pebble conglomerate. East side of Victorio Canyon, on end of spur a quarter of a mile northwest of BM 6148 (north-central part of sec. 18, Block 43). Contains the brachiopods *Avonia* spp., *Buxtonia* (*Kochiproductus*) *victorioensis* King, *Chonetes* large sp., *Enteletes* sp., *Leptodus* sp., orthotetacean indet., *Rhipidomella* sp., and *Stenocisma* sp.; the pelecypod *Acanthopecten* sp.; and the gastropods *Anomphalus* sp., *Babylonites* sp., and a pleurotamarian. A shark's tooth was observed in the field.

USGS 8543, F 2692 (field label Pb 12).—Bone Spring Limestone, limestone layers interbedded with unit of limestone-pebble conglomerate. West of Victorio Canyon on south side of ridge, and three-quarters of a mile north-northeast of Estes Place (west-central part of sec. 14, Block 43). Contains the fusulinids and other foraminifers *Climacammina* sp., *Spandelinoides* sp., *Pseudofusulina setum* (Dunbar and Skinner) var., *Parafusulina schucherti* Dunber and Skinner, *P. imlayi* Dunber, and *P.* spp.; the sponges *Fissispongia* n. sp., *Girtyocoelia dunbari* R. H. King, *Heliospongia vokesi* R. H. King, and *Stereodictyum orthoplectum* Finks; the coral *Lophophyllum* sp.; the bryozoan *Fistulipora* sp.; a crinoid calyx; the brachiopods *Aulosteges*? sp., *Enteletes* cf. *E. dumblei* Girty, *Hustedia* sp., *Isogramma* sp., productid indet., *Scacchinella* sp., and *Wellerella* sp.; a pelecypod with revolving lirae; and the gastropods *Glabrocingulum* sp., "*Trachydomia*" sp., and "*Worthenia*" sp.

USGS 8542, F 2713 (field label Pb 11).—Bone Spring Limestone, from limestone beds interbedded near top of lowest unit of thin-bedded dolomite. West of Victorio Canyon on south side of ridge a mile east of Estes Place (center of sec. 17, Block 43). Contains the fusulinids and other foraminifers *Geinitzina* sp., *Spandelinoides* sp., *Endothyra* sp., a millerellid, *Parafusulina diabloensis* Dunbar and Skinner, and *P. imlayi* Dunbar var.; the corals *Cladochonus* sp. and *Triplophyllum* sp.; the bryozoan *Cystodictya* sp.; and the brachiopods *Derbyia* sp., *Entelets* cf. *E. dumblei* Girty, *Leptodus* sp., *Meekella difficilis* Girty, *Neospirifer* sp., productids indet., "*Spiriferina*" sp., *Streptorhynchus* sp., and *Wellerella* sp.

USGS 14435, F 9810 (field label C 12).—Hueco Limestone, near base, on slope above inlier of Montoya Dolomite. Northwest side of Victorio Canyon 1½ miles northest of Estes Place (northeastern part of sec. 14, Block 43). Fusulinids and other foraminifers occur in a detrital conglomeratic limestone, in both the matrix and the pebbles, all the free fusulinid shells in the matrix being abraded. Field relations indicate that the strata are of Hueco age, and this is confirmed by the fusulinid species, but their manner of occurrence indicates that they have been redeposited in their present position. The foraminifers include *Geinitzina* sp., *Spandelina* sp., *Endothyra* sp., a bradyinid, *Tetrataxis* sp., *Staffella* sp., *Schubertella kingi*? Dunbar and Skinner, *Parafusulina linearis* (Dunbar and Skinner), *Pseudofusulina emaciata* (Beede), and *Pseudoschwagerina beedei* Dunbar and Skinner.

USGS 14429, F 9807 (field label C 6).—Hueco Limestone, upper part. In Victorio Canyon, a few feet above channel, near junction of a side canyon from southeast, 2 miles east-southeast of Estes Place (southwestern part of sec. 16, Block 43). Contains the fusulinids and other foraminifers *Tetrataxis* sp., spanelinids, *Ozawainella*? sp., *Schubertella kingi* Dunbar and Skinner, *Pseudofusulina* aff. *P. powwowensis* (Dunbar and Skinner), *P.* sp., *Schwagerina* sp., *Parafusulina*? sp.; the sponge *Heliospongia vokesi* R. H. King; cup corals; rhomboporoid bryozoans; crinoid columns and echinoid plates; the brachiopods *Chonetes* sp., *Dictyoclostus* (n. subgen.) cf. *D. hessensis* (King), *Glossothyris* sp., and *Punctospirifer* sp.; and the gastropods "*Anomphalus*" sp., *Straparollus* (*Euomphalus*) sp., a bellerophontid, a murchisonid, and a pleurotomarian.

USGS 14436, F 9811 (field label C 13).—Hueco Limestone, upper part, about a quarter of a mile southwest of and upstream from locality C 6, 1½ miles southeast of the Estes Place (southwest cor. sec. 18, Block 43). All the fusulinid shells in this collection are maturely rounded, but are not fragmented, and have clearly been transported and redeposited. Field relations indicate that the strata containing them are of Hueco age, and all the identified species are of Hueco type. Contains the fusulinids and other foraminifers *Climacammina* sp., *Staffella* sp., *Schubertella kingi* Dunbar and Skinner, *Parafusulina linearis* (Dunbar and skinner), *Pseudofusulina*? sp., *Schwagerina bellula*? Dunbar and Skinner, and *S.*? sp.

USGS 8560a, F 2718 (field label Ph 26).—Hueco Limestone, three-quarters of a mile southwest of Estes Place (southwestern part of sec. 16, Block 43). Contains the fusulinids and other foraminifers *Geinitzina* sp., *Tetrataxis* sp., *Staffella* sp., a millerellid, *Ozawainella*? sp., *Pseudofusulina* aff. *P. powwowensis* (Dunbar and Skinner), *P.* sp., and *Schwagerina*? sp.

USGS 14428, F 9806 (field label C 5).—Hueco Limestone, tilted on Victorio flexure. Strike ridge 6 miles west-northwest of Estes Place and 2½ miles east of Dagger Tank (northwestern part of sec. 3, Block 44). Contains the fusulinids and other foraminifers *Climacammina* sp., a spandelinid, *Tetrataxis* sp., *Schubertella*? sp., *Pseudofusulina* cfr. *P. powwowensis* (Dunbar and Skinner), and *P.* sp.

SECTION 29. VICTORIO PEAK

The following sections are of the Hueco, Bone Spring, and Victorio Peak Limestones on the east slope of Victorio Peak west of the West-Pyle Cattle Co. headquarters, or Corn Ranch (west-central part of sec. 6, Block 66, Twp. 6, into the southeastern part of sec. 10, Block 43). Two sections were measured here during the investigation, both of which are given, because each contains important collections of identified fossils, and because the two sections have different scopes and were measured at somewhat different places, thus illustrating the varying stratigraphic features of the locality. These and other sections which have been measured here were discussed by Dunbar (1953, p. 802–809).

Section 29a (same as section C of Dunbar, 1953, fig. 2 and pl. 1A) was measured by P. B. King and R. E. King in 1928, and begins nearly due west of the ranch, at the foot of the Sierra Diablo escarpment, on the north side of a reentrant valley, passes south of a prominent limestone lens ("Kříž lens") at the top of the lower cliffs, and extends up an eastern spur of Victorio Peak nearly to its summit, or as far as the cliffs of the Victorio Peak Limestone could be scaled. Brachiopods collected in this section were identified by R. E. King (1931) and fusulinids by Dunbar and Skinner (1937).

Section 29b (same as section B of Dunbar, 1953, fig. 2 and pl. 1A) was measured by J. Brookes Knight in 1931, and begins about half a mile north of the first section in the next reentrant valley at the foot of the Sierra Diablo escarpment, but converges upward with the first section, passing north of the prominent limestone lens and ending near the middle of the Bone Spring Limestone, or above its highest abundantly fossiliferous layers. Larger fossils collected in this section were identified by P. E. Cloud, Jr., and E. L. Yochelson and fusulinids and other foraminifers by L. G. Henbest (written commun., 1955, 1954).

Section 29a

Top of Victorio Peak; no higher beds exposed.

Victorio Peak Limestone (type section): *Feet*

31. Rocks similar to unit 30, extending to top of peak, forming an unscalable cliff; thickness estimated — 200
30. Limestone, medium-crystalline, light-gray; contains subspherical chert nodules as much as 4 in. in diameter. Bedding planes are a foot or two apart, but the rock is coherent and weathers massive, forming remarkably fluted cliffs. Upper 200 ft is more dolomitic than remainder, and weathers buff and pitted. Strata 100 ft above base contain the fusulinid *Schwagerina setum* Dunbar and Skinner, and the brachiopods *Waagenoconcha montpelierensis* (Girty), *Productus ivesi* Newberry, *Spirifer marcoui infraplicata* King, and *Spirifer* (*Neospirifer*) *pseudocameratus* Girty (REK 496, REK 500; D & S 132) — 450
29. Limestone, medium-crystalline, light-gray, cherty; thin bedded but coherent; forms massive outcrops and a bench at top. Contains the brachiopods *Meekella difficilis* Girty, *Chonetes subliratus* Girty, *Productus ivesi* Newberry, *Lyttonia nobilis americanus* (Girty), *Spirifer marcoui infraplicata* King, *Hustedia meekana* (Shumard), and *Composita mexicana* (Hall) (REK 499). In 1936 a collection was made from approximately this unit, from cliff falls on the southeast side of Victorio Peak; according to Cloud and Yochelson it contains a cup coral; rhomboporoid, fistuliporoid, and other bryozoans; the brachiopods *Avonia* sp., *Buxtonia* (*Kochiproductus*) *victorioensis* King, *Chonetes* sp., "*Marginifera*" spp., productid indet., *Prorichthofenia* sp., *Rhipidomella* sp., and *Wellerella* cf. *W. elegans* (Girty); and the pelecypod *Streblopteria* sp. (USGS 8545; field label Pb 14) — 150

Intergradation.

Bone Spring Limestone:

28. Limestone, dark-gray to black; in 6-in to 1-ft beds; contains small chert nodules — 33
27. Limestone, fine-grained, gray; in 1- to 2-ft beds; contains small subspherical chert nodules and a few fossils — 55
26. Limestone, black, dense, platy; in moderately thick beds; contains thin wavy laminae; forms steep slope below Victorio Peak — 247
25. Limestone, black, dense; platy to papery, fissile; weathers buff or brown. Top of unit forms summit of an outer spur of Victorio Peak — 154
24. Limestone, black, dense, platy; weathers buff; in 10- to 20-ft units; interbedded with chert in 1- to 3-ft beds; and gray fossiliferous limestone — 71
23. Limestone, gray; contains abundant silicified fossils, mostly massive bryozoans although some beds are crowded with fusulinids. Contains the fusilinids *Parafusulina schucherti* Dunbar and Skinner, and *Parafusulina* sp., and the brachiopod *Productus ivesi* Newberry (REK 477, D & S 131) — 25

Bone Spring Limestone—Continued *Feet*

22. Limestone, fine-grained, white; with indistinct bedding; forms a cliff that rims the outer spurs of Victorio Peak — 100
21. Covered, except for a few ledges of fossiliferous limestone like those beneath — 50
20. Limestone, fine-grained, gray; forms a ledge; contains abundant silicified fossils. These include the fusulinid *Parafusulina diabloensis* Dunbar and Skinner, and the brachiopods *Enteletes dumblei* Girty, *Meekella attenuata* Girty, *Derbya nasuta* Girty, *Chonetes biplicatus* King, *C. spinoliratus diabloensis* King, *Productus ivesi* Newberry, *Marginifera sublaevis* King, *M.*? *whitei* King, *Prorichthofenia teguliferoides* King, *Lyttonia nobilis americanus* (Girty), *Spiriferina angulata* King, and *Hustedia hessensis* King (REK 476, D & S 130); massive bryozoans also observed — 5
19. Limestone, black, siliceous, thin-bedded to platy; with some interbedded 6-in to 2-ft layers of gray granular fossiliferous limestone. These contain fusulinids; massive bryozoans; crinoid stems, the brachiopods *Marginifera*, *Pugnax*, and various productids; and the gastropod *Platyceras* — 66
18. Limestone; in 1-ft ledges; separated by platy black siliceous limestone; forms slopes. The ledges contain the fusulinids *Parafusulina diabloensis* Dunbar and Skinner and a slender species of *Parafusulina;* and the brachiopods *Prorichthofenia teguliferoides* King, and *Pugnoides elegans* (Girty) (REK 475, D & S 129) — 67
17. Limestone, fine-grained; in 2- to 6-ft beds; gray, weathering light gray and to a rough surface. Contains silicified fossils, including, fusulinids, cup corals, and *Hustedia* — 22
16. Limestone, black, siliceous, thin-bedded. Contains *Hustedia hessensis* King and *Composita subtilita* (Hall) (REK 474); productids also observed — 73

Unconformity (?).

Hueco Limestone:

Main body of formation:

15. Limestone lens or reef (termed "Kříž lens" by Dunbar, 1953, p. 802, and "Huecoan bioherm" by Stehli, 1954, p. 282), which forms prominent cliff about a quarter of a mile in length, at top of lower bench of eastern spur of Victorio Peak. Section crosses south edge of lens, which tapers southward, and thickens northward to more than 150 ft, the overlying beds through unit 18 wedging out against it. Consists of dense faintly bedded limestone, weathering to light-gray rough surfaces, containing some small chert masses. Abundant cup corals, massive bryozoans, *Hustedia*, and a large *Omphalotrochus* observed — 115
14. Limestone, dense, gray, thin-bedded; with shaly partings; bedding surfaces somewhat wavy; some layers contain much chert. Contains the fusulinids *Triticites victorioensis* Dunbar and Skinner and *Schwagerina laxissima* Dunbar and Skinner; and

Section 29a—Continued

Hueco Limestone—Continued

Main body of formation—Continued — *Feet*

the brachiopods *Productus ivesi* Newberry *Buxtonia peruviana* (d'Orbigny), and *Avonia boulei* (Kozlowski) (REK 472, D & S 100) — 44

13. Limestone, dense, light-gray; in 1- to 3-ft beds; contains small subspherical chert nodules; forms a massive cliff. Contains slender fusulinids as much as half an inch in length, and the brachiopods *Chonetes subliratus* Girty, *Productus ivesi* Newberry, and *Linoproductus cora* (d'Orbigny) (REK 471) — 50
12. Limestone, thin-bedded to platy, dark-gray; weathers pale buff — 4
11. Limestone, finely crystalline, gray nodular; contains numerous fossils that appear in cross section; a *Chonetes* observed in float — 25

Powwow Member:

10. Sandstone, shaly, poorly consolidated, buff; partly covered by wash from above — 16
9. Sandstone, calcareous, medium-grained; in part cross bedded; contains rounded limestone pebbles; forms two ledges. Imprints of long, slender fusulinids observed on bedding surfaces — 22
8. Shale, reddish, sandy, poorly exposed — 33
7. Conglomerate, red to buff; formed of pebbles of red sandstone, limestone, and chert, in a coarse sandstone matrix; grades upward into coarse red sandstone — 17
6. Shale, sandy, maroon-red, poorly exposed — 13
5. Limestone, dense, splintery, brown — 1
4. Covered — 6
3. Limestone, dense, splintery, brown — 2
2. Covered — 7
1. Sandstone, gray, quartzitic — 5

Base of exposure at edge of alluvial fan; probably near base of Hueco Limestone and Powwow Member.

Section 29b

Bone Spring Limestone:

19. Limestone, black, unfossiliferous; extends up spur to base of Victorio Peak Limestone; not measured. (See section 29a) — (?)
18. Limestone, black, siliceous, thin-bedded; with interbedded 1-ft ledges of dark-gray bioclastic fossiliferous limestone. These contain the fusulinids *Ozawainella* sp., *Staffella*? sp., *Parafusulina imlayi* Dunbar, *P.* aff *P. bösei* Dunbar and Skinner, and *Parafusulina*? sp.; the sponges *Fissipongia* n. sp., *Lyssacina* incertae sedis, and spicules; a cup coral; the bryozoans *Fenestella* sp., *Fistulipora* sp., *Septopora* sp., and *Striatopora* sp.; the brachiopods *Avonia* sp., *Buxtonia* (*Kochiproductus*) *victorioensis* King, *Chonetes consanguineus* Girty, *C.* (*Chonetinella*) *victorianus* (Girty), *Crurithyris* sp., *Derbyia* sp., *Enteletes* sp., *Hustedia mormoni* (Marcou), *H.* sp., *Leptodus* sp., "*Marginifera*" cf. "*M.*" *walcottiana* (Girty), "*M.*" (*Kozlowskia*) aff. "*M.*" (*K.*) *wabashensis* (Norwood and Pratten), "*M.*" sp., *Meekella* sp., productids indet., *Rhipidomella* sp., *Scacchinella* sp., *Spiriferina* sp., and *Wellerella* sp.; the pelecypod *Acanthopecten* sp.; and the gastropods *Apachella* sp., *Euconispira pulchra* Batten, *Glabrocingulum* sp., *Platyceras* sp., and *Shewdagonia*? sp. (USGS 8561, F 2710; field label Pb 7) — 115

Bone Spring Limestone—Continued — *Feet*

17. Limestone, dark-gray; in 1- to 2-ft beds; interbedded with thin-bedded siliceous black limestone — 35
16. Limestone, gray, massive; forms a ledge; contains silicified fossils. The limestone is bioclastic, consisting of fragments of calcareous fossil debris of sand to pebble size, with some larger angular limestone cobbles, all variably silicified. Contains the fusulinids and other foraminifers *Climacammina* sp., *Geinitzina* sp., *Spandelina* sp., *Tetrataxis* spp., *Ozawainella* sp., **Schubertella kingi* Dunbar and Skinner, *Boultonia* aff. *B. rawi* Lee, ?*Schwagerina pseudoregularis* Dunbar and Skinner, ?*S. gumblei* Dunbar and Skinner, **Pseudoschwagerina gerontica* Dunbar and Skinner var., **P. texana*? Dunbar Skinner, *Parafusulina diabloensis* Dunbar and Skinner, **P. linearis* Dunbar and Skinner, and var., *P. schucherti* Dunbar and Skinner and *P.* spp. (F 2716; field label Pb 6). The fusulinids are preserved partly as whole shells, partly as fragments and detritus with varying degrees of rounding. They represent a depositional aggregate in which forms characteristic of the Hueco (marked by asterisk) have been reworked and mixed with those characteristic of the Bone Spring. Unit 16 also contains the sponge *Heliospongia vokesi* R. H. King; the corals *Cladochonus* sp., *Lonsdaleia*? sp., and *Triplophyllum* sp.; the bryozoans *Chainodictya*? sp., *Cystodictya* sp., *Domopora*? sp., *Fistulipora* sp., *Septopora* sp., and *Striatopora* sp.; the brachiopods *Chonetes* (*Chonetinella*) *victorianus* (Girty), *Enteletes* cf. *E. dumblei* Girty, *Hustedia mormoni* (Marcou), "*Marginifera*" cf. "*M.*" *sublaevis* King in part, and "*M.*" (*Kozlowskia*) cf. "*M.*" *capaci* (d'Orbigny); the gastropods *Babylonites* sp. and *Straparollus* (*Euomphalus*) *glabribasis* Yochelson; an annelidlike *Spirorbis;* and solenoporoid and other algae (USGS 8562, field label Pb 6) — 15
15. Limestone, gray; in 1- to 2-ft beds; contains silicified fossils; interbedded with thin-bedded black limestone and cherty shale — 30
14. Limestone, massive, gray, bioclastic; with a few embedded angular limestone cobbles; contains silicified fossils of Bone Spring aspect — 15
13. Limestone, gray, fossiliferous; in very irregular 1- to 2-ft beds, interbedded with thin-bedded black limestone and cherty shale — 18

Unconformity (?).

Hueco Limestone:

Main body of formation: *Feet*

12. Northern edge of limestone lens or reef (unit 15 of section 29a); massive limestone with embedded angular fragments of fossiliferous limestone. Contains abraded and rounded fragments of fusulinid shells, probably including *Parafusulina linearis* Dunbar and Skinner, *Pseudofusulina powwowensis* Dunbar and Skinner, ?*Schwagerina bellula* Dunbar and Skinner, and *Pseudoschwagerina* sp. (F 2706, filed label Ph 10) ---- 7
11. Limestone, fine-grained, dark-gray; contains black chert nodules; in 1-ft beds; with marl partings. Contains the fusulinids and other foraminifers *Geinitzina* sp., *Schubertella kingi* Dunbar and Skinner, *Parafusulina linearis* (Dunbar and Skinner) var., *Pseudofusulina franklinensis* (Dunbar and Skinner), and var.; the cup coral *Lophophyllum* sp.; an orthoceratid cephalopod; the gastropod *Omphalotrochus* sp.; and the brachiopods *Avonia* (n. subgen.) cf. *A. boulei* (Kozlowski), *Chonetes* sp., *Dictyoclosfus* (n. subgen.) cf. *D. hessensis* (King), "*Marginifera*" sp,. a productid, *Neospirifer* sp., and *Rhipidomella* sp. (USGS 8556, F. 2721; field label Ph 9) ---- 37
10. Limestone, dolomitic, cherty, light-gray; forms a massive ledge. Near top, contains the fusulinids *Schubertella kingi* Dunbar and Skinner, *Pseudoschwagerina? laxissima* (Dunbar and Skinner), and *Schwagerina bellula* Dunbar and Skinner (F 2687; field label Ph 8; identified by C. O. Dunbar, 1953, p. 804) ---- 32
9. Limestone, very dark gray, cherty; in 2- to 3-ft beds, with marl partings. Contains the fusulinids *Triticites victorioensis* Dunbar and Skinner, *Pseudoschwagerina? laxissima* (Dunbar and Skinner), *Pseudofusulina franklinensis* (Dunbar and Skinner), and *P. texana* Dunbar and Skinner (F 2715; field label Ph 7; identified by C. O. Dunbar, 1953, p. 804); the coral *Lophophyllum* sp.; the bryozoans *Cystodictya* sp. and *Goniocladia* sp.; the pelecypods *Aviculopecten?* sp., *Aviculopinna?* sp., and *Conocardium* sp.; and the brachiopods *Buxtonia* (*Kochiproductus*) *victorioensis* King, *Chonetes* cf. *C. consanguineus* Girty, *Composita* sp., *Derbyia* sp., *Dictyoclostus* (*Chaoiella*) aff. *D. boliviensis* (d'Orbigny), *Enteletes* aff. *E. wordensis* King, *Hustedia* sp., *Linoproductus* large n. sp., "*Marginifera*" *cf.* "*M.*" *wabashensis* (Norwood and Pratten, "*M.*" sp., *Neospirifer* sp., *Rhipidomella* sp., *Spirifer* sp., "*Spiriferina*" sp., and *Waagenoconcha* sp. (USGS 8555; field label Ph 7) ---- 30
8. Limestone, very dark gray, cherty; in 2- to 3-ft beds. Contains few larger fossils, but fusulinids and other foraminifers are abundant, including *Climacammina* sp., *Endothyra* sp., *Geinitzina* sp., *Parafusulina linearis* (Dunbar and Skinner), *P.* sp., *Pseudoschwagerina? laxissima* (Dunbar and Skinner), *P. beedei* Dunbar and Skinner, *Schwagerina bellula?* Dunbar and Skinner, ?*S. bellula* Dunbar and Skinner, *S. knighti* Dunbar and Skinner, *Spandelina* sp., and *Tetrataxis* sp. (F. 2707; field label Ph 6) ---- 33
7. Limestone, dark-gray, massive, cherty; forms a strong ledge. Contains the foraminifers *Geinitzina* sp., juvenaria of fusulinids, and a fragment of a larger fusulinid; a lonsdaleoid coral cf. *Waagenophyllum texanum* Heritsch; and the gastropod *Omphalotrochus* sp. (USGS 8554, F 2689; field label Ph 5) ---- 30

Powwow Member:

6. Limestone, marly, black; interbedded with shale. This unit, and the one next beneath, contain *Parafusulina* ("*Schwagerina*") *linearis* (Dunbar and Skinner) (F 2700; field label Ph 4; identified by C. O. Dunbar, 1953, p. 804); the coral *Syringopora* sp.; the pelecypod *Edmondia* sp; and the brachiopods *Chonetes* n. sp.?, and *Linoproductus* cf. *L. cora* (d'Orbigny) (USGS 8553; field label Ph 4) ---- 15
5. Sandstone, calcareous, yellow, fossiliferous; with interbedded marl; forms a ledge ---- 15
4. Sandstone, yellow; forms a ledge ---- 6
3. Marl, gray, and interbedded yellow sandstone; unfossiliferous ---- 35
2. Sandstone and siltstone, poorly consolidated ---- 55
1. Conglomerate, yellow; contains limestone pebbles; forms a ledge ---- 8

Base of exposure at edge of alluvial fan; probably near base of Hueco Limestone and Powwow Member.

Summary of section 29

Section 29a:		
Part of Victorio Peak Limestone exposed		800
Bone Spring Limestone		968
Hueco Limestone:		
Main body of formation	238	
Part of Powwow Member exposed	122	
Part of Hueco Limestone exposed		360
Section 29b:		
Part of Bone Spring Limestone measured		228
Hueco Limestone:		
Main body of formation	169	
Part of Powwow Member exposed	134	
Part of Hueco Limestone exposed		303

SECTION 30. VICTORIO CANYON

The following is a section of the Hueco and Bone Spring Limestones at the portal of Victorio Canyon, beginning at its channel and proceeding south, up a spur of Victorio Peak to top of outer bench, beyond which beds were not measured (south-central part of sec. 3, Block 66, Twp. 6, into northeastern part of sec. 1, Block

43). The section was measured by J. Brookes Knight in 1936. Larger fossils were identified by P. E. Cloud, Jr., and E. L. Yochelson and fusulinids and other foraminifers by L. G. Henbest (written commun., 1954, 1955). Earlier collections from the same locality have been identified by R. E. King (1931), and Dunbar and Skinner (1937) (REK 459, 470; D & S 101, 102, 103), but their lists are not reproduced here.

Top of outer bench on north spur of Victorio Peak; higher beds, mainly black limestone, not measured.

Bone Spring Limestone: *Feet*

7. Limestone, dolomitic; in 3- to 4-ft ledges, with a pebbly layer 10 ft below top. Contains poorly preserved fossils resembling those beneath. Long, slender fusulinids abundant at top ---- 85
6. Limestone, slightly dolomitic, light-gray; in 2-ft beds. The rock is abundantly fossiliferous, bioclastic, and in part contains limestone pebbles. The pebbles contain a staffellid, abundant *Schubertella kingi* Dunbar and Skinner, *Parafusulina* or *Pseudofusulina* sp., and *Pseudofusulina powwowensis*? (Dunbar and Skinner) var., which are fusulinids of Hueco type. The matrix contains the fusulinids and other foraminifers *Geinitzina* sp., *Tetrataxis* sp., *Quinqueloculina*? sp., *Ozawainella*? sp., *Staffella* sp., **Schwagerina* aff. *S. bellula* Dunbar and Skinner, **Pseudofusulina*? *laxissima* (Dunbar and Skinner) or *P. powwowensis* (Dunbar and Skinner) var., ?*Schwagerina gumblei* Dunbar and Skinner, ?*Parafusulina diabloensis* Dunbar and Skinner, and *P. schucherti* Dunbar and Skinner; the fusulinids are largely of Bone Spring type, with the exception of those marked by an asterisk, which are of Hueco type (F 2723; field label Pb 8). Reworking and mixing of fusulinids and other foraminifers from different stratigraphic levels is indicated. Larger fossils include *Lonsdaleia*? sp., and other cup corals; the bryozoans *Fenestella* sp., *Fistulipora* sp., *Polypora* sp., and *Rhombopora* sp.; crinoid stems; the brachiopods *Chonetes* (*Chonetinella*) *victorianus* Girty, *C.* large sp., *Enteletes* sp., *Hustedia hessensis* King, "*Marginifera*" (*Kozlowskia*) cf. "*M.*" *capaci* (*d'Orbigny*), *Meekella* sp., and *Streptorhynchus* sp.; and the gastropods *Apachella* sp., *Euconispira pulchra* Batten, and *Straparollus* (*Euomphalus*) *glabribasis* Yochelson (USGS 8539; field label Pb 8) ---- 27

Unconformity (?).

Hueco Limestone:

Main body of formation:

5. Limestone, slightly dolomitic, dark-gray, massive; forms cliffs. Fossils scarce and poorly preserved ---- 72
4. Limestone, cherty; forms a slope. Contains the fusulinids and other foraminifers *Climacammina* sp., *Geinitzina* sp., *Spandelinoides*? sp., *Endothyra* sp., *Staffella* sp., *Ozawainella* sp., *Schubertella kingi* Dunbar and Skinner, *Triticites*? spp., *Pseudoschwagerina texana* Dunbar and Skinner, *Pseudofusulina huecoensis* Dunbar and Skinner, *Parafusulina* *linearis* (Dunbar and Skinner), and *Parafusulina* slender sp. (F. 2717; field label Ph 12) ---- 5

Main body of formation—Continued *Feet*

Hueco Limestone—Continued

3. Limestone, slightly dolomitic, dark-gray, cherty, massive; forms cliffs; some beds brecciated. Contains larger fossils like those in unit beneath, such as productids and bellerophontids, but few or no fusulinids ---- 130

Powwow Member:

2. Limestone, sandy and marly, black; interbedded with shale; both very fossiliferous. Contains the fusulinids and other foraminifers *Spandelinoides*? sp., *Ozawainella* spp., *Schubertella* sp., *Schwagerina bellula*? Dunbar and Skinner, *Pseudofusulina powwowensis* (Dunbar and Skinner), and *Parafusulina linearis* (Dunbar and Skinner) var.; the bryozoan *Stenopora* sp.; the brachiopods *Avonia* (n. subgen.) cf. *A. boulei* (Kozlowski), *A.* sp., *Buxtonia* (*Kochiproductus*) *victorioensis* King, *Chonetes* n. sp., *Composita* sp., *Crurithyris* sp., *Derbyia* sp., *Dictyoclostus wolfcampensis* (King), *Linoproductus* cf. *L. cora* (d'Orbigny), "*Marginifera*" aff. "*M.*" *lasallensis* (Worthen), and *Squamularia* sp.; the pelecypods *Allorisma* sp., *Aviculopecten*? sp., *Aviculopinna* sp., a myalinid, "*Nucula*" sp., a parallelodontid, and *Pseudomonotis* sp.; and the gastropods bellerophontid indet., "*Donaldina*" sp., *Euconispira* cf. *E. missouriensis* (Shumard), a murchisonid, *Naticopsis* sp., and a pseudozygopleuroid (USGS 8557, F 2694; field label Ph 11) ---- 45
1. Sandstone, red and brown; with seams of conglomerate in upper part; unfossiliferous ---- 30

Base of exposure at level of channel of Victorio Canyon; probably near base of Hueco Limestone and Powwow Member.

Summary of section 30

Part of Bone Spring Limestone measured		112
Hueco Limestone:		
Main body of formation	207	
Part of Powwow Member exposed	75	
Part of Hueco Limestone exposed		282

SECTION 31. NORTH OF VICTORIO CANYON

The following is a section of the Hueco, Bone Spring, and Victorio Peak Limestones, beginning at the foot of the Sierra Diablo escarpment 2 miles north of the portal of Victorio Canyon, and extending westward to a promontory of the Victorio Peak Limestone at the top of the escarpment (northwest cor. sec. 2, Block 66, Twp. 6, across the northern part of sec. 22, Block 42). The section was measured in 1936, the lower part (through unit 11) being hand leveled and described in detail by J. Brookes Knight, and the higher strata covered in less detail by observations of P. B. King, with thicknesses estimated. Larger fossils were identified by P. E. Cloud, Jr., and E. L. Yochelson and fusulinids and other foraminifers by L. G. Henbest (written commun., 1954, 1955).

Crest of Sierra Diablo escarpment; no higher beds exposed.

	Feet
Victorio Peak Limestone:	
18. Limestone, fine-grained; oolitic in part; light- to dark-gray; thin- to medium-bedded, with some thicker beds at top. Some interbedded layers are marly or slightly sandy, very cherty, and weather buff. Fossils moderately abundant in some layers. A mile to the south of end of section were collected a sponge; the bryozoan *Phyllopora* sp.; the echinoderm "*Echinocrinus*" sp.; the brachiopod *Buxtonia* (*Kochiproductus*) sp.; the gastropods bellerophontid indet., *Callistomaria*? sp., *Meekospira* sp., loxonematid indet., *Stegocoelia*? sp., and *Warthia* cf. *W. waageni* Yochelson; an ammonite; and the scaphopod *Plagioglypta* sp. (USGS 8546; field label Pb 15)	250
17. Limestone, gray, massive; with widely spaced faint bedding planes, with low original dip. The unit forms sheer unscalable walls, recessed into embayments, shelters, and caves, and in places with pinnacles standing in front, separated from the rest by weathering along joints	250
16. Limestone, medium-grained, gray; in 1- to 2-ft beds, some crowded with fusulinids; forms slopes and small ledges. Unit is transitional both vertically and laterally, from gray limestone facies of Victorio Peak into black limestone facies of Bone Spring; both it and units 14 and 15 beneath merge into typical cliff-making Victorio Peak Limestone on first spur north of Victorio Canyon	100
Intergradation.	
Bone Spring Limestone:	
15. Limestone, black; in 6- to 18-in. beds	340
14. Limestone, gray, granular; contains silicified fossils; forms a ledge. Merges with basal part of Victorio Peak Limestone to the south, but wedges out to north	10
13. Limestone, black. In lower three-quarters is very thin bedded or platy, with closely spaced light and dark laminae. In upper quarter the beds are thicker, weather light gray, and contain much chert. Bedding slopes irregularly at low angles, probably due to original dip of deposit	395
12. Irregular cliff; on line of section formed of thin-bedded black limestone, with some thicker beds near top; farther south includes massive reefy limestone beds	50
11. Limestone, black to dark-gray, fine grained; in 1- to 2-ft beds; contains silicified fossils and bands and lenses of brown chert; interbedded toward top with thinner bedded black limestone. This unit, and that next beneath, contains the fusulinids *Schubertella kingi* Dunbar and Skinner var., *Pseudofusulina setum* (Dunbar and Skinner), *Parafusulina fountaini* Dunbar and Skinner var., and *P.*? spp.; the coral *Lonsdaleia*? sp.; the bryozoan *Fistulipora* sp.; a platycerid gastropod; and the brachiopods *Meekella* sp., *Avonia* sp., *Prorichthofenia* sp., a productid, *Hustedia* sp., and *Enteletes* cf. *E. dumblei* Girty (USGS 8540, F 2705; field label Pb 9)	122
10. Slope, with a reefy ledge of brecciated limestone at top, containing silicified fossils of Bone Spring type, including large fusulinids	33
Conformity (?).	
Hueco Limestone:	
Main body of formation:	
9. Limestone, dolomitic, gray, massive; with irregular wavy bedding in lower half; forms a cliff. Contains a few silicified fossils	25
8. Limestone, dolomitic, fine-grained, gray, thin-bedded; contains black chert nodules	10
7. Limestone, dolomitic, gray, massive; almost without bedding; forms a cliff. Contains poorly preserved silicified fossils	28
6. Limestone, dolomitic, thin-bedded, cherty. Contains the fusulinids and other foraminifers *Climacammina* spp., *Tetrataxis* sp., *Schubertella kingi* Dunbar and Skinner, *Pseudofusulina powwowensis*? (Dunbar and Skinner), *Pseudoschwagerina beedei* Dunbar and Skinner, and *Schwagerina* sp. (F 2702; field label Ph 23)	10
5. Limestone, dolomitic, thin-bedded, cherty; forms a slope	10
4. Limestone, dolomitic, very cherty; forms a ledge	10
3. Limestone, partly dolomitic, partly calcitic, gray; in 1- to 2-ft beds, with marl partings; forms a slope. Contains the fusulinids *Schubertella kingi* Dunbar and Skinner, *Pseudoschwagerina*? *laxissima* (Dunbar and Skinner), *P.* sp., *Pseudofusulina* sp., *Parafusulina linearis* (Dunbar and Skinner) (F 2708; field label Ph 22); corals, *Composita*, and small productids observed	48
2. Limestone, dolomitic; forms upper part of lower cliff. The rock is bioclastic, fragmental, and contains many silicified fossils. Fusulinids are preserved as abraded to entire shells. These and other foraminifers include a bradyinid, *Staffella* sp., *Triticites* aff. *T. subventricosus* Dunbar and Skinner, *Pseudofusulina powwowensis*? (Dunbar and Skinner), *Schwagerina bellula*? Dunbar and Skinner, *S*? *hessensis* (Dunbar and Skinner), and *Parafusulina linearis* (Dunbar and Skinner) var. (F 2722; field label Ph 21); crinoid columns and corals observed	20
1. Limestone, calcitic, fine-grained, nearly black; with marly partings. Contains the bryozoan *Stenopora* sp.; and the brachipods *Chonetes* sp., *Buxtonia* (*Kochiproductus*) *victorioensis* King, *Linoproductus* cf. *L. cora* (d'Orbigny), and a productid; fusulinids were not	

Hueco Limestone—Continued *Feet*

Main body of formation—Continued

seen in place, but a float block contains *Schubertella?* sp., and *Parafusulina linearis* (Dunbar and Skinner) USGS 8558, F 2699; field label Ph 20) 25

Base of section at edge of alluvial fan; no lower beds exposed.

Summary of section 31

Part of Victorio Peak Limestone exposed	600
Bone Spring Limestone	950
Part of Hueco Limestone exposed	186

SECTION 32. MARBLE CANYON

The following is a section of the Hueco, Bone Spring, and Victorio Peak Limestones on the ridge south of Marble Canyon, beginning near the base of the Sierra Diablo escarpment half a mile south of portal of the canyon and 3 miles southwest of old Figure Two Ranch headquarters, and ending on a projecting angle of the crest of the escarpment half a mile east of Chambers triangular station (across the northern part of sec. 21, Block 66, Twp. 5). A section was measured here by P. B. King and R. E. King in 1928, but few significant fossil collections were made. The lower part of the section was again measured by J. Brookes Knight in 1931, from the base of the escarpment to the top of the outer bench (through unit 46). The section given here is that of Knight, but the higher part has been added from the section of King and King, and from observations which were made along the crest of the escarpment, in 1938 and earlier. Larger fossils were identified by P. E. Cloud, Jr., and E. L. Yochelson (written commun., 1954), and fusulinids were identified by C. O. Dunbar and J. W. Skinner (1937).

A suite of fossil collections from nearby, on the ridge north of Marble Canyon, was made by G. B. Richardson and G. H. Girty in 1907, and identifications by Girty were partly reported in the Van Horn folio (Richardson, 1914, p. 5; USGS 7165, 7165a, 7168a to 7168h; field locality 85). However, the ridge north of the canyon lies in a dolomitic reef facies of the Permian rocks and yielded few fossils except in the Hueco Limestone near the base and the Victorio Peak Limestone near the top; Girty observed a resemblance between the facies of the latter and that of the much younger Capitan Limestone.

Top of escarpment; no higher beds exposed.

Victorio Peak Limestone:

50. Limestone, gray; in beds a few feet thick, parts of which have low original dips; forms ledges and slopes at top of escarpment. Some interbedded marl; platy, siliceous brown limestone; and slightly sandy cherty buff limestone. Fossils are moderately abundant in places and are partly silicified. From several places along the

Victorio Peak Limestone—Continued *Feet*

rim of the escarpment northwest of upper end of section, near head of Marble Canyon, were collected the sponges *Actinocoelia meandrina* Finks, *Defordia densa* Finks and *Strioderma coscinum* Finks; crinoid stems; the brachiopods *Buxtonia* (*Kochiproductus*) *victorioensis* King, *Neospirifer* sp., and a large productid (USGS 7011, 14444; field label C 19) 250

49. Limestone, light-gray to white, granular or crystalline; in thick beds, with some thinner beds; forms a sheer unscalable cliff that rims the Sierra Diablo escarpment. Contains sparse brown chert nodules. In 1928, at head of ridge south of Marble Canyon, was collected the brachiopod *Buxtonia victorioensus* King (type) (REK 498) 250

Intergradation.

Bone Spring Limestone:

48. Limestone, black; in 2- to 8-in. beds; irregularly bedded, with partings of shale and chert; forms a cliff 175
47. Limestone, black, thinly laminated, platy; interbedded below with siliceous brown shale. Forms a long slope between upper cliffs and lower bench of Sierra Diablo escarpment. Thickness measured on ridge south of Marble Canyon intrusive, where there is a low original dip toward south, away from reef masses north of Marble Canyon 695
46. Limestone, dolomitic, gray; without bedding; lenticular; passes laterally into thinner bedded black limestone. Parts are brecciated, the fragments including not only gray limestone, but black limestone and chert. Forms crest of outer bench of escarpment. Abundantly fossiliferous; contains large *Parafusulina* sp.; sponge spicules; the bryozoan *Fistulipora* sp.; the brachiopods *Meekella* sp., *Leptodus* sp., *Prorichthofenia* sp., a productid, *Hustedia mormoni* (Marcou), *Squamularia* sp., *Enteletes* sp., and *Dielasma* sp.; and a triolobite (USGS 7010, D & S 134; field label 21 K) 27
45. Limestone, black, platy, shaly; with thin chert beds; weathers yellow brown and forms a slope 55
44. Limestone, dolomitic, coarsely crystalline, gray; forms ledges on slope. Partly silicified and poorly preserved fusulinids, crinoid columns, and echinoid spines observed 25
43. Limestone, black, thin-bedded, shaly 3
42. Limestone, dolomitic, coarsely to finely crystalline, gray; in 2-ft beds. Contains irregularly silicified areas; poorly preserved fusulinids and crinoid columns observed 8
41. Limestone, dark-gray to black, thin-bedded; with chert bands; weathers brown to light gray; forms a slope 45
40. Limestone, dolomitic, crystalline, light-gray; weathers deeply pitted; forms ledges on slope. Abundant fusulinid molds observed, some filled by calcite 45

Bone Spring Limestone—Continued	Feet
39. Limestone, dolomitic, gray; forms a ledge; top and base is massive, but middle is thinly bedded. Contains poorly preserved fusulinids (D & S 133; field label 21 J)	10
38. Limestone, black, thin-bedded, poorly exposed; forms a slope, with a few ledges of gray cherty limestone	27
37. Limestone, dolomitic, massive, brecciated, silicified; forms a rounded ledge. Contains poorly preserved fusulinids (D & S 111; field label 21 I); a sponge, crinoid columns, and a large spiriferoid brachiopod observed	30
36. Limestone, coarsely crystalline, light-gray; in 2- to 3-ft ledges; contains chert lenses; interbedded with thinner bedded more compact limestone. Contains poorly preserved, silicified fusulinids (D & S 110; field label 21 H); crinoid columns observed	66
35. Limestone, dolomitic; forms a slope	5
34. Limestone, dolomitic, light-gray, massive; forms a ledge	18
33. Slope; underlying beds concealed	8
32. Limestone, dolomitic, light-gray	3
31. Limestone, dolomitic, dark-gray, thin-bedded; contains small chert nodules and a few fossils	25
Conformity (?).	
Hueco Limestone:	
Main body of formation:	
30. Limestone, dolomitic, thinly and evenly bedded; lower part dark gray, upper part light gray to pinkish; contains large chert nodules in lower part, and some fusulinid molds. Forms sheer massive cliffs	175
29. Limestone, dolomitic, thin-bedded; forms a slope; contains scattered large chert nodules, and near the middle a few calcitized fusulinids	40
28. Limestone, dolomitic, light-gray, massive. At top, contains the fusulinids *Schubertella kingi* Dunbar and Skinner and *Schwagerina emaciata* (Beede) (D & S 109; field label 21 G)	15
27. Limestone, dolomitic, thin-bedded; contains a few chert nodules	10
26. Limestone, dolomitic, massive; forms a cliff, containing chert nodules in lower half	35
25. Limestone, calcitic, thin-bedded. Contains the fusulinids *Schubertella kingi* Dunbar and Skinner and *Schwagerina emaciata* (Beede) (D & S 108; field label 21 F). A later collection at about the same level contains the brachiopods *Derbyia* sp. and *Linoproductus* sp. (USGS 8551; field label Ph 2)	3
24. Limestone, massive	4
23. Limestone, marly. Contains the fusulinids *Schubertella kingi* Dunbar and Skinner and *Schwagerina emaciata* (Beede) (D & S 107; field label 21 E)	4
22. Limestone, dolomitic, massive	10

Hueco Limestone—Continued	Feet
Main body of formation—Continued	
21. Limestone, dark-gray, irregularly bedded. Contains the fusulinids *Schubertella kingi* Dunbar and Skinner, *Schwagerina emaciata* (Beede), and *Triticites powwowensis* (Dunbar and Skinner) (D & S 106; field label 21 D)	4
20. Limestone, dark-gray, massive; contains a few fusulinids	8
19. Limestone, gray, irregularly bedded; contains many fusulinids	16
18. Slope; underlying beds concealed	6
17. Limestone, light-gray, irregularly bedded; contains a few silicified fossils	4
16. Slope; underlying beds concealed	18
15. Limestone, granular, gray; contains silicified fossil fragments	5
Powwow Member:	
14. Limestone, marly, irregularly bedded; forms a slope. Contains the fusulinids *Schubertella kingi* Dunbar and Skinner and *Schwagerina emaciata* (Beede) (D & S 105; field label 21 B); other poorly preserved fossils observed	5
13. Marl: poorly exposed	14
12. Limestone, granular, gray. Fusulinids not observed, but contains fragments of other fossils	5
11. Limestone, marly, nodular. Contains the fusulinids *Staffella* sp. and *Schwagerina emaciata* (Beede) (D & S 104; field label 21 A)	3
10. Slope; underlying beds concealed	8
9. Limestone, pinkish-gray, unfossiliferous	3
8. Sandstone, arkosic, yellow; poorly exposed	12
7. Conglomerate, arkosic, red; contains pebbles of igneous rocks	5
6 Slope; underlying beds concealed	10
5. Conglomerate, arkosic, red	10
4. Sandstone, arkosic, poorly consolidated, red	10
3. Slope; underlying beds concealed	5
2. Conglomerate, arkosic	5
1. Covered; at nearby localities base of Powwow Member is a conglomerate, containing pebbles of chert and red sandstone	5
Angular unconformity.	
Pennsylvanian rocks at base of section. (See section 12.)	

Summary of section 32

Part of Victorio Peake Limestone exposed		500
Bone Spring Limestone		1,270
Hueco Limestone:		
Main body of formation	357	
Powwow Member	100	
Total Hueco Limestone		457

FOSSIL COLLECTIONS FROM HUECO LIMESTONE NEAR MARBLE CANYON

An outcrop of marl and marly limestone forms a conspicuous bluff just above the channel on the north side of the portal of Marble Canyon (approx. units 11 to 14 of section 32) (east-central part of sec. 20, Block 66, Twp. 5). Collections have been made here by various geologists at different times, including G. B. Richardson and G. H. Girty, R. E. King, J. W. Skinner, and J. Brookes Knight. The following fossils have been identified:

REK 456, D & S 113, 114.—Collected by R. E. King and J. W. Skinner, and identified by R. E. King (1931) and by Dunbar and Skinner (1937): The fusulinids *Schubertella kingi* Dunbar and Skinner, *Pseudoschwagerina uddeni* (Beede and Knicker), *P. texana* Dunbar and Skinner, *Schwagerina huecoensis* Dunbar and Skinner, and *S. knighti* Dunbar and Skinner; and the brachiopods *Orthotichia kozlowskii* King, *Chonetes permianus*? Shumard, *Isogramma millepunctata* (Meek and Worthen), *Productus semistriatus* Meek, *P. wolfcampensis* King, *Linoproductus cora* (d'Orbigny), *Marginifera dugoutensis*? King, and *Composita subtilita angusta* King.

USGS 7050, 8550, F 2718b (field labels 22, Ph 1).—Collected by J. Brookes Knight in 1931 and 1936; identified by L. G. Henbest, P. E. Cloud, Jr., and E. L. Yochelson (written commun., 1955, 1954): The fusulinids and other foraminifers *Climacammina* sp., textulariids, *Geinitzina* sp., *Endothyra* sp., a bradyinid, *Staffella lacunosa*? Dunbar and Skinner, *Ozawainella huecoensis*? Dunbar and Skinner, *Schubertella kingi* Dunbar and Skinner, *Pseudofusulina huecoensis* Dunbar and Skinner, and var., *P. powwowensis* (Dunbar and Skinner), *Schwagerina knighti* Dunbar and Skinner, *Paraschwagerina gigantea* (White), *Pseudoschwagerina uddeni* (Beede and Knicker), and *P. texana* var. *ultima* Dunbar and Skinner; the coral *Lophophyllum* sp.; the bryozoans *Fenestella* spp., *Fistulipora* sp., and *Septopora* sp., ecinoid plates and a crinoid calyx; the brachiopods *Chonetes* sp., *Cleiothyridina* sp., *Composita* sp., *Crurithyris* sp., *Dictyoclostus* (*Chaoiella*) aff. *D. boliviensis* (d'Orbigny), *D.* (n. subgen.) cf. *D. hessensis* (King), *D. wolfcampensis* (King), *Isogramma* sp., "*Marginifera*" (*Kozlowskia*) *capaci* (d'Orbigny), *Schizophoria* sp., and *Squamularia* sp.; the pelecypods *Aviculopecten*? sp. and *Septimyalina* sp.; the gastropods *Amphiscapha* cf. *A. muricata* (Knight), a bellerophontid, *Naticopsis* sp., *Omphalotrochus obtusispira* (Shumard), and *Pharkidonotus* sp.; an orthoceratid cephalopod; and a trilobite.

SECTION 33. MINE CANYON

The following is a section of the Hueco Limestone on the north side of the portal of Mine Canyon, beginning about 1¾ miles west-southwest of old Figure Two Ranch headquarters, above outcrops of lower fossiliferous shale of Pennsylvanian age and proceeding to the top of the outer bench of Sierra Diablo escarpment (southeastern part of sec. 15, Block 66, Twp. 5). The section was measured by J. Brookes Knight in 1931, but some additional fossil collections were made in 1936. Fusulinids were identified by C. O. Dunbar and J. W. Skinner (1937) and larger fossils by P. E. Cloud, Jr., and E. L. Yochelson (written commun., 1954).

	Feet
Bone Spring Limestone:	
22. Dolomitic facies overlying top of section, not traversed	(?)
Conformity (?).	
Hueco Limestone:	
Main body of formation:	
21. Limestone, dolomitic, light-gray, thinly and and evenly bedded; contains abundant fusulinid molds; forms almost unscalable cliffs; thickness estimated	200
20. Limestone, dolomitic, light-gray; contains small calcitized fusulinids; forms a massive bench	38
19. Limestone, dolomitic, dark-gray to black; contains large spherical chert nodules; forms a slope below cliffs. Contains the fusulinids *Schubertella kingi* Dunbar and Skinner, *Triticites powwowensis* Dunbar and Skinner, *Pseudoschwagerina beedei* Dunbar and Skinner, and *Schwagerina emaciata* (Beede) (D & S 121; field label 13 F)	46
18. Limestone, dolomitic, massive	50
17. Limestone, dolomitic, light-gray, massive. Contains the fusulinids *Schubertella kingi* Dunbar and Skinner, *Schwagerina emaciata* (Beede), and *S. huecoensis* Dunbar and Skinner (D & S 120; field label 13 E); other silicified fossils observed	55
16. Limestone, thin-bedded; forms a slope. Contains the fusulinids *Schubertella kingi* Dunbar and Skinner, *Schwagerina emaciata* (Beede), and *Pseudoschwagerina* sp. (D. & S 119; field label 13 D)	25
15. Limestone, gray, massive; forms lowest ledge, irregularly bedded in lower part; contains large round chert nodules and silicified fossil fragments	43
14. Limestone, fine-grained; gray below and black toward top; contains many large chert nodules. Contains unidentifiable fusulinids; the coral *Chaetetes* sp.; echinoid spines; and the brachiopods *Dictyoclostus* (*Chaoiella*) aff. *D. boliviensis* (d'Orbigny), *D.* cf. *D. hessensis* (King), productid indet., *Neospirifer* sp., and *Hustedia* sp. (USGS 7001, D & S 118; field label 13 C); bryozoans observed	33
13. Limestone, coarse-grained, gray; with many chert nodules. Contains unidentifiable fusulinids; sponge spicules; the corals *Clisiophyllum* sp. and *Lophophyllum* sp.; the bryozoans *Anisotrypa* sp., *Cystidictya* sp., *Fistulipora* sp., *Polypora* sp., *Septopora* sp., and *Stenopora* sp.; echinoid spines and crinoid columns; the brachiopods *Cleiothyridina* cf. *D. hessensis* (King), *D.* (*Chaoiella*) aff. cf. *D. wolfcampensis* (King), *D.* (n. subgen.) cf. *D. hessensis* (King), *D.* (*Chaoiella*) aff. *D. boliviensis* (d'Orbigny), *Dielasma* sp., *Hustedia* sp., "*Marginifera*" (*Kozlowskia*) cf. "*M.* (*K.*) *wabashensis* (Norwood and Pratten), *Rhipidomella* sp., and *Squamularia* sp., the pelecypod *Cypricardina* sp.; and the gastropod *Platyceras* sp. (USGS D & S 117; field label 13 B)	17

Hueco Limestone—Continued

Powwow Member: *Feet*

12. Limestone, marly; poorly exposed on slope; contains abundant large bryozoans — 22
11. Limestone, granular, gray. Contains the fusulinids *Schubertella kingi* Dunbar and Skinner, *Schwagerina huecoensis* Dunbar and Skinner, and *S. emaciata* (Beede); the sponge *Stereodictyum orthoplectum* Finks; the coral *Campophyllum* sp.; the bryozoans *Anisotrypa* sp., *Cystidictya* sp., *Fistulipora* sp., *Meekopora* sp., *Septopora* sp., and *Stenopora* sp.; echinoid spines and plates, crinoid columns and a calyx; the brachiopods *Buxtonia* (*Kochiproductus*) *victorioensis* (King), *Composita* sp., *Dictyoclostus* (*Chaoiella*) aff. *D. boliviensis* (d'Orbigny), *D.* cf. *D. hessensis* (King), *D.* cf. *D. wolfcampensis* (King), *D.* sp., *Enteletes* aff. *E. wordensis* King, *Hustedia* sp., *Linoproductus* sp., "*Marginifera*" (*Kozlowskia*) cf. "*M.*" (*K.*) *wabashensis* (Norwood and Pratten), productid indet., *Rhipidomella* sp., *Rhynchopora* sp., *Schizophoria* sp., and *Squamularia* sp.; the pelecypod *Aviculopecten*? sp.; the gastropods *Omphalotrochus obtusispira* (Shumard), *Naticopsis* sp., and a loxonematacean; and a trilobite (USGS 7001a, 7004, 8552, D & S 116 field labels 13 A, Ph 3) — 3
10. Limestone, marly, thin-bedded, poorly exposed. Contains the fusulinids *Schubertella kingi* Dunbar and Skinner, *Schwagerina huecoensis* Dunbar and Skinner, *S. emaciata* (Beede), *S. nelsoni* Dunbar and Skinner, and *Pseudoschwagerina beedei* Dunbar and Skinner (D & S 115; field label 13 AA) — 45
9. Shale and sandstone, arkosic, red — 3
8. Sandstone, arkosic, brown — 10
7. Slope; beds concealed — 15
6. Sandstone, arkosic; contains small pebbles — 3
5. Shale, arkosic, red — 20
4. Conglomerate, arkosic, red; contains small limestone pebbles — 13
3. Shale, sandy; gray at base; poorly exposed — 25
2. Sandstone, arkosic, red; conglomeratic at base — 25
1. Conglomerate, arkosic, massive; composed of pebbles of limestone and igneous rocks — 4

Angular unconformity.

Shale of Pennsylvanian age at base of section, poorly exposed in upper part.

Summary of section 33

Hueco Limestone:	
Main body of formation	507
Powwow Member	188
Total Hueco Limestone	695

SECTION 34. SOUTH OF BLACK JOHN CANYON

The following is a section of the Hueco Limestone half a mile south of Black John Canyon, on the divide between the canyon and drainage to the southeast, up the main outer bench of Sierra Diablo escarpment, northeast of which rocks are downfaulted (east-central part of sec. 13, Block 66, Twp. 5). The section given here is based on detailed measurement of the lower beds (through unit 11) by J. Brookes Knight in 1931, with higher beds added from a more generalized section by P. B. King and R. E. King in 1928. Fusulinids collected by Knight were identified by Dunbar and Skinner (1937) and a small lot of brachiopods by P. E. Cloud, Jr., and E. L. Yochelson (written commun., 1954).

Section 34a is included to illustrate variation in thickness of Hueco Limestone. It was measured in 1928 by P. B. King and R. E. King on a flat-topped outlier in the downfaulted area, about half a mile northeast of the main section (north-central part of sec. 12, Block 66, Twp. 5).

Bone Spring Limestone: *Feet*

13. Shale, siliceous, brown; interbedded with granular light-gray dolomitic limestone; forms top of outer bench. These and higher beds were not measured, as they form edge of a reef mass with original dips toward northeast, which extends up to Victorio Peak Limestone — (?)

Conformity (?).

Hueco Limestone:

Main body of formation:

12. Limestone, dolomitic, finely crystalline, gray; weathers dirty gray and pitted; in 6-in to 1-ft beds, but forms massive cliffs. Contains some subspherical chert nodules. Thickness estimated — 750
11. Limestone, light-gray; contains small fusulinids — 8
10. Limestone, thin-bedded — 12
9. Limestone, marly; forms a slope between cliffs. Contains the fusulinids *Pseudoschwagerina uddeni* (Beede and Knicker), *P. texana* Dunbar and Skinner, and *Schwagerina huecoensis* Dunbar and Skinner (D & S 122; field label 16 A) — 3
8. Limestone, dolomitic; forms a cliff — 17
7. Limestone, dolomitic, gray, massive; contains unidentified fusulinids (D & S 123; field label 16 B) — 18

Powwow Member:

6. Limestone, thin-bedded. Contains unidentified fusulinids and the brachiopods *Linoproductus*? (cf. *Cancrinella*) sp., *L.* sp., and *Composita* sp. (USGS 7056, D & S 124; field label 16 C): bellerophontid gastropods observed — 15
5. Limestone, forming scattered ledges on slope, with fossils in float — 20
4. Slope, covered by talus — 50
   (Trachyte sill about 10 ft thick)
3. Slope, covered by talus — 70
2. Conglomerate, arkosic — 20
1. Conglomerate; composed of limestone pebbles — 10

Angular unconformity.

Beds of Devonian age at base of section.

Section 34a

Top of outlier; no higher beds exposed.

Bone Spring Limestone: *Feet*

4. Shale, siliceous, brown; capped by a 4-ft bed of dolomitic limestone, containing bryozoans 44

Conformity(?).

Hueco Limestone:

Main body of formation:

3. Limestone, dolomitic; forms a slope 80
2. Limestone, dolomitic, finely crystalline, light-gray; weathers dirty gray or pitted; forms ledges and cliffs. Contains some small subspherical chert nodules as much as 10 in. in diameter, and fusulinid molds; near middle was collected *Composita mexicana* (Hall) (REK 462). About 125 ft below top is a thin trachyte sill 355

Powwow Member:

1. Slope; underlying beds concealed 55

Angular unconformity.

Fusselman and Montoya Dolomites at base of section. (See section 9.)

Summary of section 34

Main section:	
Hueco Limestone:	
Main body of formation	808
Powwow Member	180
Total Hueco Limestone	993
Section 34a:	
Hueco Limestone:	
Main body of formation	435
Powwow Member	55
Total Hueco Limestone	490

SECTION 35. BLACK JOHN CANYON

The following is a section of parts of the Hueco and Bone Spring Limestones on the west side of the south fork of Black John Canyon, about a mile south of Apache Spring (center of east line of sec. 14, Block 66, Twp. 5); a pair of minor faults displaces the Hueco and Bone Spring immediately to the northeast. The section combines observations and measurements by J. Brookes Knight and P. B. King in 1931. A fusulinid from the collections was identified by C. O. Dunbar and J. W. Skinner (1937) and the ostracodes by I. G. Sohn (written commun., 1960). The rest of the fossils were identified by P. E. Cloud, Jr., and E. L. Yochelson (written commun., 1954).

Higher beds on slope not measured.

Bone Spring Limestone: *Feet*

11. Limestone, black, thin-bedded; forms a slope. The brachiopods *Chonetes* and *Marginifera*, pelecypods, and possible algae observed 50
10. Limestone, dark-gray, granular; partly silicified on surface; contains layers of subangular limestone cobbles of different texture from matrix. Forms several ledges, but is lenticular, wedging out into black limestone northeastward. Contains fusulinids, a sponge, and crinoid stems (USGS 7055a; field label 20 A); bryozoans, and productid, spiriferoid, and rhynchonellid brachiopods observed 20
9. Limestone, black, thin-bedded to platy; with interbedded thin layers of granular fossiliferous limestone 25
8. *Molluscan ledge.*—Limestone, dark-gray, coarse-grained, bioclastic; contains a rich fauna dominated by mollusks, partly silicified. Forms a lens several hundred feet long which tapers into black platy limestone. Contains the fusulinid *Parafusulina diabloensis* Dunbar and Skinner; the sponges *Anthracosycon uniforme* Finks and *Stioderma coscinum* Finks; cup and tabulate corals including *Aulopora* sp., *Cladochonus* sp. and *Lonsdaleia*? sp.; echinoid spines and crinoid columns; the bryozoans *Acanthocladia* sp., *Septopora* sp., and *Striatopora* sp.; the brachiopods *Chonetes* sp., *Leptodus* sp., and various productids; the pelecypods *Anthraconeilo* sp., *Astartella nasuta* Girty, *A* sp., "*Cypricardinia*" sp., *Nucula* sp., nuculoid indet., *Nuculana* sp., *Parallelodon* spp., *Pleurophorus* sp., *Pteria*? sp., and *Streblopteria* sp.; the gastropods *Anomphalus* sp., *Apachella* sp., *Babylonites* sp., *Bellerophon deflectus* Chronic, *B.* sp., bellerophontid indet., *Cinclidonema* sp., *Discotropis girtyi* Yochelson, *Donaldina*? sp., *Euphemites* sp., *Glabrocingulum* sp., *Glyptospira* sp., *Knightites* (*Restispira*) sp., cf. *Loxonema* sp., *Naticopsis* sp., *Orthonema* sp., *Peruvispira* sp., pleurotomarian indet., pseudozygopleuran indet., *Shewdagonia*? sp., sublitid indet., *Warthia waageni* Yochelson, and "*Worthenia*" sp.; orthoceratid and nautiloid cephalopods; the scaphopods "*Laevidentalium*" sp., and *Plagioglypta* sp.; the chiton "*Gryphochiton*" sp.; the pteropod *Hyolithes* sp.; the ostracodes *Bairdia* sp., *Bairdiocypris*? sp., *Healdia* sp., *Hollinella* sp. or spp., *Kellettina* sp., and *Roundyella*? sp.; and the trilobite *Anisopyge* sp. (USGS 6938, 7055, D & S 135; field label 20) 5
7. Limestone, black; wtih some thin beds of granular limestone 10
6. Limestone, granular, gray, massive; wedges out northeastward 25
5. Limestone, black, platy; weathers gray brown; forms a slope 50
4. Limestone, bioclastic; partly silicified on surface; contains abundant crinoid columns, a few fusulinids, and limestone pebbles of possible organic origin; forms ledges; interbedded with black platy limestone 75
3. Limestone, black, thin-bedded to platy; interbedded wtih siliceous shale 10
2. Limestone, dolomitic, bioclastic; of irregular texture; contains abundant crinoid columns and a few fusulinids. Forms thick beds and ledges 10

Conformity(?).

Hueco Limestone:

1. Limestone, dolomitic, thinly and regularly bedded; contains fusulinids. Forms steep cliffs, extending to canyon bottom. Thickness estimated 500

Base of section, no lower beds exposed.

Summary of section 35

	Feet
Part of Bone Spring Limestone measured	280
Part of Hueco Limestone exposed	500

SECTION 36. APACHE PEAK

The following is a section of the Hueco, Bone Spring, and Victorio Peak Limestones on the north spur of Apache Peak, beginning on the south side of portal of Apache Canyon and extending to summit of peak (southeastern part of sec. 5, Block 66, Twp. 5, into northeastern part of sec. 1, Block 42). A section was measured on the spur by P. B. King and R. E. King in 1928, and was remeasured along the same course by P. B. King in 1931. The section given here is that of 1931, but some data have been added from the earlier section, including the fossil collection of unit 18, whose brachiopods were identified by R. E. King (1931). Thickness of the Bone Spring Limestone represents vertical distances obtained by hand leveling, and is not corrected for an original dip to northeast, off a reef mass to the southwest.

	Feet
Top of peak; no higher beds exposed.	
Victorio Peak Limestone:	
25. Limestone, light-gray, thick-bedded; contains chert lenses. Some granular layers on this peak and on the outlier to south, contain large productids, *Leptodus*, *Marginifera*, and gastropods. Limestone of Apache Peak stands about 300 ft lower than main body of Victorio Peak Limestone on crest of escarpment 1¼ miles to south, but intervening outliers demonstrate its continuity and indicate an original dip to northeast	50
Intergradation.	
Bone Spring Limestone:	
24. Limestone, black, thin-bedded; forms a slope	60
23. Limestone, black; contains long lenses of black and brown chert, and some beds of dark-gray granular limestone; forms a ledge	50
22. Limestone, black, slabby; weathers white	50
21. Limestone, dark-gray, granular, fossiliferous; in 6-in. beds	6
20. Shale, siliceous; interbedded with platy black limestone; weathers gray or yellow. Has an original dip of about 5° northeastward	372
19. Shale, siliceous, platy or stony, brown	75
18. Limestone, dark-gray, granular; contains silicified fossils. At about this level were collected the brachiopods *Chonetes permianus* Shumard and *Composita subtilita* (Hall), and various gastropods (REK 483)	3
17. Shale, siliceous; with interbedded platy black limestone	10
16. Limestone, dark-gray, granular, cherty; in 1-ft beds; weathers light gray or white	37
15. Shale, siliceous; interbedded with dense platy	
13. Shale, siliceous	10
tains abundant silicified fossils	10
14. Limestone, dark-gray, granular; in 2-ft beds; con-	
black limestone; weathers yellow	48

Bone Spring Limestone—Continued	Feet
12. Limestone, dolomitic, thin-bedded; contains many limestone pebbles and a few poorly preserved fossils. Contains a 3-ft igneous sill in upper part	50
11. Slope; underlying beds concealed	13
10. Limestone, gray, granular, fossiliferous	2
9. Marl, forming a slope	8
8. Limestone, dolomitic; in 2- to 3-ft beds; weathers drab gray and jagged. Contains numerous silicified crinoid columns, and other fossils	16
7. Shale, siliceous, brown; and platy black limestone	33
Unconformity (?).	
Hueco Limestone:	
Main body of formation:	
6. Limestone, dolomitic, thin-bedded; in part very cherty	37
5. Limestone, dolomitic, thick-bedded; forms ledges	26
4. Limestone dolomitic, thin-bedded; forms ledges separated by slopes	20
3. Limestone, dolomitic, massive; weathers drab gray and to a rough surface; forms prominent ledges	32
2. Limestone, dolomitic, gray; forms thin ledges	32
Powwow Member:	
1. Conglomerate, bluff; formed of limestone pebbles in a marl matrix; poorly exposed in most places	48
Angular unconformity.	
Fusselman Dolomite at base of section.	

Summary of section 36

Part of Victorio Peak Limestone exposed		50
Bone Spring Limestone		853
Hueco Limestone:		
Main body of formation	147	
Powwow Member	48	
Total Hueco Limestone		195

FOSSIL COLLECTIONS FROM VICTORIO PEAK LIMESTONE IN NORTHEASTERN SIERRA DIABLO

Fossils were collected from the Victorio Peak Limestone in the northeastern Sierra Diablo, near the rim of the escarpment, at various localities between Victorio and Apache Canyons, or near the upper ends of sections 31, 32, and 36, some of which have been listed in the sections. All collections are from the upper beds of the Victorio Peak Limestone exposed at their locality, 500 feet or more above the base of the formation, but are not necessarily near the stratigraphic top of the formation. Collections 7006 and 7011 were made by P. B. King in 1931; collection 8546 (Pb 15) was made by P. B. King and J. Brookes Knight in 1936; the rest were made by Knight in 1938. Fusulinids and other foraminifers were identified by L. G. Henbest, and larger fossils by P. E. Cloud, Jr., and E. L. Yochelson (written commun., 1955, 1954).

USGS 8546 (field label Pb 15).—Crest of Sierra Diablo escarpment north of portal of Victorio Canyon. (See unit 18, section 31, p. 154.)

USGS 7011, 14444 (field label C 19).—Crest of Sierra Diablo escarpment near head of Marble Canyon. (See unit 50, section 32, p. 155.)

USGS 7006.—Crest of Sierra Diablo escarpment at head of Black John Canyon, from half a mile north of North Diablo triangulation station, for half a mile northwestward (northern part of sec. 5, Block 42). Contains undetermined fusulinids and sponges; crinoid stems; the bryozoans *Fistulipora* sp., *Rhombopora* sp., and *Septopora* sp.; the brachiopods *Avonia* sp., *Chonetes* sp., *Derbyia* sp., *Enteletes* sp., *Hustedia* sp., *Leptodus* sp., *Meekella* sp., *Neospirifer* sp., productid indet., *Rhipidomella* sp., "*Spirifer*" sp., and *Stenocisma* cf. *S. inequalis* (Girty); the the pelecypods *Acanthopecten* sp., parallelodontid indet., and *Streblopteria* sp.; and a tooth of *Helodus* or *Orodus* type.

USGS 14470, F 9837 (field label C 29).—Crest of Sierra Diablo escarpment, near preceding and farther northwest, about a mile north of North Diablo triangulation station (northwest cor. Sec. 5, Block 42). Contains much abraded shells of at least two species of *Parafusulina;* the sponges *Actinocoelia meandrina* Finks and *Defordia densa* Finks; cup corals and crinoid stems; fenestrate and fistuliporoid bryozoans; the brachiopods *Avonia* sp., *Buxtonia* (*Kochiproductus*) sp., *Chonetes* sp., *Composita* sp., *Dictyoclostus* (*Chaoiella*) *quadalupensis* (Girty), *Dielasma* sp., *Enteletes dumblei* Girty, *Hustedia mormoni* (Marcou), *Leptodus* sp., "*Marginifera*" spp., *Meekella*? or *Geyerella*? sp., *Noespirifer* sp., *Rhipidomella* sp., *Rhynchopora* sp., *Stenocisma* cf. *S. inequalis* (Girty), *Streptorhynchus* sp., and *Wellerella* cf. *W. elegans* (Girty); gastropods, including *Babylonites;* and the trilobite *Anisopyge*? sp.

USGS 14445, F 9818 (field label C 20).—South rim of Apache Canyon 3 miles west of North Diablo triangulation station and 2 miles northeast of Slaughter Ranch (center of sec. 20, Block 32). Contains the dasycladacean green alga *Macroporella* sp.; poorly preserved fusulinids or bryozoans; and the brachiopods "*Spirifer*" sp., and *Enteletes* sp.

USGS 14448, F 9820 (field label C 22), and USGS 14449, F 9821 (field label C 23).—Two collections about half a mile apart, on north slope of first valley south of Apache Canyon, 2 miles west-southwest of North Diablo triangulation station and 2 miles northeast of Slaughter Ranch (central part of sec. 8, Block 42). Contains the fusulinids and other foraminifers *Climacammina* sp., *Geinitzina* sp., *Spandelinoides* sp., **Tetrataxis* sp., *Endothyra* sp., **Schubertella kingi* Dunbar and Skinner var., **Parafusulina*? aff. *P. bösei* var. *attenuata* Dunbar and Skinner, P. *schucherti* Dunbar and Skinner, *P. diabloensis* Dunbar and Skinner, and *Pseudofusulina setum*? (Dunbar and Skinner). (Asterisks indicate forms which occur in both collections.)

FOSSIL COLLECTIONS FROM BONE SPRING LIMESTONE NORTHWEST OF PORTAL OF APACHE CANYON

Fossils were collected in the lower part of the Bone Spring Limestone at several levels a mile west-northwest of the portal of Apache Canyon, above the outer bench of the Sierra Diablo escarpment (northeastern part of sec. 6, Block 66, Twp. 5). No section was measured, but the collections are listed below in stratigraphic order. The collections were made by J. Brookes Knight in 1936; fusulinids and other foraminifers were identified by L. G. Henbest, and larger fossils by P. E. Cloud, Jr., and E. L. Yochelson (written commun., 1955, 1954). Some cephalopods have been identified by A. K. Miller and W. M. Furnish (Miller and Furnish, 1940a; Miller, 1945).

USGS 14443, F 9814 (field label C 16).—Molluscan ledge in lower part of Bone Spring Limestone, about 100 ft above base. Fossils occur in a lens of bioclastic limestone, lying in platy black limestone, or in much the same association as those of the molluscan ledge in Black John Canyon (unit 8, section 35), and show a similar diversity.

Includes poorly preserved fusulinids; several genera of sponges; the bryozoan *Septopora* sp.; echinoid spines; the brachiopods *Composita* small sp., *Isogramma* sp., and productids indet.; the pelecypods *Astartella* sp., myalinids indet., nuculoid indet., *Nuculana* spp., *Paleoneilo* sp., *Parallelodon* sp., pectenoid indet., *Permophorus* sp., *Pteria*? sp., and others; the gastropods *Anomphalus* sp., *Apachella* sp., *Bellerophon* sp., *Donaldina*? sp., *Euphemites* cf. *E. imperator* Yochelson, *E.* sp., *Knightites* (*Retispira*) sp., murchisonid indet., *Naticopsis* sp., *Peruvispira* sp., *Pharkidonotus* sp., pseudozygopleuran indet., *Stegocoelia*? sp., "*Strobeus*" sp., sublitid indet., "*Trachydomia*" sp., *Warthia waageni* Yochelson, and "*Worthenia*" sp.; the nautiloids *Michelinoceras* spp., *Mooreoceras* sp., *Pseudorthoceras* sp., *Metacoceras mammiferum* Miller, *M. megapora* Miller, *M.* spp., and *Cooperoceras*? sp. (Miller, 1945, p. 282–283); the ammonite *Propinacoceras knighti* Miller and Furnish (holotype) (Miller and Furnish, 1940a, p. 42–44); the scaphopod *Plagioglypta* sp.; and the trilobite *Anisopyge* sp.

USGS 14443, F 9817 (field label C 18 C).—Bone Spring Limestone, 50 ft above base. Except for a single brachiopod, *Rhipidomella* sp., collection consists of fusulinids and other foraminifers, which include *Climacammina* sp., *Geinitzina* sp., *Endothyra* sp., *Tetrataxis* sp., **Parafusulina linearis*? (Dunbar and Skinner) and var., *?*P. gracilitatis* (Dunbar and Skinner), **Pseudofusulina powwowensis* (Dunbar and Skinner), **Pseudoschwagerina texana*? Dunbar and Skinner, **Schwagerina bellula* Dunbar and Skinner var., and *Parafusulina*? spp. Of the fusulinids in this collection, only the last are of Bone Spring type, the remainder, marked by asterisks, being of Hueco type. The two types have a different lithic appearance, and the association suggests redeposition of fusulinids from several stratigraphic levels.

USGS 14442, F 9816 (field label C 18 B).—Bone Spring Limestone, near base. Dolomite, crowded with poorly preserved fusulinids, which include *Parafusulina linearis*? (Dunbar and Skinner), *Pseudofusulina powwowensis* (Dunbar and Skinner), and *Pseudoschwagerina texana* Dunbar and Skinner. These are all of Hueco type, and there is no evidence in the sample for or against the possibility of their redeposition in Bone Spring beds.

USGS 14441, F 9815 (field label C 18 A).—Basal Bone Spring Limestone or topmost Hueco Limestone, apparently somewhat lower stratigraphically than preceding. Sample is a fragment of limestone crowded with fusulinids and other foraminifers, which show two different associations.

One group occurs in pebbles in the limestone and includes *Geinitzina* sp., *Spandelina*? sp., *Schubertella kingi* Dunbar and Skinner, *Parafusulina linearis*? (Dunbar and Skinner), *Pseudofusulina powwowensis* (Dunbar and Skinner), and *Schwagerina* aff. *S. bellula* Dunbar and Skinner. All these fusulinids are of Hueco type.

The matrix contains *Parafusulina diabloensis* Dunbar and Skinner and a very slender species of *Parafusulina*?. The first is definitely of Bone Spring type, but the affinities of the second are uncertain.

The occurrence of *Parafusulina diabloensis* in the matrix suggests strongly that the rock containing it is part of the Bone Spring Limestone, and that the fusulinids of Hueco type in the pebbles have been redeposited.

SECTION 37. FIRST SECTION IN APACHE CANYON

The following is the northeasternmost of five sections of the Hueco, Bone Spring, and Victorio Peak Limestones in the Apache Canyon. The section is on the northwest wall of the canyon, on a spur extending east-southeast from the peak marked by elevation point 5741, beginning at the channel of the canyon and proceeding to the summit of the peak (across southern part of sec. 6, Block 66, Twp. 5). The section was measured by J. Brookes Knight in 1938; fusulinids and other foraminifers were identified by L. G. Henbest, and larger fossils by P. E. Cloud, Jr., and E. L. Yochelson (written commun., 1955, 1954).

Top of peak; no higher beds exposed.

Victorio Peak Limestone: *Feet*

28. Limestone, granular, light-gray; in 1-ft. beds; contains some chert. Contains the sponge *Jereina cylindrica* Finks; a cup coral; the brachiopods *Dictyoclostus* (*Chaoiella*) *guadalupensis* (Girty), *Enteletes* sp., "*Marginifera*" sp., and *Rhipidomella* sp; and the gastropods *Discotropis* cf. *D. girtyi* Yochelson, *Euphemites exquisitus* Yochelson, and *Knightites* (*Retispira*) sp. (USGS 14461; field label C 27 D) ---------- 100
27. Limestone, granular, gray; in 1- to 2-ft beds; upper half forms a cliff and lower half a slope; poorly preserved fossils observed. Base lies at about same altitude as base of main body of Victorio Peak Limestone half a mile to southwest, but is stratigraphically higher, the lower beds of Victorio Peak Limestone wedging out into black limestone facies of Bone Spring northeastward, with original dip ---------- 110

Intergradation.

Bone Spring Limestone:

26. Limestone, black to dark-gray, platy ---------- 160
25. Limestone, gray, granular; forms a ledge ---------- 3
24. Limestone, dark-gray, siliceous, platy; with a few 6-in. to 1-ft. beds. Beds have an original dip northeastward, in places as steep as 25° ---------- 370
23. Limestone, dark-gray, shaly, very thin bedded, yellow; with original dips as steep as 25° ---------- 50
22. Limestone, gray, granular, bioclastic, brecciated; forms a reeflike lenticular ledge. Abundantly fossiliferous; contains corals, massive bryozoans, and the brachiopods *Avonia* and *Dictyoclostus* ---------- 5
21. Limestone, dark-gray, siliceous, platy; a few ledges of gray granular limestone in lower part, in one of which a well-preserved gastropod was observed ---------- 55

Bone Spring Limestone—Continued *Feet*

20. Limestone, gray, oolitic; contains siliceous masses; forms a massive reeflike, lenticular ledge. Large fusulinids observed ---------- 5
19. Limestone, dark-gray, siliceous, platy; weathers brown and forms a slope. Poorly preserved bellerophontid gastropods observed ---------- 50
18. Limestone, shaly, buff; splits into paper-thin sheets; passes upward into dark-gray platy siliceous limestone, with some interbedded layers of granular limestone. Unit has irregular dips. A ledge near middle contains the brachiopod *Lissochonetes* sp. (USGS 14460; field label C 27 B); sponge spicules and euomphalid gastropods observed ---------- 40
17. Limestone, dark-gray, siliceous, platy ---------- 25
16. Limestone, dark-gray, siliceous, platy; weathers yellow; a thin bed of gray granular limestone at top, contains silicified fossils ---------- 27
15. Limestone, gray, granular; forms ledges and contains silicified fossils of Bone Spring type; interbedded with dark-gray siliceous thin-bedded limestone; weathers yellow ---------- 8
14. Limestone, dolomitic, finely conglomeratic; forms a ledge. Contains the brachiopod *Marginifera*? sp., and the fusulinids and other foraminifers *Geinitzina* sp., *Schwagerina*? *franklinensis* Dunbar and Skinner, *S. gumblei* Dunbar and Skinner, *Parafusulina* aff. *P. lineata* Dunbar and Skinner, *P. schucherti* Dunbar and Skinner, and *P.* spp. (USGS 14447, F 9819; field label C 21 A) ---------- 3
13. Limestone, dolomitic; weathers craggy and and forms a slope. Silicified crinoid columns observed ---------- 8

Unconformity.

Hueco Limestone:

Division B:

12. Limestone, dolomitic, light-gray; forms a ledge ---------- 3
11. Limestone, dolomitic; weathers craggy and forms a slope ---------- 12
10. Limestone, calcitic or only slightly dolomitic, gray, thin-bedded; weathers light gray and to a smooth surface; forms upper part of lower bench in canyon. Contains abundant molds of small fusulinids; a collection 30 ft below the top includes *Schubertella kingi* Dunbar and Skinner, *Schwagerina bellula*? Dunbar and Skinner, and *Pseudofusulina* sp. (F 9826; field label C 27 "special collection") ---------- 142

Division A:

9. Limestone, dolomitic, massive; weathers craggy; contains abundant molds of small fusulinids ---------- 205
8. Limestone, dolomitic, thick-bedded; contains much chert in topmost ledge; forms a slope ---------- 38
7. Limestone, dolomitic, massive; weathers craggy; contains small cherty masses. Contains abundant molds of small fusulinids and some crinoid columns ---------- 25

Hueco Limestone—Continued

Division A—Continued

	Feet
6. Limestone, dolomitic, thick-bedded to massive; forms ledges; does not weather so craggy as adjacent units; chert absent in this and units beneath	48
5. Limestone, dolomitic, thin-bedded; forms a slope	40
4. Limestone, dolomitic, massive; weathers craggy	15
3. Limestone, dolomitic, gray-brown; does not weather so craggy as adjacent units	10
2. Limestone, dolomitic, massive; weathers craggy; forms ledges. Contains molds of small fusulinids; extends down to channel of Apache Canyon	30
1. Strata not exposed on line of section; thickness to base of Hueco Limestone probably	20–50

Angular unconformity.

Fusselman Dolomite, exposed beneath Hueco Limestone a quarter of a mile to northeast.

Summary of section 37

Part of Victorio Peak Limestone exposed		210
Bone Spring Limestone		809
Hueco Limestone:		
Division B	157	
Division A	431–461	
Total Hueco Limestone		588–618

SECTION 38. SECOND SECTION IN APACHE CANYON

The following is a section of the Hueco, Bone Spring, and Victorio Peak Limestones on the northwest wall of Apache Canyon, three-quarters of a mile southwest of section 37, from the channel of the canyon, up a spur to the rim at a point half a mile southwest of Elusive triangulation station (west-central part of sec. 2, Block 42, to center of sec. 1, Block 32). The section was measured by J. Brookes Knight in 1938; fusulinids and other foraminifers were identified by L. G. Henbest; a few larger fossils were identified by P. E. Cloud, Jr., and E. L. Yochelson (written commun., 1955, 1954).

Rim of canyon; no higher beds exposed.

Victorio Peak Limestone:

	Feet
33. Limestone, light-gray, granular, thick-bedded to massive; forms ledges and cliffs. Strata dip northeastward and lower part intertongues with black limestone beds of Bone Spring. Contains three species of *Pseudofusulina* or *Parafusulina*, or both, apparently of Bone Spring type (F 9836; field label C 28 I)	150

Intergradation.

Bone Spring Limestone:

	Feet
32. Limestone, dark-gray, compact; in 1- to 2-ft beds; forms a slope and contains some chert and a few fossils	60
31. Limestone, gray, compact; forms a cliff. Contains abraded and broken fusulinid shells, which include ?*Parafusulina diabloensis* Dunbar and Skinner, and other parafusulinids of Bone Spring type (F 9835; field label C 28 H)	50
30. Limestone, gray, fine-grained to compact; in 1- to 2-ft beds; contains many silicified fossils of Bone Spring aspect	100
29. Limestone, dark-gray to black; in 6-in to 1-ft beds	55
28. Limestone, dark-gray to black; interbedded with layers of gray granular limestone that contains silicified fossils	100
27. Limestone, dark-gray to black; in 1- to 2-ft beds; some lenses of granular limestone near base, which contain bryozoans	85
26. Limestone, dark-gray to black, thinly laminated; in 6-in to 1-ft beds; weathers buff and forms a slope. Contains a well-preserved sponge (USGS 14467; field label C 28 G). This unit, and next two above, have an original dip of 12° to the northeast	95
25. Limestone, gray, granular, reefy; contains abundant bryozoans, sponges, and other fossils	35
24. Limestone, gray to light-gray; weathers buff or brown; platy or thinly laminated, in 6-in to 1-ft beds. Near middle is a 6-ft bed of more granular limestone. Beds of unit have irregular original dips	110
23. Limestone, black, thinly laminated, thin-bedded	15
22. Limestone, light-gray, weathers buff; siliceous, platy. Has steep irregular original dips	25
21. Limestone, granular, massive, lenticular and reefy; contains sponges	15
20. Limestone, gray to dark-gray, siliceous, platy; forms a slope	12
19. Limestone, granular, massive, reefy and lenticular	8
18. Limestone, dark-gray, thin-bedded	7
17. Limestone, light-gray; brecciated in part; very massive, but reefy and lenticular; contains silicified fossils	60
16. Limestone, marly; forms slopes with interbedded ledge-making dark-gray limestone. Contains abundant silicified fossils of Bone Spring type, including the brachiopod *Hustedia* sp., as well as the fusulinids and other foraminifers *Geinitzina* sp., *Endothyra* sp., *Quinqueloculina* sp., *Ozawainella* sp., *Staffella*? sp., *Schwagerina gumbeli* Dunbar and Skinner, *Parafusulina diabloensis* Dunbar and Skinner, *P. fountaini* Dunbar and Skinner, and *P. imlayi*? Dunbar (USGS 14466, F 9834; field label C 28 F)	30
15. Limestone, dolomitic; contains the fusulinids and other foraminifers *Tetrataxis* sp., *Parafusulina schucherti* Dunbar and Skinner, and *P. fountaini* Dunbar and Skinner (F 9833; field label C 28 E); echinoderm fragments observed	7
14. Limestone, dolomitic; weathers craggy; contains poorly preserved large fusulinids	10

Unconformity.

Hueco Limestone:

Division C:

13. Limestone, dolomitic, dark-gray (weathers brown and craggy), very massive. Contains abundant molds of small fusulinids and poorly preserved *Omphalotrochus*. Unconformable surface at top of unit slopes north-

	Feet
Hueco Limestone—Continued	
Division C—Continued	
eastward and cuts out this unit on next ridge to northeast	40
Division B:	
12. Limestone, light-gray; in 2-ft beds; interbedded with thinner layers of white dolomitic limestone. Near top it contains the fusulinids *Parafusulina linearis* (Dunbar and Skinner), and *Pseudoschwagerina? laxissima* (Dunbar and Skinner), and *P.* sp. (F 9832; field label C 28 D)	45
11. Limestone, light-gray, finely granular, massive. Contains many fusulinids and other foraminifers, whose shells are variably abraded; these include *Climacammina* sp., *Staffella* sp., *Schubertella kingi* Dunbar and Skinner, *Pseudofusulina emaciata?* (Beede), *P. gracilitatis?* (Dunbar and Skinner) var., *P. powwowensis* (Dunbar and Skinner), and *Parafusulina linearis* (Dunbar and Skinner) var. (F 9831; field label C 28 C)	10
10. Dolomite, white, porcelaneous, splintery	5
9. Limestone, light-gray, massive; contains many fusulinids, and other fossils, poorly preserved	30
8. Limestone, dolomitic, gray	5
7. Limestone, light-gray; in 2-ft beds; contains the fusulinids and other foraminifers *Geinitzina* sp., *Schubertella kingi* Dunbar and Skinner var., *Parafusulina linearis* (Dunbar and Skinner), and *Pseudoschwagerina texana* Dunbar and Skinner (F. 9830; field label C 28 B); other fossils are poorly preserved	25
6. Limestone, light-gray; in 2-ft beds	32
5. Limestone, light-gray; interbedded with white dolomitic limestone that contains fusulinid molds	35
4. Limestone, gray; contains at the base the fusulinids and other foraminifers *Spandelinoides* sp., *Endothyra* sp., *Schubertella kingi* Dunbar and Skinner, *Triticites ventricosus?* (Meek and Hayden) var., *T.* sp., and *Pseudofusulina?* sp. (F 3805; field label C 28 A)	30
Division A:	
3. Limestone, slightly dolomitic, light-gray; in 8- to 18-in. beds; interbedded with thin-bedded white dolomitic limestone	35
2. Limestone, dolomitic, dark-gray, thin-bedded; contains fusulinid molds in part	17
1. Limestone, dolomitic, dark gray; weathers brown; in 4- to 6-ft beds; contains many molds of small fusulinids	120
Alluvium of floor of Apache Canyon at base of section; lower beds concealed. In the field it was estimated that the lowest exposed beds are 300–400 ft above base of Hueco, as exposed in northeastern part of canyon.	

Summary of section 38

	Feet
Part of Victorio Peak Limestone exposed	150
Bone Spring Limestone	879
Hueco Limestone:	
Division C	40
Division B	217
Part of division A exposed	172
Part of Hueco Limestone exposed	429

SECTION 39. THIRD SECTION IN APACHE CANYON

The following is a section of the Hueco, Bone Spring, and Victorio Peak Limestones on the northwest wall of Apache Canyon, a mile southwest of section 38, from the channel of the canyon to the rim at a point 1½ miles south of Elusive triangulation station (across southwestern part of sec. 10, Block 32). The section was measured by J. Brookes Knight in 1938; fusulinids and other foraminifers were identified by L. G. Henbest (written commun. 1955).

	Feet
Rim of canyon; no higher beds exposed.	
Victorio Peak Limestone:	
31. Limestone, dolomitic, fine-grained, light-gray; weathers yellow; in massive beds, containing fusulinid molds as much as three-quarters of an inch in length	20
30. Limestone, dolomitic, light-brown; in massive beds, containing molds of large fusulinids	105
29. Limestone, somewhat dolomitic, crystalline, light-gray; forms a massive cliff. Contains the fusulinids and other foraminifers *Climacammina* sp., *Geinitzina* sp., *Schubertella kingi* Dunbar and Skinner var., *Parafusulina linearis* (Dunbar and Skinner) var., *P.* cfr. *P. diabloensis* Dunbar and Skinner or *Pseudofusulina*, and ?*P. fountaini* Dunbar and Skinner var. (F 9825; field label C 26 C); cross sections of brachiopods observed	105
28. Limestone, dolomitic, light-gray; forms ledges; interbedded with marl. Molds of fusulinids and a fenestellid bryozoan observed	25
27. Limestone, dolomitic, fine-grained, light-gray; forms a massive ledge	15
Conformity.	
Bone Spring Limestone:	
26. Limestone, dolomitic, saccharoidal, brown; weathers dark gray; contains small fusulinid molds. Forms a set of very massive dark ledges, as viewed from a distance, which contrast with the lighter colored ledges above	168
25. Dolomite, white, porcelaneous	1
24. Limestone, dolomitic, fine-grained; in 3-ft beds; contains poorly preserved silicified fossils	20
23. Limestone, dolomitic, cherty, marly; weathers yellow; contains large fusulinid molds	25
22. Limestone, dolomitic, light-gray; contains large fusulinids. Weathers craggy and forms massive ledges	30
21. Limestone, somewhat dolomitic, light-gray, compact; interbedded with pink chert. Contains the fusulinids and other foraminifers *Bradyina?* sp., *Geinitzina?* sp., and *Parafusulina linearis* (Dunbar and Skinner) var. (F 9824; field label C 26 B); a cup coral, crinoid columns, and a *Hustedia* observed	27

Unconformity.

Hueco Limestone:

	Feet
Division C:	
20. Limestone, dolomitic, thin-bedded; forms conspicuous light-gray outcrops; contains molds of small fusulinids	45
19. Limestone, dolomitic, dark-gray, thick-bedded; a few layers full of small fusulinid molds	85
18. Limestone, dolomitic; forms ledges that are conspicuously light gray, with a few layers full of small fusulinid molds	37
17. Limestone, dolomitic, dark-gray, thin-bedded; weathers to a rough surface; a few layers full of fusulinid molds	65
16. Dolomite, white, porcelaneous	3
15. Limestone, dolomitic, dark-gray; weathers craggy; contains small fusulinid molds	10
14. Dolomite, white, porcelaneous	1
13. Limestone, dolomitic, light-gray; weathers craggy; contains some small fusulinid molds; forms top of a bench	90
12. Limestone, dolomitic, dark-gray; forms massive ledges	30
11. Limestone, dolomite, light-gray; in 1- to 4-ft beds, some of which contain molds of small fusulinids	30
10. Limestone, dolomitic; contains fusulinid molds and forms a slope	3
Division B:	
9. Limestone, in alternating thin and thick beds	22
8. Limestone, dark-gray. Contains the fusulinids and other foraminifers *Climacammina* sp., *Spandelina* sp., *Geintzina* sp., a bradyinid, *Tetrataxis* sp., *Schubertella kingi*? Dunbar and Skinner, *Pseudofusulina emaciata* (Beede), and *Pseudoschwagerina* cf. *P. beedei* Dunbar and Skinner (F 9828; field label C 26 A)	5
7. Limestone, gray; in beds as much as 6 ft thick. Forms top of a bench	130
6. Limestone, light- to dark-gray; mostly in 1-ft beds, with some 3-ft beds. In lower 50 ft are some interbedded 5-ft beds of dolomitic limestone that contains the fusulinids and other foraminifers *Spandelina* sp., *Geinitzina* sp., *Tetrataxis* sp., textulariids, *Schubertella kingi* Dunbar and Skinner, and *Triticites* spp. (F 9829; field label C 26 AA). These dolomitic beds are probably equivalent to upper part of division A farther northeast in Apache Canyon	170
Division A:	
5. Limestone, dark-gray; forms a ledge	2
4. Slope; underlying beds concealed	3
3. Limestone, dolomitic, light-gray, massive; contains molds of small fusulinids	8
2. Slope; underlying beds concealed	10
1. Limestone, dark-gray; in massive ledge	5

Base of section in channel of Apache Canyon; no lower beds exposed.

Summary of section 39

		Feet
Part of Victorio Peak Limestone exposed		270
Bone Spring Limestone		271
Hueco Limestone:		
Division C	399	
Division B	327	
Part of division A exposed	28	
Part of Hueco Limestone exposed		754

SECTION 40. FOURTH SECTION IN APACHE CANYON

The following is a section of the Hueco, Bone Spring, and Victorio Peak Limestones on the south wall of Apache Canyon 2 miles southwest of section 39, from the floor of the canyon to the elevation point 5841 on the rim (north half of east line of sec. 18, Block 32). The section was measured by J. Brookes Knight in 1931; no fossils were collected, although they were observed and recorded in the field.

Rim of canyon; no higher beds exposed.

	Feet
Victorio Peak Limestone:	
10. Limestone, dolomitic; forms thinner ledges than below which alternate with slopes to top	100
9. Limestone, dolomitic, evenly bedded; forms a cliff	60
Conformity.	
Bone Spring Limestone:	
8. Limestone, dolomitic, thin- to thick-bedded; forms ledges	200
Unconformity.	
Hueco Limestone:	
Division C:	
7. Limestone, dolomitic, gray; forms ledges on slope, but passes into a massive cliff on next spur to west	50
6. Limestone, dolomitic, light-gray; in 1 to 5-ft ledges; contains traces of fossils	80
5. Limestone, dolomitic, gray, massive; forms cliffs; contains a few fossils, including large productid brachiopods and a large euomphalid gastropod	75
Division B:	
4. Limestone, light-gray, thin- to thick-bedded	78
3. Limestone, light-gray; forms a massive ledge; contains a large *Meekella*, productid brachiopods, and a large euomphalid gastropod	5
2. Limestone, light-gray, thin- to thick-bedded. Fusulinids observed in float	205
1. Limestone, light-gray, thin- to thick-bedded. Many silicified shells of *Composita* observed on weathered surfaces	25

Alluvium of floor of Apache Canyon at base of section; no lower beds exposed.

Summary of section 40

Part of Victorio Peak Limestone exposed		160
Bone Spring Limestone		200
Hueco Limestone:		
Division C	205	
Part of division B exposed	313	
Part of Hueco Limestone exposed		518

SECTION 41. APACHE TANK

The following is a section of the Hueco, Bone Spring, and Victorio Peak Limestones on the southwest wall of Apache Canyon above Apache Tank, up to summit marked by elevation point 5690, 1½ miles northwest of section 40 (northeastern part of sec. 14, Block 32). The section was measured by J. Brookes Knight in 1931, but additional observations and collections were made in 1938. Fusulinids were identified by L. G. Henbest, and larger fossils by P. E. Cloud, Jr., and E. L. Yochelson (written commun., 1955, 1954).

	Feet
Rim of canyon; no higher beds exposed.	
Victorio Peak Limestone:	
11. Limestone, dolomitic, in 2- to 3-ft ledges; forms a slope. A large euomphalid gastropod observed	110
10. Limestone, dolomitic, light-gray; with ramifying siliceous masses in top beds. Forms a massive cliff	60
Conformity.	
Bone Spring Limestone:	
9. Limestone, dolomitic; in 1- to 8-ft beds; thicker beds are granular and weather jagged, thinner ones dense. Contains a myalinid pelecypod (USGS 7007a; field label 29 B); poorly preserved large euomphalid gastropod observed	165
8. Limestone, dolomitic, light-gray, splintery; lower beds porcelaneous, higher ones granular and weather jagged	18
7. Limestone, gray and yellow; interbedded with marl	22
6. Marl, gray, yellow, and pink	18
5. Conglomerate, formed of limestone pebbles and cobbles, standing in massive ledges, with intervening slopes	36
Unconformity.	
Hueco Limestone:	
Division C:	
4. Limestone, dolomitic, thin-bedded; poorly exposed on slope	52
3. Limestone, dolomitic, thin-bedded. In 1931, about 30 ft from base, was collected the fusulinid *Triticites* (=*Pseudofusulina*) *powwowensis* Dunbar and Skinner (D and S 125; field label 29 A). In 1938, from same general level, were collected *Schubertella*? sp., *Pseudofusulina* aff. *P. uddeni* (Dunbar and Skinner), and *Schwagerina hessensis*? Dunbar and Skinner (F 9805; field label C 4)	105
2. Limestone, dolomitic, poorly bedded, massive. Contains fusulinids; the corals *Syringopora* sp., and *Lonsdaleia* sp.; the brachiopods *Dictyoclostus* sp. and *Composita* sp.; and the gastropod *Omphalotrochus obtusispira* (Shumard) (USGS 7007; field label 29 AA)	60
1. Limestone, dolomitic, dark-gray; forms ledges	11
Base of section in stream channel; no lower beds exposed.	

Summary of section 41	Feet
Part of Victorio Peak Limestone exposed	170
Bone Spring Limestone	259
Part of Hueco Limestone (division C) exposed	228

SECTION 42. SIERRA PRIETA

The following is a section of the Hueco and Victorio Peak Limestones exposed on the south side of Sierra Prieta, which form the roof rocks of the Sierra Prieta intrusive. The Hueco Limestone was measured from the intrusive contact three-quarters of a mile northwest of Black Mountain Tank, across a high conical hill and lower hills to the south, to the alluvial valley near the tank (eastern part of sec. 47, block N). The Victorio Peak Limestone was measured on the low scarp south of the alluvial valley (northeastern part of sec. 50, block N). The section was measured by J. Brookes Knight in 1938; fusulinids and other foraminifers were identified by L. G. Henbest (written commun. 1955); other fossils were observed in the field, but were not collected.

	Feet
Top of scarp; no higher beds exposed.	
Victorio Peak Limestone:	
22. Limestone, dark-gray, dolomitic; weathers craggy; interbedded with white or light-gray porcelaneous dolomite	50
21. Limestone, dolomitic, light-gray, massive	10
20. Limestone, dolomitic, light-gray; weathers brown and craggy; interbedded with compact buff thin-bedded dolomitic limestone; a poorly preserved bellerophontid gastropod observed	20
19. Slope on north face of scarp; underlying beds concealed; probably thin-bedded dolomitic limestone	35
18. Alluvial valley 900 ft broad; underlying beds concealed; probably thin-bedded or marly dolomitic limestone	150
Unconformity.	
Hueco Limestone:	
17. Limestone, dolomitic, dark blue-gray; weathers craggy	10
16. Limestone, dolomitic, white or light-gray, porcelaneous; some dark-gray craggy dolomitic limestone; mostly poorly exposed, but forms ledges in part	45
15. Swale; underlying beds concealed	15
14. Limestone, dolomitic, light-gray splintery; interbedded darker craggy-surfaced dolomitic limestone, with a few 1-ft beds of white porcelaneous dolomitic limestone. Both light-gray and dark-gray dolomitic limestone beds contains numerous molds of small fusulinids	30
13. Limestone, dolomitic, dark-gray	5
12. Limestone, dolomitic light-gray; with a 1-ft bed of white porcelaneous dolomitic at base	15
11. Limestone, dolomitic, light-gray, partly splintery, partly craggy	100
10. Limestone, dolomitic, light-gray, splintery	40
9. Limestone, dolomitic, dark-gray; weathers to smooth light-gray surfaces; forms 1- to 2-ft beds	25

Hueco Limestone—Continued	*Feet*
8. Limestone, dolomitic; in alternating dark-gray and light-gray layers; weathers craggy. Top bed contains large pseudoschwagerinids which were unidentifiable in the laboratory (F 9839; field label C 31 B)	15
7. Limestone, dolomitic, dark-gray to black; weathers craggy and forms a conspicuous ledge	17
6. Limestone, dolomitic, dark-gray; weathers craggy; interbedded with light-gray dolomitic limestone. Contains many molds of small fusulinids	13
5. Limestone, dolomitic, dark-gray; forms a massive ledge. Contains *Climacammina* 2 sp., *Geinitzina* sp., *Spandelina* sp., and *Schwagerina* aff. *S. hawkinsi* Dunbar and Skinner (F 9838; field label C 31 A)	12
4. Limestone, dolomitic, dark-gray; forms a massive ledge	8
3. Limestone, dolomitic, dark blue-gray; parts more calcitic than others. Beds near middle form a hogback ridge. A bellerophontid observed	50
2. Limestone, dolomitic, dark blue-gray; weathers blue; probably slightly altered by intrusive; in 1- to 2-ft beds. Poorly preserved staffellid foraminifers and an *Omphalotrochus* observed	100
1. Contact rocks next to intrusive: Limestone, dolomitic, gray or brown, marmorized and bleached; weathers yellow; alternating with bluish thin-bedded baked and silicified limestone, probably originally argillaceous. Crinoid columns observed in top layer	47
Intrusive contact at base of section; igneous rock of Sierra Prieta intrusive beneath.	

Summary of section 42

Part of Victorio Peak Limestone exposed	265
Part of Hueco Limestone exposed	547

SECTION 43. SOUTH MESA

The following is a section of the Bone Spring Limestone, Victorio Peak Limestone, Cutoff Shale, sandstone tongue of Cherry Canyon Formation, and Goat Seep Limestone, at the north end of the Sierra Diablo, from south of Babb Canyon and the Babb flexure, to the top of South Mesa. The section is in two parts:

Section 43a was measured by P. B. King and R. E. King in 1928, and covers the Bone Spring Limestone and Victorio Peak Limestone, which are exposed at the east end of the cuesta that borders Babb Canyon on the south, beginning in a reentrant valley a mile south of the portal of the canyon (mainly in western part of sec. 29 Block 67, Twp. 4). A small collection made in 1936 has been inserted at its appropriate position; identifications were made by P. E. Cloud, Jr., and E. L. Yochelson (written commun., 1954).

Section 43b covers the upper part of the Victorio Peak Limestone, and the higher formations, and is tied to section 43a by the occurrence in both of the distinctive middle division of the Victorio Peak Limestone. The section extends up the east face of South Mesa at about midlength, or nearly due west of the old Babb Ranch (along eastern half of center line of sec. 18, Block 67, Twp. 4). Sections were measured here by P. B. King and R. E. King in 1928, and by J. Brookes Knight in 1936. Fusulinids collected in 1928 were identified by C. O. Dunbar and J. W. Skinner (1937), and the brachiopods by R. E. King (1931). Fusulinids and other foraminifers collected in 1936 were identified by L. G. Henbest, and larger fossils by P. E. Cloud, Jr., and E. L. Yochelson (written commun., 1955, 1954). The section given below combines the field observations of 1928 and 1936 and includes both sets of fossil identifications.

Section 43b

Top of South Mesa; no higher beds exposed	
Goat Seep Limestone:	*Feet*
24. Limestone, dolomitic, light-gray to pink; weathers brown and to rough surface; in thin to thick irregular beds. Contains rounded chert nodules, geodes, and silicified fossils. The latter include poorly preserved fusulinids; the sponges *Actinocoelia meandrina* Finks, *A.*? sp., and *Stioderma coscinum* Finks; a cup coral; the bryozoan "*Acanthocladia*" sp.; the pelecypod "*Aviculopecten*" sp. indet.; the gastropod *Platyceras* sp. indet.; and the brachiopods *Chonetes* (*Chonetinella*) sp., "*Marginifera*" sp. aff. *M. occidentalis* Schwellwein or *M. walcottiana* (Girty), "*M.*" sp., *Dictyoclostus* (*Chaoiella*) cf. *D. guadalupensis* (Girty), *Leptodus* cf. *L. americanus* Girty, *Composita* sp., *Neospirifer* sp., *Stenocisma* n. sp., *Hustedia* cf. *H. mormoni* (Marcou), *Wellerella* cf. *W. elegans* (Girty), *Enteletes* spp., *Rhynchopora*? sp., *Dielasma* sp., and a phricodothyrinid (USGS 8548, F 2688; field label Pd 1)	200
Conformity.	
Sandstone tongue of Cherry Canyon Formation:	
23. Sandstone, fine-grained to silty, buff; weathers brown; mostly thin bedded, but with thicker layers toward base	150
22. Sandstone, medium-grained, dolomitic; weathers brown; forms a massive bed. Contains poorly preserved fusulinids. Thickness variable; lies with irregular contact on underlying shale and limestone, of which it contains chips and pebbles	5-40
Unconformity.	
Cutoff Shale:	
21. Shale, fine-grained, sandy	22
20. Limestone, laminated, sandy	5
19. Limestone, gray to black, fine-grained, platy to medium-bedded; some platy fine-grained sandstone. A *Squamularia* observed. Forms a bench	139
18. Shale, siliceous and sandy, buff	11
17. Limestone, dense, platy, buff and gray	8

Cutoff Shale—Continued	Feet
16. Slope; underlying beds concealed	11
15. Limestone, gray, dense, platy	18
14. Shale, siliceous; interbedded with platy gray limestone	33
13. Limestone, dense, gray, thinly laminated. Contains *Composita mira* (Girty) (REK 506); poorly preserved brachiopods and a possible ammonite observed	15
12. Limestone, thin-bedded, dark-gray, and siliceous shale, poorly exposed	13
Conformity.	
Victorio Peak Limestone:	
Upper division:	
11. Limestone, dolomitic, dark-gray; forms massive ledges; interbedded with thinner bedded limestone. Collection of 1928 contains the fusulinid *Schwagerina setum*? Dunbar and Skinner, and the brachiopods *Productus dartoni sullivanensis* King, *Productus ivesi* Newberry, *Lyttonia nobilis americanus* (Girty), *Spirifer* (*Neospirifer*) *pseudocameratus* Girty, and *Squamularia guadalupensis* (Shumard) (D & S 137, REK 493). In 1936 collections were made near top of unit (USGS 8535, F 2698; field label Pb 2) and near middle of unit (USGS 8534, F 2691; field label Pb 1). These contain the fusulinids and other foraminifers *Geinitzina* sp., *Endothyra* sp., a schubertellid or millerellid, *Parafusulina bakeri* Dunbar and Skinner var., *P. fountaini* Dunbar and Skinner, and *Pseudofusulina setum* (Dunbar and Skinner); lophophyllid corals; the bryozoans "*Batostomella*" sp., a fistuliporoid, and "*Stenopora*" sp.; the gastropod *Babylonites* sp.; and the brachiopods *Buxtonia* (*Kochiproductus*) cf. *B. victorioensis* King, *Chonetes* (*Chonetinella*) spp., *Composita* sp., "*Dictyoclostus*" aff. *D. semistriatus* (Meek), *Hustedia* sp., *Leptodus* sp., "*Marginifera*" spp., *Neospirifer* cf. *N. pseudocameratus* (Girty), *Rhipidomella* sp., "*Spirifer*" sp., and *Squamularia* sp.	65
Middle division:	
10. Limestone, dolomitic, white or light-gray; forms a slope	15
9. Limestone, dolomitic, dark-gray; forms a massive ledge	5
8. Limestone, dolomitic, white or light-gray; forms a slope	10
7. Limestone, dark-gray; forms a massive ledge	3
6. Limestone, dolomitic, white or light-gray; forms a slope; slender fusulinids observed	38
5. Limestone, dolomitic, dark-gray; contains calcite vugs; forms a prominent ledge	3

Victorio Peak Limestone—Continued	Feet
Middle division—Continued	
4. Limestone, dolomitic, dense, white or light-gray; in 1- to 2-ft beds. Contains irregular specks of crystalline calcite. Forms a slope with thin ledges	45
Lower division:	
3. Limestone, dolomitic, dark-gray; forms ledges	23
2. Limestone, dolomitic, light-gray; weathers pitted; forms a massive ledge; contains small crinoid columns	8
1. Limestone, medium-bedded; poorly exposed at base of slope	33

Base of section covered by alluvium; no lower beds exposed.

Section 43a

Top of cuesta; higher beds exposed north of Babb canyon (see section 43b).

Victorio Peak Limestone:	
Upper division:	
7. Limestone, dark-gray, thick-bedded; forms dip slope of cuesta	50
Middle division:	
6. Limestone, dolomitic, light-gray, thin-bedded; with partings of marly sandstone. Weathers white and forms a conspicuous light-colored band on hillsides	34
Lower division:	
5. Limestone, gray, thick-bedded; interbedded with layers of light-gray dolomitic limestone in upper part; includes lower part of middle division as distinguished in section 42b	260
4. Limestone, dolomitic, gray; weathers drab gray or gray brown; in 1- to 2-ft beds; forms thick ledges and cliffs	300
3. Sandstone, fine-grained, brown	12
2. Limestone, finely crystalline, dark-gray; weathers light gray; in 1- to 10-ft beds; forms ledges and cliffs. Contains irregular chert nodules	250

Break in section. (Across reentrant valley a mile south of portal of Babb Canyon; a fault of small displacement follows the valley, and some of lower part of Victorio Peak Limestone may be cut out along it; basal Victorio Peak overlies the Bone Spring Limestone south of the valley.)

Bone Spring Limestone:	
1. Limestone, black to dark-gray, weathers drab gray; fine grained; in 3- to 6-in. beds; in part with brown chert bands, and with marl partings. Some beds contain silicified fossils. In 1936 were collected the brachiopods *Chonetes* sp., *Avonia* sp., *Buxtonia*? cf. *B.* (*Kochiproductus*) sp., and the gastropod *Anomphalus*? sp. (USGS 8538; field label Pb 5). Thickness about	500

Base of section covered by alluvium.

Summary of section 43

Part of Goat Seep Limestone exposed	200
Sandstone tongue of Cherry Canyon Formation	155–190
Cutoff Shale	275

Summary of section 43—Continued

	Feet
Victorio Peak Limestone:	
Upper division (in section 43b)	65
Middle division (in section 43b)	119
Lower division (approx., in section 43a)	822
Total Victorio Peak Limestone	1,006
Part of Bone Spring Limestone exposed	500

FOSSIL COLLECTIONS FROM VICTORIO PEAK LIMESTONE SOUTHEAST OF SOUTH MESA

Southeast of South Mesa, foothills fringing the northeast-facing escarpment of the Sierra Diablo consist of Victorio Peak Limestone that has been downfaulted and tilted. Collections were made from it by R. E. King in 1928, and by J. Brookes Knight in 1936. Brachiopods in the first collections were identified by R. E. King (1931). Fusulinids and other foraminifers in the second were identified by L. G. Henbest, and larger fossils by P. E. Cloud, Jr., and E. L. Yochelson (written commun., 1955, 1954).

USGS 8536 (*field label Pb 3*).—Victorio Peak Limestone. Hogback ridge at foot of Sierra Diablo escarpment, 3 miles southeast of South Mesa, southwest side near west end (northeastern part of sec. 5 Block 31). Contains the brachiopods *Meekella* sp., *Prorichtofenia* sp., *Buxtonia*? cf. (*Kochiproductus*) sp., and "*Spirifer*" sp.

USGS 8537, F 2709 (*field label Pb 4*).—Victorio Peak Limestone. Near foot of northeast slope of hogback ridge, about half a mile east of its western end (northeastern part of sec. 4, Block 31). Contains the fusulinids and other foraminifers *Geinitzina*? sp., *Pseudofusulina setum* (Dunbar and Skinner) and *Pseudofusulina* or *Parafusulina* sp.; the brachiopods *Chonetes* sp., *Buxtonia* (*Kochiproductus*)? sp., "*Marginifera*" sp., *Avonia* small sp., *Enteletes*? sp. and *Rhipidomella* sp.; the pelecypod ?*Astartella* sp.; *Meekospira* sp. and other gastropods; and the scaphopod *Plagioglypta* sp.

USGS 8541 (*field label Pb 10*).—Victorio Peak Limestone, float on alluvial fan below and north of locality Pb. 4. Contains *Buxtonia* (*Kochiproductus*) cf. *B. victorioensis* King.

REK 494.—Victorio Peak Limestone, at approximately the same locality as Pb 4. Contains the brachiopods *Productus schucherti* King, *Marginifera manzanica* Girty, *M. reticulata angusta* King, *Martinia rhomboidalis* Girty, and *Composita subtilita* (Hall).

REK 495.—Victorio Peak Limestone at east end of hogback ridge, about half a mile east of locality Pb 4 and REK 494 (northwestern part of sec. 3, Block 31). Contains the brachiopods *Chonetes permianus* Shumard and *Productus ivesi* Newberry.

USGS 8547 (*field label Pb 17*).—Victorio Peak Limestone. Ridge of downfaulted rocks 1½ miles northwest of portal of Apache Canyon, and about 4 miles southeast of preceding localities (southeast part of sec. 43, Block 66, Twp. 4). Contains *Enteletes* cf. *E. dumblei* Girty.

FOSSIL COLLECTIONS FROM GOAT SEEP LIMESTONE NORTH OF SOUTH MESA

The Goat Seep Limestone is preserved in a series of mesalike outliers for about 10 miles north of South Mesa, beyond the map area. (See King, P. B., 1949.) Collections were made in these outliers by R. E. King in 1928, and by J. Brookes Knight in 1936. Brachiopods in the 1928 collections were identified by R. E. King (1931); fusulinids and other foraminifers in the 1936 collections were identified by L. G. Henbest, and larger fossils by P. E. Cloud, Jr., and E. L. Yochelson (written commun., 1955, 1954).

REK 504, D & S 139.—Goat Seep Limestone at east end of North Mesa (north of present map area, western part of sec. 40, Block 67, Twp. 3). Includes unidentified fusulinids and the brachiopods *Enteletes wordensis* King, *Meekella skenoides* Girty, *Linoproductus waagenianus* (Girty), *Avonia signata* (Girty), *Marginifera opima* (Girty), *Aulosteges guadalupensis* Shumard, *A. tuberculatus* King, *Lyttonia nobilis americanus* (Girty), *Camarophoria venusta* Girty, *Spirifer* (*Neospirifer*) *pseudocameratus* Girty, *Hustedia meekana* (Shumard), and *Composita emarginata affinis* Girty.

USGS 8549 (*field label Pd 2*).—Goat Seep Limestone, near base. Same locality as REK 504. Contains a polyporoid bryozoan and the brachiopods *Linoproductus*? sp., *Marginifera* aff. *M. lasallensis*? (Meek and Worthen), *M.*? sp., "*Pustula*" sp., *Dictyoclostus* (*Chaoiella*) cf. *D. guadalupensis* (Girty), *Stenocisma* sp., *Composita* sp., and *Wellerella* sp.; fusulinids observed in field, but not reported on.

F 2697 (*field label Pd 3*).—Goat Seep Limestone, from float near Dos Alamos Hills (sec. 17, Block 67, Twp. 3). A porous coquina, crowded with large very slender fusulinids that are probably *Parafusulina maleyi* var. *referta* Dunbar and Skinner.

SECTION 44. HIGH POINT OF DELAWARE MOUNTAINS

The following is a section of the Bone Spring Limestone and Brushy Canyon Formation on a promontory of Delaware Mountains near the northeast corner of the map area. The section begins at the fault at the west base of the mountains, on a salient 3 miles north-northwest of Cone triangulation station, and proceeds eastward to the summit of a mesalike outlier at the crest (center of sec. 4 to center of sec. 3, Block 65, Twp. 4). The section was measured by R. E. King in 1928; fusulinids were identified by C. O. Dunbar and J. W. Skinner (1937), and brachiopods by R. E. King (1931). This section is the same as section 49 of King (1948, pl. 8).

	Feet
Summit of outlier; no higher beds exposed.	
Brushy Canyon Formation:	
Main body of formation:	
13. Sandstone, coarse, light-buff; in thick beds, interbedded with thinner bedded finer grained sandstone; some bedding surfaces show molds of large parafusulinids	205
Pipeline shale member:	
12. Shale, sandy, dark-gray, thinly laminated	33
Conformity (?).	
Bone Spring Limestone:	
11. Limestone, black, dense; in 2- to 6-in. beds; forms a prominent cliff. A few poorly preserved fossils observed	264

Bone Spring Limestone—Continued *Feet*

10. Shale, sandy, thinly laminated, gray; weathers yellow brown. The shale contains concretions of black granular limestone a foot or two broad and a foot thick, also some interbedded 3- to 6-in. layers of black limestone — 82
9. Limestone, black, dense, thinly laminated; forms a cliff; contains spherical concretions 3-in. to 1-ft across — 115
8. Limestone, black, dense; sandy in part; thin-bedded to papery — 126
7. Limestone, black, sandy; in 8-in. to 1-ft beds — 18
6. Limestone, black, unevenly bedded; contains irregular masses of chert and siliceous limestone. Some beds very fossiliferous — 93
5. Limestone, black; very thinly and evenly bedded, with a few thicker bedded fossiliferous layers. Forms a well-defined ledge. Contains the fusulinid *Parafusulina* sp., and the brachiopods *Meekella attenuata* Girty, *Productus leonardensis* King, *Productus occidentalis* Newberry, *Productus* sp., *Striatifera pinnaformis* (Girty), *Prorichthofenia likharewi* King, *Pugnoides bidentatus* (Girty), *Pugnoides texanus*? (Shumard), *Spirifer* (*Neospirifer*) *mexicanus latus* King, *Ambocoelia guadalupensis* Girty, and *Hustedia meekana* (Shumard) (REK 491 D & S 153) — 77
4. Limestone, black, platy or papery; with some layers of granular chert — 132
3. Limestone, black; in 1- to 6-in. beds; contains many thick chert layers and granular siliceous layers — 72
2. Limestone, black; in beds half an inch to 5 in. thick, but somewhat irregularly bedded, with interbedded chert layers as much as 3 in. thick, and lenses of fossil breccia that contain whole shells of brachiopods. These include *Meekella attenuata* Girty, *Chonetes permianus* Shumard, *Linoproductus waagenianus* (Girty), and *Ambocoelia guadalupensis* Girty (REK 490) — 258
1. Limestone, black; in even beds half an inch to an inch thick, with a few chert bands — 308

Base of section at fault at foot of escarpment; no lower beds exposed.

Summary of section 44

Brushy Canyon Formation:	
Part of main body of formation exposed	205
Pipeline Shale Member	33
Part of Brushy Canyon Formation exposed	238
Part of Bone Spring Limestone exposed	1,545

STRATIGRAPHIC SECTIONS AND FOSSIL COLLECTIONS OF CRETACEOUS ROCKS

Sections 45–54, which follow, were measured in the southern and western parts of the Sierra Diablo during the present investigation. Some of these are plotted graphically on plate 13 where, to complete the stratigraphic picture, four other sections to the south and west have been included; these were measured by other geologists and are described in their publications. The locations of these four sections are as follows:

(A) *Devil Ridge above Devil Ridge thrust.*—Section of Yucca Formation, Bluff Mesa Formation, Cox Sandstone, and Finlay Limestone, measured by J. Fred Smith, Jr. (1940, p. 625–628, sec. 3). Measured southwestward across Front Ridge and Devil Ridge at a locality about 3½ miles west of the edge of the present report area and 5 miles south of town of Sierra Blanca, in northwestern part of Block 69½.

(B) *Southwest of Eagle Flat below Devil Ridge thrust.*—Section of Washita Group measured by J. Fred Smith, Jr. (1940, p. 628–629, sec. 5). Measured southwestward across low ridges south of Bola siding, in southwestern part of present report area, in sec. 46, Block 69, Twp. 8, and sec. 3, Block 69, Twp. 9. A section of the overlying Eagle Ford Formation is given in the original publication, but is not plotted on plate 13.

(C) *Spar Valley, below Devil Ridge thrust.*—Section of Yucca Formation, Bluff Mesa Formation, Cox Sandstone, Finlay Limestone, and Washita Group, measured by Elliot Gillerman (1953, p. 19–29, secs. 2, 4, 5, and 6). As plotted on plate 13, the section combines various partial sections measured in the vicinity of Spar Valley on the east side of the Eagle Mountains about 5 miles south of southern edge of present report area. To complete the sequence, the basal Cretaceous beds exposed near Eagle Spring just south of the present report area have been plotted from descriptions by Gillerman.

(D) *Flat Mesa, north of Sierra Blanca.*—Section of Cox Sandstone, Finlay Limestone, Kiamichi Formation, and basal part of Washita Group, described by W.S. Adkins (1932, p. 352) and measured by P. B. King (unpub. field notes, 1930). Measured across north end of Flat Mesa about 6 miles north-northwest of town of Sierra Blanca, near the center of the east line of Block 71, Twp. 7.

SECTION 45. EAGLE FLAT

The following is a section of parts of the Campagrande Limestone and Cox Sandstone on a mesa 1¼ miles east of Eagle Flat section house (sec. 8, Block 68 Twp. 8). The section was measured by P. B. King and J. Brookes Knight in 1931. Fossils were observed in the field, and a few were collected in 1938, which proved to be unidentifiable.

Top of mesa; no higher beds preserved.

Cox Sandstone: *Feet*

5. Sandstone, massive, sugary, light-brown: forms remnant on top of mesa at west end — 25

Campagrande Limestone:

4. Limestone, marly; contains *Exogyra* and *Trigonia* — 10
3. "Nodosaria bed." Limestone, massive, sandy, dark-gray, evenly bedded. Shells of the medium-sized foraminifer *Haplostiche* ("*Nodosaria*") occur on weathered surfaces, and many unidentifiable shells appear in cross section, probably mainly oysters (USGS 17828; field label K 10) — 25
2. Limestone, nodular, light-gray; interbedded with marl; in part conglomeratic — 30
1. "Cap ledge." Limestone, massive, light-gray; at base of slope — 10

Base of section covered by alluvium.

Summary of section 45

	Feet
Part of Cox Sandstone exposed	25
Part of Campagrande Limestone exposed	75

SECTION 46. STREERUWITZ HILLS

The following is a section of part of the Campagrande Limestone in the Streeruwitz Hills, 4½ miles northwest of Eagle Flat section house (northwestern part of sec. 22, Block 57). The section was measured by J. Brookes Knight in 1931. The top unit of this section appears to be the basal unit of section 45, and the two sections combined give an approximate total thickness of the Campagrande Limestone in the district of 205 ft; however, units of the lower part of the Campagrande in nearby sections in the Streeruwitz Hills are much thinner than in section 46, due to overlap on an eroded topography of Hueco Limestone and Precambrian rocks.

Top of section; no higher beds preserved.

Campagrande Limestone:	Feet
3. "Cap ledge." Limestone, massive, dark- to light-gray; nodular in upper part; contains chert pebbles in lower 4 ft	55
2. Conglomerate, mainly limestone pebbles, but includes some chert pebbles, in a limestone matrix that is red below, grayer above	80
1. Conglomerate, red; contains pebbles and cobbles of limestone and chert from Allamoore Formation	5

Unconformity.

Hueco Limestone at base of section.

Summary of section 46

Part of Campagrande Limestone exposed	140

SECTION 47. DOME PEAK

The following is a section of the Campagrande Limestone and Cox Sandstone on Dome Peak (summit 5485). The section was measured by P. B. King and J. Brookes Knight in 1931. The Campagrande Limestone was measured a mile south of the peak on the west side of the ridge, southwest from the road from Sierra Blanca to the Keen Ranch (east-central part of sec. 28, Block 51). Two sections of the Cox Sandstone were measured, one on the west slope (northeastern part of sec. 21, Block 51), the other on the south slope (west half of sec. 22, Block 51); descriptions of units in the two sections have been combined in the text, and thicknesses averaged. No fossils were collected, but they were observed in parts of the Campagrande Limestone.

Top of Dome Peak; no higher beds preserved.

Cox Sandstone:	Feet
37. Sandstone, massive, brown	8
36. Sandstone, shaly, buff	12
35. Sandstone, massive, sugary, crossbedded; forms rimrock at top of Dome Peak	36
34. Sandstone, friable; forms a slope	25

Cox Sandstone—Continued	Feet
33. Sandstone, massive, brown; crossbedded in part; forms ledges, with a 10-ft bed of marly limestone in lower part	82
32. Sandstone, friable; forms a slope	15
31. Sandstone, massive, brown; with many pebbly seams; forms prominent ledges	19
30. On west slope of Dome Peak; red sandy shale interbedded with gray marly limestone; on south slope; represented by a 4-ft layer of conglomerate, formed of limestone fragments	25
29. Sandstone, white or buff, pebbly; forms a slope; contains small pebbles and ferruginous nodules	21
28. Sandstone, friable, crossbedded, white	16
27. Sandstone, massive, brown	5
26. Sandstone, friable; forms a slope	8
25. Sandstone, massive, brown; with pebbly seams; passes at top into a conglomerate of chert and quartz pebbles	5
24. Sandstone, friable; forms a slope	6
23. Sandstone, massive, brown	22
22. Sandstone, shaly, red; with thin beds of coarser sandstone; forms a succession of benches and slopes	40
21. Sandstone, slabby or shaly, white or red; forms slopes, with several ledges of massive brown pebbly sandstone in upper part	25
20. Sandstone, massive, brown, pebbly	10
19. Sandstone, marly, red; forms a slope	8
18. Sandstone, massive sugary brown; contains well-rounded chert and quartz pebbles; in part crossbedded. Small spherical limonite nodules occur on weathered surfaces. Forms prominent ledge, which breaks out into cubical blocks	18
17. Marl and shale, poorly consolidated, gray or purple; at top, a conglomerate of rounded chert pebbles in a yellow marl matrix. In most places, poorly exposed on slope and covered by blocks from bed above	100
16. Limestone, marly, gray; interbedded with purple shale	43
15. Marl, gray; forms a slope, with a 2-ft ledge of gray limestone at top	12
14. Sandstone, brown, shaly; with a 2-ft ledge of red limestone at top	12
13. Sandstone, thin-bedded, slabby; with small-scale crossbedding	10
12. Sandstone, massive, sugary, brown; crossbedded in part	16
Campagrande Limestone:	
11. Marl, sandy; forms a slope	5
10. Limestone rusty-brown; in 2-ft beds	7
9. Marl, nodular, blue-gray to brown	5
8. Limestone, light-gray to gray-brown; with marl partings	9
7. Marl and thin layers of nodular limestone	16
6. Limestone, dark blue-gray; contains oysters and rudistids in upper part	6
5. Shale and marl with beds of brown dense nodular limestone	16

Campagrande Limestone—Continued

	Feet
4. "Nodosaria bed." Limestone, dark-gray or gray-brown, sandy; in 1- to 2-ft beds; contains fragments of oysters and echinoids	16
3. Marl, nodular limestone, and conglomerate	22
2. "Cap ledge." Limestone, massive, nodular light-gray; contains chert pebbles at base	8
1. Conglomerate, composed of pebbles of Hueco Limestone, in a sandy or marly limestone matrix	9

Unconformity.

Hueco Limestone at base of section; about a mile to the southeast the Hueco is truncated and the Campagrande Limestone lies directly on red sandstone of the Hazel Formation.

Summary of section 47

Part of Cox Sandstone exposed	599
Total Campagrande Limestone	119

SECTION 48. ROCK CRUSHER

The following is a section of the Campagrande Limestone and Cox Sandstone on the north slope of the high knob northeast of the Gifford-Hill rock crusher, on the opposite side of the Texas and Pacific Railway (summit 5188; north half of sec. 26, Block 67, Twp. 8). The section was measured by P. B. King in 1936, but the sequence here had been described previously by Richardson (1914, p. 6). No fossils were recorded by King, but Richardson observed gastropods, oysters, and an *Exogyra* in the Campagrande Limestone.

Top of knob 5188; no higher beds preserved.

Cox Sandstone:	Feet
13. Sandstone, massive, pebbly, crossbedded	10
12. Sandstone, fine-grained, thin-bedded; forms a slope	65
11. Sandstone, massive, crossbedded; very pebbly at top	70
10. Sandstone, fine-grained, thin-bedded, poorly exposed; with a massive sandstone ledge 15 ft above base	59
9. Sandstone, massive, brown, coarse-grained; in 2- to 10-ft beds, which form prominent ledges and break out in rectangular blocks. Contains dispersed quartz and chert pebbles in places, and some layers are crossbedded. Weathered surfaces are dark-brown and quartzitic	95
8. Sandstone, fine-grained, thin-bedded, shaly, gray or red. Upper part poorly exposed and much covered by float from above. A bed of massive sandstone may occur near middle, but it is represented only by loose blocks that might have slumped from above	112
Campagrande Limestone:	
7. Limestone, buff, dense; with conchoidal fracture; forms a prominent ledge	4
6. Shale, reddish, poorly exposed	17
5. Limestone, gray, granular; contains limestone pebbles	1
4. Shale, reddish, poorly exposed	13
3. Limestone, brown, sandy and pebbly; forms a ledge	4

Campagrande Limestone—Continued

	Feet
2. Shale, reddish, sandy, poorly exposed	18
1. Conglomerate, formed of pebbles as much as an inch in diameter of quartz, chert, and limestone, in a coarse sandstone matrix, with thin beds of calcareous sandstone at top	6

Unconformity.

Hueco Limestone at base of section.

Summary of section 48

Part of Cox Sandstone exposed	411
Total Campagrande Limestone	63

SECTION 49. COX MOUNTAIN

The following is a section of the Campagrande Limestone, Cox Sandstone, Finlay Limestone, and Kiamichi Formation on Cox Mountain (secs. 19 and 20, Block 45½. The Cox Sandstone was measured on the north face of the mountain, west of a prominent reentrant, the Finlay and Kiamichi at various favorable places on the summit of the mountain. The whole section was originally measured by P. B. King and R. E. King in 1928; the Finlay and Kiamichi were measured again in more detail by J. Brookes Knight in 1938; the text given below contains data from both sections. Fossils from the Kiamichi Formation that were collected in 1938 were identified by R. W. Imlay (written commun., 1940), and his determinations are given in the text. Fossils collected in 1928 were examined by W. S. Adkins (1932, p. 353), who reported virtually the same assemblage, which he regarded as of Kiamichi age (see table 11, p. 87).

Tertiary:	Feet
18. Basalt, vesicular; forms three remnants on top of mountain; at base, a conglomerate of limestone cobbles a few feet thick, partly derived from Cretaceous rocks, partly from earlier rocks	30
Unconformity.	
Kiamichi Formation:	
17. Shale, brown, sandy. Contains *Oxytropidoceras acuticarinatum* (Shumard), *O. bravoense* Böse, *Natica*? sp., *Trigonia emoryi* Conrad, *Exogyra texana* Roemer, *Gryphaea navia* Hall, *G.* cf. *G. corrugata* Gabb, *Pecten* (*Neithea*) *subalpinus* Böse, and *Protocardia texana* (Conrad) (USGS 17838, 17280; field labels K 3 G, K 2); horn corals and colonial corals observed. According to Imlay, correlation with the Kiamichi is signified by the *Gryphaea navia;* the species of *Oxytropidoceras* range through beds of late Fredericksburg age	15
16. Sandstone, brown; forms a ledge	3
15. Marl, yellowish, sandy. A collection from this unit, and unit 13 below, contains *Oxytropidoceras* cf. *O. supani* (Lasswitz), *Nerinea*? sp., *Tylostoma* sp., *Natica*? sp., *Pecten* (*Neithea*) sp., *Exogyra texana* Roemer, and *Enallaster texanus* (Roemer) (USGS 17857; field label K 2 EF). According to Imlay, occurrence of an ammonite like *Oxytropidoceras supani* indicates a late Fredericksburg age, but not necessarily a Kiamichi age	8

	Feet
Kiamichi Formation—Continued	
14. Sandstone, yellow; contains oysters	2
13. Limestone, blue-gray, marly; contains abundant fossils, such as *Pecten*, *Exogyra*, oysters, and *Turritella*?	15
12. Marl and limestone, forming a slope, containing *Lunatia*? sp. (USGA 17836; field label K 1 D)	15
11. Limestone, brown; forms a prominent ledge; cross sections of shells are visible, possibly rudistids	5
10. Limestone, marly; forms a slope	6
Finlay Limestone:	
9. Limestone, massive, gray; forms 1- to 3-ft ledges; contains obscure rudistids, chamids, and other fossils. This, and lower beds of the formation are reported to contain the chamid *Toucasia* sp., and the other mollusks *Protocardia filosa* Conrad and *Tylostoma* sp., (DeFord and Brand, 1958, fig. 11, p. 23)	10
8. Marl, forming a slope	5
7. Limestone, gray; forms a ledge	2
6. Limestone, gray, nodular, marly, sandy in part; contains gastropod steinkerns, oysters, and many other poorly preserved fossils	28
5. Sandstone, yellow-brown, ripple-marked	3
4. Limestone, gray, marly	8
Cox Sandstone:	
3. Sandstone and clay, poorly exposed	16
2. Sandstone, coarse, yellow-brown; weathers brown; in 5-ft beds that break out into great cubical blocks. Many layers are crossbedded on a large scale, and some bedding surfaces are ripple marked. Some layers are conglomeratic, containing quartz and chert pebbles as much as 1½ in. across. Weathered surfaces are dotted with ferruginous pellets. Some purplish shaly sandstone is interbedded, but is mostly obscured by float from the more massive layers. About 10 ft of nodular limestone, with 15 ft of shale beneath is reported 225 ft below the top (DeFord and Brand, 1958, p. 23, fig. 11), but was not recorded in 1928	390
Campagrande Limestone:	
1. Limestone, thin-bedded, conglomeratic, white; with yellow and pink mottling; passes into a more massive ledge at top	20
Unconformity.	
Hueco Limestone at base of section.	

Summary of section 49

Part of Kiamichi Formation exposed	69
Total Finlay Limestone	56
Total Cox Sandstone	406
Total Campagrande Limestone	20

SECTION 50. BLACK KNOBS

The following is a section of the Campagrande Limestone and Cox Sandstone on Black Knobs, 5½ miles east of Cox Mountain (summit 5480, west-central part of sec. 15, Block 44). The section was measured by P. B. King and R. E. King in 1928.

Top of knobs; no higher beds preserved.

	Feet
Cox Sandstone:	
7. Sandstone, medium-grained, crossbedded, bluff; contains small limonite nodules	20
6. Shale, sandy, buff and purple	15
5. Sandstone, coarse-grained, massive	20
4. Sanstone, buff, shaly	13
3. Sandstone, medium- to coarse-grained, pink; weathers purple in places, in others to a brown crust. Texture uneven, in part contains seams of well-rounded chert and quartz pebbles as much as an inch in diameter, in part crossbedded	20
Campagrande Limestone:	
2. Limestone, massive, lumpy and nodular, light-gray; weathers pale brown and forms a prominent ledge. In places weathered surface contains irregular limonite veinlets	19
1. Limestone, sandy and marly, white or buff; with some harder reddish dolomitic layers and a few beds of sandstone	40
Unconformity.	
Hueco Limestone at base of section.	

Summary of section 50

Part of Cox Sandstone exposed	88
Total Campagrande Limestone	59

SECTION 51. ROBERTS MESA

The following is a section of the Finlay Limestone at the east end of Roberts Mesa (east-central part of Sec. 10, Block 39). The section was measured in 1936 by J. Brookes Knight. Fossils were identified by R. W. Imlay (written commun., 1940).

Top of mesa; no higher beds preserved.

	Feet
Finlay Limestone:	
7. Limestone, marly; contains rudistids	10
6. Limestone, massive; contains rudistids; forms a ledge at rim of mesa	3
5. Marl, sandy	12
4. Sandstone, massive, coarse-grained, crossbedded, ripple-marked; contains silicified wood. (This unit is separately shown on geologic map.)	8
3. Marl, light-gray, fossiliferous. Contains *Natica*? cf. *N.*? *pedarnales* Roemer, *Tylostoma* sp., *Exogyra texana* Roemer, *Lima* sp., *Protocardia* cf. *P. texana* (Conrad), and *Homomya* sp. (USGS 17844; field label K 9). According to Imlay, these fossils are probably of Fredericksburg age	20
2. Shale, sandy, with a 2-ft bed of yellow fine-grained sandstone at top	15
1. Limestone, containing abundant poorly preserved oyster shells, including *Ostrea* cf. *O. crenulimargo* Roemer (USGS 17843; field label K 8)	3
Base of section covered by alluvium.	

Summary of section 51

Part of Finlay Limestone exposed	71

SECTION 52. NORTON MESA

The following is a section of the Finlay Limestone on the northeast side of Norton Mesa (southeastern part of sec. 16, Block 34). The section was measured by

P. B. King in 1936, and fossils were collected in 1938, which have been identified by R. W. Imlay (written commun., 1940).

Top of Mesa; no higher beds preserved.

Finlay Limestone:	Feet
12. Sandstone, brown, platy	1
11. Marl	2
10. Limestone, gray; contains rudistids; forms rim of mesa	3
9. Marl, and nodular limestone, containing *Exogyra* cf. *E. texana* Roemer, *Pecten* (*Neithea*) cf. *P. occidentalis* Conrad, and *Natica*? sp. (USGS 17281; field label K 2)	15
8. Sandstone, medium-grained, brown, partly laminated, partly crossbedded; forms a prominent ledge on slope of mesa. (This unit is separately shown on geologic map.)	5
7. Marl, sandy	15
6. Sandstone, medium-grained, brown; forms a ledge	4
5. Marl, sandy, buff; contains limestone lumps and interbedded layers of sandstone and nodular limestone. At west end of mesa contains *Anchura*? sp., *Natica*? cf. *N. incisa* Giebel, *Ampullina*? sp., *Cardita* sp., *Protocardia* cf. *P. texana* (Conrad), *Homomya*? cf. *H.*? *alta* Roemer, *Exogyra texana* Roemer, and *Enallaster* cf. *E. texanus* (Roemer) (USGS 17900; field label K 12). According to Imlay, these fossils are probably of Fredericksburg age	19
4. Sandstone, calcareous, buff; forms a ledge	1
3. Marl, soft, sandy, buff	10
2. Sandstone, fine-grained, brown; forms a ledge *Gryphaea* and *Alectryonia* observed	4
1. Marl	3

Base of section covered by alluvium.

Summary of section 52

Part of Finlay Limestone exposed	82

COLLECTIONS FROM FINLAY LIMESTONE AND KIAMICHI FORMATION WEST OF ROBERTS MESA AND NORTON MESA

The following three collections amplify the faunas of the Finlay and Kiamichi Formations. They were collected in the plateau country west of Roberts and Norton Mesas, in the Triple Hill quadrangle a short distance beyond the west edge of the report area. The first was collected during the present investigation, the second and third during the investigation of C. C. Albritton, Jr., and J. F. Smith, Jr., (1965); all were identified by R. W. Imlay.

Finlay Limestone (*USGS 17899, field label K 11.*)—Fossiliferous marl underlying capping 6-ft limestone ledge. Three miles southwest of Roberts Ranch and half a mile west of road to Sierra Blanca (sec. 19, Block 38). Collected by P. B. King and J. Brookes Knight in 1938 and identified by R. W. Imlay (written commun., 1940). Contains *Anchura*? sp., *Tylostoma* sp., *Nerita* sp., *Exogyra texana* Roemer, *Protocardia texana* (Conrad) *Lima*? sp., and *Enallaster* cf. *bravoensis* Böse. According to Imlay, these fossils are probably of Fredericksburg age.

Finlay Limestone.—From strata 54–82 ft below Kiamichi(?) Formation. Northeastern part of Triple Hill quadrangle, west of Norton Mesa (Block 35). Collected by J. F. Smith, Jr., and identified by R. W. Imlay (written commun., 1950). Contains *Exogyra texana* Roemer, *Trigonia* sp., *Protocardia texana* Conrad, *P. multisriata* Shumard *P*, sp., *Cardium*? cf. *C.*? *subcongestum* Böse, *Cypremeria* sp., *Pecten* (*Neithea*) *occidentalis* Conrad, *Brachydontes* sp., *Modiolus concentrice-costellatus* (Roemer), *Sphaera* cf. *S. roblesi* (Böse), *Tapes*? sp., *Neritina*? cf. *N.*? *elpasensis* Stanton *Tylostoma* sp., *Gyrodes*? sp., *Aporrhais*? sp., *Monodonta*? sp., *Cerithium*? cf. *C.*? *pecosense* Stanton, and *Turritella seriatim-granulata* Roemer.

Kiamichi(?) Formation.—From 34-ft unit of sandstone overlying top limestone layer of Finlay Limestone. Northeastern part of Triple Hill quadrangle, west of Norton Mesa (Block 35). Collected by J. F. Smith, Jr., and identified by R. W. Imlay (written commun., 1948). Contains *Turritella seratim-granulata* Roemer, *Cerithium*? sp., *Ostrea* sp., *Pecten* (*Neithea*) sp., *Pecten* (*Syncyclonema*) sp., *Nucula* sp., *Nuculana*? sp., *Cardium* cf. *C. congestum* Conrad, *C.*? sp., *Trigonia emoryi* Conrad, *Protocardia* sp., and *Engonoceras* cf. *E. peirdenale* (Von Buch).

SECTION 53. EASTERN SIERRA PRIETA

The following is a section of the Campagrande Limestone, Cox Sandstone, and Washita Group on the east slope of the southeast prong of Sierra Prieta about due east of Black triangulation station (west-central part of sec. 21, Block 68, Twp. 4). A section was measured here by P. B. King and R. E. King in 1928, and again in more detail by J. Brookes Knight in 1938; the section given here is that by Knight. Fossils collected by Knight were identified by R. W. Imlay (written commun., 1940).

Sill of igneous rock at top of mountain.

Intrusive contact

Washita Group:	Feet
38. Sandstone, marly, pink	8
37. Marl, gray; partly covered by float of igneous rock. Contains *Cardita* sp., *Cyprimeria* sp., *Pecten* (*Neithea*) sp., *Alectryonia quadriplicata* (Shumard), *A.* cf. *A. subovata* Shumard, *Gryphaea washitaensis* Hill, *Kingena*? sp., *Nautilus*? sp., *Enallaster bravoensis* Böse, and *Hemiaster* n. sp. (USGS 17914; field label K 14 K). According to Imlay, these fossils do not afford a definite correlation, but the presence of *Alectryonia quadriplicata* suggests an age not younger than lower Mainstreet	65
36. Sandstone, brown	2
35. Marl, yellow; mostly covered by float of igneous rock. Contains many *Gryphaea washitaensis* Hill (USGS 17913; field label K 14 J)	22
34. Covered by float of igneous rock; some intermingled float of brown shale	10
33. Marl, pink; mostly covered by float of igneous rock. Contains *Kingena*? sp. (USGS 17912; field label K 14)	10
32. Limestone, marly; packed with shells of *Gryphaea washitaensis* Hill and *Pecten* (*Neithea*) *texanus* Roemer (USGS 17911; field label K 14 H)	15

Washita Group—Continued	Feet
31. Marl, with a profusion of shells. Contains *Anchura*? sp., *Tylostoma*? sp., *Turritella* sp., *Lima wacoensis* (Roemer), *Pecten* (*Neithea*) *subalpinus* Böse, *Gryphaea washitaensis* Hill, *Enallaster* cf. *E. texanus* (Roemer), *Tetragramma* cf. *T. taffi* (Cragin), and *Pseudopyrina clarki* (Böse) (USGS 17910; field label K 14 G). According to Imlay, correlation with Fort Worth or Denton is indicated by *Pseudopyrina clarki*	27
30. Marl; white; with numerous fossils. Contains *Pecten* (*Neithea*) *subalpina* Böse, *Pholadomya* cf. *P. sanctisabae* Roemer, *Gryphaea washitaensis* Hill, *Cyprimeria* cf. *C. crassa* Meek, *C.* cf. *C. texana* (Roemer), *C.* sp., *Alectryonia* aff. *A. carinata* (Larmarck), *Pinna* sp., *Lima wacoensis* (Roemer), *L.* sp., *Cercomya* sp., *Isocardita* cf. *I. medialis* (Conrad), *Tapes*? cf. *T.*? *vibrayeana* d'Orbigny, *Enallaster texanus* (Böse), *Phymosoma* cf. *P. texanum* (Roemer), *Pseudopyrina* cf. *P. inaudita* (Böse), *Dumblea symmetrica* Cragin, *Holaster simplex* Shumard, *Holectypus limitus* Böse, *Engonoceras* sp., *Mortoniceras wintoni* (Adkins), *Prohysteroceras*? sp., *Cymatoceras texanum* (Shumard), *Tylostoma* cf. *harrisi* Whitney, *Tylostoma* sp., and *Amauropsis*? sp. (USGS 17909; field label K 14 F). According to Imlay, a correlation with the Denton or Weno is indicated. *Pervinqueria wintoni* has been recorded from the Weno and Pawpaw, *Dumblea symmetrica* ranges as high as the Weno; *Holectypus limitus* has been recorded from Fort Worth to Mainstreet; *Pseudopyrina inaudita* is known from Fort Worth to Denton	25
29. Limestone, containing *Gryphaea;* forms a ledge	1
28. Marl, gray. Contains abundant *Gryphaea corrugata* Say and *G.* aff. *G. washitaensis Hill,* as well as *Natica* sp., *Tylostoma* cf. *T. harrisi* Whitney, and *Turritella* sp. (USGS 17906; field label K 14 E2)	32
27. Sandstone, red-brown, platy; interbedded with clay and marl toward top. Contains *Trigonia* cf. *T. emoryi* Conrad, *Lima* sp., and *Gryphaea corrugata* Say var. (USGS 17907; field label K 14 E)	40
26. Poorly exposed; one outcrop of yellow clay	12
25. Sandstone, yellow-brown, slabby. Contains *Gryphaea corrugata* Say (USGS 17906; field label K 14 D)	5
24. Clay, gypsiferous, yellow	12
23. Slope, covered by float of igneous rock	25
22. Marl, yellow, sandy; much concealed by float of igneous rock. Contains *Pervinqueria* cf. *P. kiliani* (Lasewitz), *P.* sp. indet., *Hamites*? sp., *Pecten* (*Neithea*) sp., and *Kingena*? sp. (USGS 17905; field label K 14 C). According to Imlay, a Duck Creek or Fort Worth age is suggested by *Pervinqueria* cf. *P. kiliani*	15
21. Marl, gray, abundantly fossiliferous. Contains *Cymatorceras texanum* (Shumard), *Eopachydiscus brazoense* (Shumard), *E.*? sp. juv., *Mortoniceras* cf. *M. leonensis* (Conrad), *M.* sp., *Idiohamites* cf. *I. fremonti* Marcous, *I.* cf. *I. comanchensis* (Adkins and Winton), *Anchura* sp., *Cercomya* sp., *Pholadomya* cf. *P. shattucki* Böse, *Homomya* cf. *H. ligeriensis* (d'Orbigny), *Trigonia* sp., *Inoceramus* cf. *I. comancheanus* Cragin, *Lima leonensis* Conrad, *L.* sp., *Pinna* sp., *Ostrea* sp., *Alectryonia* aff. *A. carinata* (Lamarck), *Pecten* (*Neithea*) *subalpinus* Böse, *Tapes*? cf. *T. chilhuahuensis* Böse, *Kingena*? cf. *K.*? *leonensis* (Conrad), *Enallaster texanus* (Roemer), *Pliotoxaster whitei* (Clark), *Pseudopyrina parryi* (Hall), *Dumblea*? sp., and *Phymosa* cf. *P. mexicana* Böse (USGS 17904; field label K 14 B). According to Imlay, correlation with the Duck Creek is shown by *Eopachydiscus brazoense*, *Idiohamites* cf. *fremonti*, *I.* cf. *I. comanchensis*, and *Inoceramus comancheanus*	30
Cox Sandstone:	
20. Sandstone, platy, mottled purple, red and white; bedding surfaces show sun cracks and fucoidal markings	10
19. Sandstone, fine-grained, massive, crossbedded, light buff; weathers lumpy. Contains a silicified log	36
18. Sandstone, coarse-grained, very massive, crossbedded, light-brown	10
17. Sandstone, friable, ocherous	18
16. Sandstone, very massive, crossbedded, light-brown	8
15. Sandstone, friable, yellow; mostly covered by float from unit above	15
14. Sandstone, slabby, brown	2
13. Sandstone, friable, marly, yellow; with a thicker ledge near base	15
12. Sandstone, yellow; contains nodules of possible algal origin	15
Campagrande Limestone:	
11. Clay, white	2
10. Shale, sandy, ocherous; contains unidentifiable oysters and other pelecypods (USGS 17903; field label K 14 A)	5
9. Sandstone, argillaceous, chalky, white	2
8. Clay ocherous	7
7. Limestone, mottled, yellow; forms a ledge. Contains nodules of posssible algal origin	2
6. Marl, ocherous; contains nodules of possible algal origin	5
5. Marl, white	5
4. Limestone, forming a ledge	2
3. Marl, gravelly, gray	8
2. Limestone, gray, lumpy; forms a massive ledge; contains obscure fossils	7
1. Limestone, light-gray to purple; weathers to rounded lumps. Contains algal nodules and poorly preserved gastropod molds	35

Unconformity.
Victorio Peak Limestone at base of section.

Summary of section 53

Part of Washita Group exposed	356
Total Cox Sandstone	129
Total Campagrande Limestone	80

OTHER FOSSIL COLLECTIONS FROM WASHITA GROUP IN EASTERN SIERRA PRIETA

The following three collections of fossils were made from the Washita Group of the eastern part of the Sierra Prieta, and supplement the data given in section 53.

USGS 17915 (field label K 15 C).—Washita Group, 25 ft above top of Cox Sandstone, a quarter of a mile south of the line of section 53 (southwestern part of sec. 20, Block 68, Twp. 4). Collected by J. B. Knight in 1938 and identified by R. W. Imlay (written commun., 1940). Contains *Eopachydiscus lacvicaniculatum* (Roemer), *E. brazoense* (Shumard), *Pervinqueria trinodosa* (Böse), *P. kiliani* (Lasswitz), and *P.* n. sp. According to Imlay, a Duck Creek age is indicated by *Eopachydiscus brazoense;* the listed species of *Pervinqueria* are recorded from both the Duck Creek and Fort Worth Formations.

USGS 17901 and 18091 (field label K 13).—Washita Group, first 25 ft of beds above Cox Sandstone, west side of southeast prong of Sierra Prieta, southwest of Black triangulation station (center of sec. 19, Block 68, Twp. 4). Collected by J. Brookes Knight in 1938, and identified by R. W. Imlay (written commun., 1940). Contains *Eopachydiscus brazoense* (Shumard), *Cymatoceras texanum* (Shumard), *C.*? sp., *Pervinqueria* sp., *P. cf. P. kiliani* (Lasswitz), *Montoniceras cf. M. leonensis* (Conrad), *Pleurotomaria* sp., *Alectryonia quadriplicata* (Shumard), *A.* aff. *A. carinata* (Lamarck), *Astarte*? sp., *Gryphaea* cf., *G. washitaensis* Hill, *Lima* sp., *Pholadomya* cf. *P. shattucki* Bose, *Homomya* aff. *H.* Ligeriensis (d' Orbiguy), *Pecten* (*Neithea*) *subalpinus* Böse, *Trigonia* sp., *Spondylus* sp,. *Kingena* cf., *K. leonensis* (Conrad) *K.* cf. *K. wacoensis* (Roemer), *K.* spp., *Enallaster texanus* (Roemer), *Pliotoxaster whitei* (Clark), *Holectypus* sp., *Pseudopyrina parryi* (Hall), and *Phymosoma* cf. *P. mexicanum* Böse.

The first two and the fourth of the ammonites listed above are of exceptionally large size and are represented only by fragments, some of which are several feet across.

According to Imlay, these fossils indicate a Duck Creek or Fort Worth age. The large *Eopachydiscus* indicates a Duck Creek age. Ammonites similar to or identical with *Pervinqueria kiliani* and with *Mortoniceras leonensis* occur in both the Duck Creek and Fort Worth Formations. *Phymosoma mexicanum* has been recorded only from the Fort Worth and Denton Formations.

USGS 17902 (field label K 13 A).—Same locality as preceding, higher beds of Washita Group. Collected by J. Brookes Knight in 1938 and identified by R. W. Imlay (written commun., 1940). Contains *Pervinqueria* cf. *P. trinodosa* Böse, *Gryphaea washitaensis* Hill, *Enallaster* sp., *Macraster* sp., and *Kingena*? sp.

SECTION 54. WESTERN SIERRA PRIETA

The following is a section of the Campagrande Limestone, Cox Sandstone, and Washita Group at the western end of Sierra Prieta ("at northwest corner of Black Mountain or Sierra Prieta"), probably below the western angle of the igneous sill (summit 5110, northwestern part of sec. 27, block N). The section was measured by J. W. Beede and W. S. Adkins in 1921, and has been published by Adkins (1932, p. 354). The text given here has been edited to agree with the styling of the other sections of this report, and additional data on fossils have been added from notes furnished by Adkins (oral commun., 1930). A section was also measured by P. B. King and R. E. King in 1928 at a locality about three-quarters of a mile farther south, but is less complete.

	Feet
Sill of igneous rock at top of mountain.	
Intrusive contact.	
Washita Group:	
14. Limestone, light-gray; largely a shell coquina. Contains *Macraster* sp., echinoid fragments, *Prohysteroceras whitei* (Böse), and *Pervinqueria trinodosa* (Böse). The two ammonites indicate a correlation with Böse's unit 5 of the Cerro de Muleros section, which may be of Fort Worth or Denton age	50
13. Marl, calcareous, with thin seams of gray nodular limestone. Contains *Dumblea symmetrica* Cragin, *Enallaster bravoensis* (Böse), *Diplopodia* sp., *Phymosa* sp., *Pyrina* sp. (abundant) *Salenia* sp., *Gryphaea washitaensis* Hill, and *Pecten* n. sp. This distinctive assemblage is like one at a similar level in the Washita Group at Cerro de Muleros, and may be equivalent to the Denton	40
12. Marl, brown, and interbedded flaggy limestone	40
11. Marl and limestone	22
10. Limestone, yellow-brown, platy	1
9. Marl, yellow-brown; contains *Pecten subalpinus* Böse and *Gryphaea* sp	11
8. Conglomerate, massive; composed of heterogeneous rounded pebbles as much as 5 mm in diameter, in a calcareous matrix	1
7. Marl, yellow-brown. Contains *Eopachydiscus brazoense* (Shumard), *Pervinqueria nodosa* (Böse), *P. trinodosa* (Böse), *P.* spp., *Mortoniceros leonensis* (Conrad), and *Idiohamites* spp., which are typical Duck Creek fossils	10
Cox Sandstone:	
6. Sandstone, fossiliferous in part	95
5. Sandstone, thin-bedded, crossbedded, brown; forms a bluff	26
4. Sandstone, crossbedded, brown; massive above, nodular below. Top beds contain abundant *Exogyra texana* Roemer, *Alectryonia carinata* (Lamarck) (casts and molds), *Pecten* sp., *Lima*? sp., *Plagiostoma*? sp., and gastropods; this is a Fredericksburg fauna	40
3. Sandstone, crossbedded, nodular, brown. Contains irregular sandy inclusions as much as a foot long	8
2. Sandstone, massive, yellow	20
Campagrande Limestone:	
1. Limestone, called Hueco limestone in published section, but probably Campagrande; thickness not stated	(?)
Base of section concealed by alluvium.	

Summary of section 54

Part of Washita Group exposed	175
Total Cox Sandstone	189
Part of Campagrande Limestone exposed	(?)

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